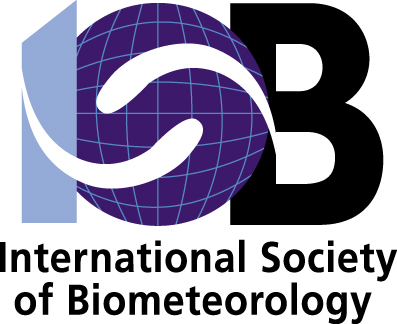
**21st International Congress OF Biometeorology**

**International Society of Biometeorology**



**September 3 – 6, 2017**

**Durham University**

**Durham, United Kingdom**



**21st International Congress of Biometeorology**

**FOREWORD**

On behalf of the Executive Board of the International Society of Biometeorology and the Scientific Programme and Local Organising Committees, I would like to warmly welcome you to Durham and Durham University for the 21st International Congress of Biometeorology (ICB). The theme for the 21st ICB is ‘Weather and Climate Information for Risk Management’. A precept of the 21st ICB is that through developing and incorporating science-based weather and climate information and prediction into planning, policy and practice, better management of the risks and opportunities arising from climate variability and change will be enabled. The purpose of the 21st ICB is therefore to reflect upon the efficacy of knowledge production in biometeorology and cognate disciplines in relation to information provision for managing weather and climate related risks.

As for all previous ICBs, the International Society of Biometeorology (ISB) has provided the main vehicle and intellectual infrastructure for the 21st Congress; congresses are organised on a triennial basis. Importantly, the 21st ICB represents a significant milestone in the history of the ISB. Established in 1955, the ISB is now over 60 years old. To celebrate this, the ISB, in conjunction with Springer, has produced a Special 60th Anniversary issue of the International Journal of Biometeorology. This will be made available to all Congress participants.

The scientific programme for the 21st ICB has been organised around a number of general paper sessions, symposia and special meetings. Given the Congress’ theme, the papers and posters presented at the 21st ICB cover a wide range of topics including human biometeorology, animal biometeorology, phenology, agriculture and forestry, the built environment, tourism, thermal comfort, aerobiology, extreme events and infectious diseases. While these topics fall within the well-known boundaries of biometeorology a feature of the 21st Congress are a number of papers and sessions that focus on the utility of climate information and strategies for managing a number of challenges posed by the variability in and the change of weather and climate. Encouragingly the 21st ICB has also attracted a number of papers that fall within the emerging area of weather sociology. Such papers not only address the impacts of weather and climate on society and how society at a range of scales might adapt to changing atmospheric conditions, but how society understands and responds to weather and climate information.

As part of the 21st ICB we are lucky to have three Symposia namely: (1) Urban Heat & Thermal Comfort: Measurement & Models; (2) Observing and Managing Diverging Ecological Responses to Climate Change and (3) Integrating Climate Information and Individual Aspects for Improved Heat Warning. All three symposia in many ways are signposts to the changing nature of biometeorology in that they address topics that clearly fall within the wider purview of climate risk management across a range of time and space scales.

During the Congress there will also be a number of events that will complement the main scientific programme. These include the Student and New Professionals (SNP) pre-Congress Workshop on September 3rd with a follow-up SNP meeting at the end of the day on September 4th, ISB Commission meetings over lunchtime on September 4th, the General Membership meeting at lunchtime on September 5th, a ‘Global Heat Health Information Network (GHHIN)’ open dialogue event at the end of the day on September 5th led by representatives from NOAA and the WMO and an immediate post-Congress meeting on September 6th for those who want to partake in an open roundtable discussion on heat warning, at the regional/individual level, as a follow-on from Symposium 3rd on Integrating Climate Information and Individual Aspects for Improved Heat Warning.

The SNP pre-Congress Workshop has been designed to provide students and early career biometeorologists with the opportunity to learn about career development and progression related matters. ISB Commission meetings will provide an opportunity for Congress participants to engage with others within a particular sub-discipline of biometeorology. At this Congress there will be three Commission meetings namely: (1) Phenology, (2) Climate and Human Health and (3) Animal Biometeorology. An overview of the ISB’s activities will be provided at the General Members Meeting; this event is open to all and is an opportunity to get involved in the work of the ISB. The GHHIN event is designed to articulate a vision for, and encourage participation in, the development of a global network of scientists, policy makers, planners and practitioners in the field of extreme heat risk management in relation to human health. The post-Symposium 3 event, after the Congress closes, will present an opportunity for ICB participants to contribute to an open discussion on heat warning at the regional to individual level in the context of a sustainable inter-sector framework that will promote health, as well as productivity, for European citizens in the context of global warming related increases in heat stress.

Complementing the scientific programme and related events, is the social programme. This includes an Icebreaker event in Durham Castle (University College) at 7pm on September 3rd, a Congress Dinner in Grey College on September 5th and post-Congress trips to either Lindisfarne (Holy Island) or Hadrian’s Wall. We hope you enjoy these events. To ensure that opportunities are maximised for networking at the Congress, we have included all morning and afternoon teas and lunches in the cost of the registration fee so that participants can focus on eating and talking as opposed to worrying about finding a place to get ‘fed and watered’. We have also included in your information packs maps of nearby pubs and coffee shops.

Over the years the International Congresses of Biometeorology have become well known for attracting participants from across the globe. The 21st ICB is no exception to this with over 150 participants from 30 plus countries presenting in either oral and/or poster sessions. An encouraging sign for the 22nd Congress and beyond, and the discipline of biometeorology in general, is the participation in the Congress of a significant contingent of student and new professionals (SNP) from a range of countries. Remembering what it was like when I first attended a conference, could I encourage the so-called ‘old-hands’ to support, when and where possible, the SNP participants by spending time discussing the content of their posters and attending their talks. It might be very clichéd but the SNP are our future.

By the time you read this I am sure you will have got a sense that Durham University and the town in which it sits, offers an exceptional location for the 21st ICB. In fact few venues in the world can rival the splendour, prestige and heritage of the City of Durham. Located on a dramatic peninsula overlooking the River Wear, Durham’s unique Norman Cathedral and Castle not only dominate the skyline but are also World Heritage Sites. Durham is a small and compact city. Everything is within easy walking distance – it is essentially a university town with a population of only 47,000. Further, Durham University (DU) is a world-class, top-100 university. It is the third oldest university in the UK and is consistently ranked amongst the top 5 UK universities. It has approximately 18,000 students, 3,500 of whom are postgraduates with over 3,000 international students from over 120 countries who study across three faculties namely, Science, Arts and Humanities and Social Sciences and Health. Durham University is also relatively unique in the higher education landscape of the UK as it is a collegiate University with 16 Colleges; in essence the Colleges are scholarly communities where students not only live but also enjoy a range of scholarly and cultural activities that complement those in their home academic departments. The University has excellent facilities including a world class library, wireless internet across the campus, state of the art meeting and lecture rooms and excellent accommodation all of which we hope you enjoy while at the Congress.

Lastly the 21st ICB would not be possible without significant financial and logistic support from a number of quarters. As Chair of the Scientific Programme and Organising Committees I am especially grateful for the financial support received from a number of sponsors including The International Society of Biometeorology, Springer, Munich Re, Campbell Scientific and Durham University’s Ustinov College. Durham University provided significant in-kind support for the Congress. Sponsor details can be found on the Sponsors page in this handbook. The dedication of the members of the Scientific Programme and Local Organising Committees to making the 21st ICB a success is also acknowledged here. We are also grateful to the keynote speakers for agreeing to participate and for what they have contributed to the Congress.

Again welcome to the 21st ICB. I trust you enjoy the Congress, its related activities and what Durham University and the City of Durham offer as a venue.

Glenn McGregor

Chair of the Scientific Programme and Local Organising Committees.

**21st International Congress of Biometeorology**

**SPONSORS**

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| C:\Users\Camila\AppData\Local\Microsoft\Windows\INetCache\Content.Word\isb_newlogoaxis2.png | The International Society of Biometeorology (ISB) is a ***Palatinate Sponsor*** of the 21st International Congress of Biometeorology. It is thus the main sponsor of the 21st ICB. Since 1956, the ISB has provided an international forum for the promotion of interdisciplinary collaboration between the disciplines of meteorology, epidemiology, climatology, biology, ecology, public health, forestry, agriculture and other cognate disciplines. |
| C:\Users\spjw56\AppData\Local\Microsoft\Windows\Temporary Internet Files\Content.Outlook\VDT1AD87\SpringerNature (2).png | Springer is a global publisher dedicated to providing the best possible service to the whole research community. It is a **Gold Plus Sponsor** of the 21st ICB and generously supports the publication of the International Journal of Biometeorology. |
| C:\Users\spjw56\AppData\Local\Microsoft\Windows\Temporary Internet Files\Content.Outlook\VDT1AD87\MunichRE.PNG | Munich Re is one of the world's leading players in the reinsurance industry with expertise in global and local risk solutions. It combines primary insurance and reinsurance under one roof. Munich Re is a **Gold Sponsor** of the 21st ICB. |
| C:\Users\spjw56\AppData\Local\Microsoft\Windows\Temporary Internet Files\Content.Outlook\VDT1AD87\Campbell (2).png | Campbell Scientific is a leading designer and manufacturer of dataloggers, data acquisition systems, and measurement and control products used worldwide in a variety of applications related to weather, water, energy, gas flux and turbulence, infrastructure, and soil. Campbell Scientific is a **Silver Sponsor** of the 21st ICB. |
| C:\Users\spjw56\AppData\Local\Microsoft\Windows\Temporary Internet Files\Content.Outlook\VDT1AD87\UstinovCollege (2).png | Ustinov College is Durham University’s sole postgraduate-only College. It is a place for postgraduate students to call home - a vibrant, safe and multinational community - supporting academic excellence and offering an unrivalled postgraduate student experience. It is a **Bronze Sponsor** of the 21st ICB. |
| C:\Users\spjw56\AppData\Local\Microsoft\Windows\Temporary Internet Files\Content.Outlook\VDT1AD87\DULogo (2).png | Durham is a world ‘top 100’ university. It’s a residential collegiate university with long traditions and modern values made up of 3000 staff and close to 18,000 students; 21 percent of students are of a non-UK origin. Durham University is an ‘in-kind’ **Bronze Sponsor** of the 21st ICB. |

**21st International Congress of Biometeorology**

**Scientific Programme and Organising Committees**

**Chair: Glenn McGregor, Department of Geography, Durham University**

**Scientific Programme Committee**

**Paul J. Beggs**Macquarie University, Australia  
*Human, aeroallergens, climate change*

**Kjell Bolmgren**Swedish University of Agricultural Sciences, Uppsala, Sweden*Phenology, forest ecology*

**Judy Cawdell-Smith**  
University of Queensland, Australia  
*Heat stress in animals, horses*

**Xiaoqiu Chen**Peking University, China  
*Phenology, agricultural and forest meteorology, plant ecology, biogeography*

**John Gaughan**The University of Queensland*Animal biometeorology, heat stress and livestock productivity*

**Debbie Hemming**UK Met Office, Exeter, UK *Climate risk analysis, forest response to environmental change, and atmosphere exchange modelling*

**Jutta Holst**Lund University, Sweden*Forest meteorology, environmental climatology*

**Yasushi Honda**University of Tsukuba, Japan  
*Environmental epidemiology, climate change, human mortality and morbidity*

**Adam Kalkstein**United States Military Academy, West Point, USA*Climate change on human health, human/environment interactions, synoptic climatology*

**Noémi Kántor**University of Szeged, Szeged, Hungary*Bioclimatology, thermal comfort, biometeorology, climatology*

**Marie Keatley**University of Melbourne, Australia  
*Phenology, citizen science and networks, resource management, environmental history*

**Ho Kim**   
Seoul National University, South Korea  
*Human health, air pollution, climate change*

**Sari Kovats**London School of Hygiene and Tropical Medicine, London, UK*Health impact assessments of climate change, environmental epidemiology in urban and rural populations*

**Liang Liang**University of Kentucky, USA  
*Phenology, bioclimatology, remote sensing*

**Dirk Schindler**   
Albert-Ludwigs-University, Freiburg, Germany  
*Forest meteorology, micrometeorology, hydrometeorology, urban meteorology, air pollution*

**Jennifer K. Vanos**University of California, San Diego, USA  
*Human thermal environment, air pollution, heat stress, urban climates, epidemiology*

**Sotiris Vardoulakis**Institute of Occupational Medicine, Edinburgh, UK*Air pollution, climate change, environmental health policy, environmental epidemiology*

**Local Organising Committee**

Camila Caiado, Mathematical Sciences, Durham University

Isabella Bovolo, Geography, Durham University

Sheila Seal, Ustinov College, Durham University

Judith Aird, Event Durham, Durham University

**21st International Congress of Biometeorology**

**General Information**

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| **Congress Location** |
| The 21st ICB will be centred around the Calman Learning Centre (CLC) located on the Lower Mountjoy site of Durham University’s City Campus. All sessions will take place in the Arnold Wolfendale, Rosemary Cramp and Ken Wade lecture theatres located in the CLC. The SNP pre-Congress Workshop and all ISB Commission meetings will take place in the Engineering Building. All refreshment breaks and the Poster viewing session will occur in Earth Science Rooms 228 – 231 (TR1 – TR4) located in the Arthur Holmes Building adjacent to the CLC. Other meeting rooms used such as the Kingsley Barrett Room and the Derman Room are located on the top floor of the CLC. |
| **Registration** |
| Registration will run continuously throughout the duration of the Congress. Registration opens at 17:00 on Sunday September 3rd in Durham Castle and will relocate to the CLC on Monday morning, September 4th. General enquiries about the Congress and related matters can be made at the Registration Desk. |
| **Icebreaker, September 3rd at 19:00** |
| The Icebreaker event will take place in the Great Hall of Durham Castle located on Palace Green opposite the Cathedral. On passing through the Castle inner gate if asked about the purpose of your visit mention you are attending the ISB Icebreaker. |
| **Congress Dinner, September 5th at 19:30** |
| Grey College, a short walk uphill from the CLC or downhill from Collingwood College will be the location of the Congress Dinner. The dress code for the dinner is smart casual. Dinner attendees are asked to arrive for a pre-dinner drink at 19:30 and take their places for dinner no later than 20:00. Your dinner ticket will be issued at the time of Congress registration. |
| **Congress Badges** |
| Congress badges will be issued at the time of registration and must be worn at all times during the Congress including refreshment breaks. |
| **Presentation Upload** |
| Speakers would have received instructions prior to the Congress about the presentation upload process. The use of personal laptops for presentations is not allowed. A student volunteer will be present in each session room. Speakers are encouraged to assemble 5-10 minutes before the commencement of their session to introduce themselves to the session chairs and ensure that their presentations have been uploaded. It will not be permitted to upload presentations once the session has started. |

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| **Poster Presenters** |
| A Formal Poster Viewing session is scheduled for Monday, September 4th, 14:30-16:00. This will take place in Earth Science Rooms 228 – 231 (TR1 – TR4) in the Arthur Holmes Building adjacent to the CLC. This is also the location of all refreshment breaks. Posters will remain up from Monday afternoon until the end of Wednesday lunchtime. Poster presenters are strongly encouraged to be present at their allocated poster board during the Poster Viewing Session on September 4th. During coffee breaks on subsequent days, poster presenters may also want to be at their poster boards.  The poster setup/take-down schedule for the 21st ICB is as follows:  Set-Up: after 12:00 – 14:00 on Monday, September, 4th  Take-Down: no later than 13:30 on Wednesday, September 6th \*.  \* Please note ICB staff will not be responsible for posters not removed from the poster boards by the take-down time. Posters left after this time will be removed for recycling |
| **Internet Access** |
| At the time of registration participants at the 21st ICB will be provided with instructions on how to access the Durham University wide wireless network. Any technical difficulties should be reported to staff at the Registration Desk |
| **POST-CONGRESS OPTIONAL TOURS, SEPTEMBER 7th (THURSDAY)** |
| Congress attendees who have pre-paid for the Lindisfarne (Holy Island) and Hadrian’s Wall tours will be issued with their tickets at the time of registration. Departure location and times will be stated on the ticket. For the Lindisfarne (Holy Island) tour it is very important that participants report promptly for the departure and return times as crossing times across the tidal flats between the mainland and Lindisfarne are restricted and dependent on the timing of tides. Any delay in departure from Durham or Lindisfarne may affect the ability to access/leave Lindisfarne. See the ICB Handbook for pick up times for the post-congress tours. |
| **Exhibitors** |
| Exhibitors will be present in Earth Science Rooms 228 – 231 (TR1 – TR4) in the Arthur Holmes Building adjacent to the CLC. Exhibitor set-up and take-down times are given below.  **Exhibitor set-up:** From 08:00 on Monday September, 4th  **Exhibitor take-down:** From 16.30 on Wednesday September, 6th  Exhibitors will receive a 3m x 2m stand space, which will include an exhibition table and access to power.  The Earth Science Rooms 228 - 231 are located on the second floor of the building. There are lifts located at either side of the building. The dimensions of the lifts are 2m x 2m. |

**21st International Congress of Biometeorology**

**Key University Locations**

A close up of a map

Description generated with high confidence

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| --- | --- | --- | --- | --- | --- |
|  | Calman Learning Centre and Arthur Holmes Building (Earth Sciences) |  | Collingwood College |  | Durham Castle (University College) |
|  | Engineering |  | Grey College |  | Hatfield College |
|  | Philosophy (next to Marriott Hotel) |  | Ustinov College |  | Palatine Centre |

**21st International Congress of Biometeorology**

**Monday – September 4, 2017**

|  |  |  |  |
| --- | --- | --- | --- |
| ***Room*** | ***Arnold Wolfendale Lecture Theatre*** | ***Rosemary Cramp Lecture Theatre*** | ***Ken Wade Lecture Theatre*** |
| **08:30** | Opening Ceremony |  |  |
| **09:00** | **Keynote 1:** J Trtanj |  |  |
| **09:30** | **Keynote 2:** P Hoeppe |  |  |
| **10:00** | **Coffee Break (10:00 - 10:30)** *ES228-ES231 (TR1-TR4), Arthur Holmes Building, Earth Sciences* | | |
|
| **Session 1** | **1A General Biometeorology** | **1B Climate Change** |  |
| **10:30** | **1A.1:** Sheridan, S | **1B.1:** Kjellstrom, T |  |
| **10:45** | **1A.2:** Murray, V | **1B.2:** Leung, A C W |  |
| **11:00** | **1B.3:** Błażejczyk, K |  |
| **11:15** | **1A.3:** Mehdipoor | **1B.4:** Cronin, J |  |
| **11:30** | **1A.4:** Vardoulakis, S | **1B.5:** Suzuki-Parker, A |  |
| **11:45** | **1A.5:** Open discussion | **1B.6:** Gosling, S |  |
| **12:00** | **Lunch Break (12:00 - 13:30)** *ES228-ES231 (TR1-TR4) Arthur Holmes Building, Earth Sciences* | | |
|
|  | **Commission Meetings** | | |
| **12:30** | 1. Phenology Commission Meeting *E005, Engineering* | 2. Animal Biometeorology Commission Meeting *E101, Engineering* | 3. Climate & Human Health Commission Meeting *E102, Engineering* |
|
|
| **Session 2** | **2A Human Health I** | **2B Agriculture & Forestry I** | **2C Human Thermal Comfort I** |
| **13:30** | **2A.1:** Honda, Y | **2B.1:** Henry, W | **2C.1:** Jacobs, S |
| **13:45** | **2A.2:** Sheridan, S | **2B.2:** Yao, F | **2C.2:** Suzuki-Parker, A |
| **14:00** | **2A.3:** Sheridan, S | **2B.3:** Zhang, J | **2C.3:** Tonouchi, M |
| **14:15** | **2A.4:** Herdt, A | **2B.4:** Moeletsi, M. E. | **2C.4:** Open Discussion |
| **14:30** | **Formal Poster Viewing with Coffee Break (14:30 - 16:00)** *ES228-ES231 (TR1-TR4) Arthur Holmes Building, Earth Sciences* | | |
|
| **Session 3** | **3A Human Health II** | **3B Agriculture & Forestry II** | **Symposium I: Urban Heat & Thermal Comfort: Measurement & Models** |
| **16:00** | **3A.1:** Thornes, J | **3B.1:** Schindler, D | **S1.1:** Vanos, J |
| **16:15** | **3A.2:** Lee, D-G | **3B.2:** Donnelly, A | **S1.2:** Kántor, N |
| **16:30** | **3A.3:** Davis, R E | **3B.3:** Tao, Z | **S1.3:** Jänicke, B |
| **16:45** | **3A.4:** McGregor, G | **3B.4:** Qian, B | **S1.4:** Hondula, D |
| **17:00** | **3A.5:** Ruuhela, R | **3B.5:** Siljamo, P | **S1.5:** Fuhrmann, C |
| **17:15** | **3A.6:** Ung, A | **3B.6:** Di Paola, A | **S1.6:** Chen, Y-C |
| **17:30** | **3A.7:**  Kassomenos, P |  | **S1.7:** Coccolo, S |
| **17:45** | **3A.8:** Vecellio, D |  | **S1.8:** Open discussion |
| **18:00** | Student & New Professionals Meeting *Kingsley Barrett Room, Calman Learning Centre* | | |
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**21st International Congress of Biometeorology**

**Tuesday – September 5, 2017**

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| ***Room*** | ***Arnold Wolfendale Lecture Theatre*** | ***Rosemary Cramp Lecture Theatre*** | ***Ken Wade Lecture Theatre*** |
| **Session 4** | **4A Human Health III** | **4B Urban Green Infrastructure & Heat Management** |  |
| **08:30** | **4A.1:** Murage, P | **4B.1:** Lee, H |  |
| **08:45** | **4A.2:** Sheng, R | **4B.2:** Yang, S-R |  |
| **09:00** | **4A.3:** Ho, H C | **4B.3:** Fischereit, J |  |
| **09:15** | **4A.4:** Hashimoto, M | **4B.4:** Kántor, N |  |
| **09:30** | **4A.5:** Allen, M | **4B.5:** Hondula, D M |  |
| **09:45** | **4A.6:** Kalkstein, A | **4B.6:** Park, S |  |
| **10:00** | **Coffee Break (10:00 - 10:30)**  *ES228-ES231 (TR1-TR4), Arthur Holmes Building, Earth Sciences* | | |
|
| **10:30** | **Keynote 3:** Sparks, T |  |  |
| **11:00** | **Keynote 4:** Williams, M |  |  |
| **11:30** | **Keynote 5:** Lacetera, N |  |  |
| **12:00** | **Lunch Break (12:00 - 14:00)** *ES228-ES231 (TR1-TR4) Arthur Holmes Building, Earth Sciences* | | |
|
| **12:30** | **General Membership Meeting** |  |  |
| **Session 5** | **5A Climate Information I** | **5B Heat Stress** | **5C Pollen** |
| **14:00** | **5A.1:** Dixon, G | **5B.1:** Hoffmann, P | **5C.1:** Rang-Kim, K |
| **14:15** | **5A.2:** Zhang, J | **5B.2:** Hosokawa, Y | **5C.2:** Cho, C |
| **14:30** | **5A.3:** Adebowale, B I | **5B.3:** Bröde, P | **5C.3:** Scheifinger, H |
| **14:45** | **5A.4:** Hewston, R | **5B.4:** Psikuta, A | **5C.4:** Nairn, J |
| **15:00** | **5A.5:** Lindberg, F | **5B.5:** Vanos, J | **5C.5:** Damialis, A |
| **15:15** | **5A.6:** Mahdi, A | **5B.6:** Schauberger, G | **5C.6:** Damialis, A |
| **15:30** | **Coffee Break (15:30 - 16:00)** *ES228-ES231 (TR1-TR4), Arthur Holmes Building, Earth Sciences* | | |
|
| **Session 6** | **6A Climate Information II** | **6B Heatwaves & Heat Information Systems** | **Symposium 2: Observing & Managing Diverging Ecological Responses to Climate Change** |
| **16:00** | **6A.1:** Fitchett, J | **6B.1:** Jones, H | **S2.1:**Schwartz, M |
| **16:15** | **6A.2:** Shumake-Guillemot, J | **6B.2:** Ebi, K L | **S2.2:** Chen, X |
| **16:30** | **6A.3:** Kažys, J | **6B.3:** Robbins, J | **S2.3:** Lang, W |
| **16:45** | **6A.4:** Jung, C | **6B.4:** Baldwin, J | **S2.4:** Keogan, K |
| **17:00** | **6A.5:** Tanaka, M | **6B.5:** Muthers, S | **S2.5:** Liang, L |
| **17:15** | **6A.6:** Adebowale, B I | **6B.6:** Urban, A | **S2.6:** Dai, J |
| **17:30** | **6A.7:** Balogun, A A | **6B.7:** Nairn, J | **S2.7:** Fu, YH |
| **17:45** | **6A.8:** Omonijo, A | **6B.8:** Nissan, H | **S2.8:** Scheifinger, H |
| **18:00** | **International Journal of Biometeorology Editorial Board,** *Derman Christopherson Room, CLC*  **(18:00)** | **Global Heat Health Information Network: Open Dialogue**, *Rosemary Cramp Lecture Theatre, CLC* **(18:00)** |  |
| **19:30** | **Congress Dinner,** *Grey College* **(19:30 - 22:30)** | | |
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**21st International Congress of Biometeorology**

**Wednesday – September 6, 2017**

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| ***Room*** | ***Arnold Wolfendale Lecture Theatre*** | ***Rosemary Cramp Lecture Theatre*** | ***Ken Wade Lecture Theatre*** |
| **Session 7** |  | **7A Human Thermal Comfort II** |  |
| **09:15** |  | **7A.1:** Ohashi, Y |  |
| **09:30** |  | **7A.2:** Yang, S R |  |
| **09:45** |  | **7A.3:** Park, S |  |
| **10:00** |  | **7A.4:** Lam, C |  |
| **10:15** |  | **7A.5:** Yoshida, A |  |
| **10:30** |  | **7A.6:** Delatore, R |  |
| **10:45** | **Coffee Break (10:45 - 11:15)** *ES228-ES231 (TR1-TR4), Arthur Holmes Building, Earth Sciences* | | |
|
| **Session 8** | **8A Vector Borne Disease** | **8B Air Pollution** | **8C Forecasting** |
| **11:15** | **8A.1:** Akinbobola, A | **8B.1:** Arroyabe, P F | **8C.1:** Estela, L B L |
| **11:30** | **8A.2:** Steinhoff, D | **8B.2:** Hart, M | **8C.2:** Keatinge, F |
| **11:45** | **8A.3:** Ma, Y | **8B.3:** Zhang, X | **8C.3:** Vintzileos, A |
| **12:00** | **New ISB Executive Board Meeting,** *Derman Christopherson Room, CLC,* **(12:00 - 13:30)** | **Lunch (12:00 - 13:30)** *ES228-ES231 (TR1-TR4) Arthur Holmes Building* | |
| **Session 9** | **9A Animal Biometeorology** | **9B Weather Sociology** | **Symposium 3: Integrating Climate Information and Individual Aspects for Improved Heat Warning** |
| **13:30** | **9A.1:** Gaughan, J | **9B.1:** Beggs, P | **S3.1:** Koppe, C |
| **13:45** | **9A.2:** Koknaroglu, H | **9B.2:** Cavan, G | **S3.2:** Spirig, C |
| **14:00** | **9A.3:** Sinkalu, V O | **9B.3:** Lokys, H | **S3.3:** Kenny, G |
| **14:15** | **9A.4:** Schauberger, G | **9B.4:** Otto, M | **S3.4:** Flouris, A |
| **14:30** | **9A.5:**  Samara, E M | **9B.5:** Ung, A | **S3.5:** Nybo, L |
| **14:45** | **9A.6:** Maia, A | **9B.6:** Ellis, K | **S3.6:** Gao, C |
| **15:00** | **9A.7:** Façanha, D A E | 9B.7: Arroyabe, P F | **S3.7:** Morabito, M |
| **15:15** | **9A.8:** Façanha, D A E |  | **S3.8:** Kjellstrom, T |
| **15:30** | **9A.9:** Nascimento, C C N |  |  |
| **15:45** | **Coffee Break (15:45 - 16:15)** *ES228-ES231 (TR1-TR4) Arthur Holmes Building* | | |
| **16:15** | **Closing Ceremony (16:15 - 17:00)** *Arnold Wolfendale, CLC* | | |
| **17:15** | **Symposium 3 Follow-Up**: Roundtable Discussion  *Kingsley Barrett Room, CLC* |  |  |

**21st International Congress of Biometeorology**

**Keynote Speakers**

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**Juli Trtanj (Keynote Speaker 1)**

*One Health & Integrated Climate and Weather Extremes Research Lead, NOAA, USA*

Juli Trtanj is the One Health and Integrated Climate and Weather Extremes Research Lead for NOAA.  She is responsible for developing and implementing the National Oceanic and Atmospheric Administration (NOAA) Health Strategy across NOAA and with other federal, state, local and international Agencies, academic and private sector partners.  She is leading efforts to build the National Integrated Heat Health Information System (NIHHIS) in partnership with the Centers for Disease Control, FEMA, OSHA, NIOSH, ASPR, EPA and other agencies.  She coordinates the NOAA One Health Working Group which brings together NOAA data, research, information and actions to inform health decision making.  She started the first multidisciplinary and multi-partner research program on Climate Variability and Human Health.  She developed and directed NOAA’s Oceans and Human Health Initiative focused on Early Warning Systems, Health Benefits from the Sea, and Graduate Training.

Juli co-chairs the US Global Change Research Program, Climate Change and Human Health Group (CCHHG) and represents NOAA on the Pandemic Prediction and Forecasting Science and Technology Working Group. She is an author on the Fourth National Climate Assessment, served on the Steering Committee of the USGCRP Climate and Health Assessment and was a Convening Lead Author for the Water-Related Illness chapter. She is the Integrated Information System for Health Lead for the Group on Earth Observations (GEO), and is directly involved with the World Health Organization (WHO), and other partners in the development of the Integrated Information Systems for heat, cholera and other water-related illnesses. She has contributed to, reviewed, or edited sections of several IPCC and US National Climate Assessment reports and authored several book chapters and journal articles. Juli earned her Master in Environmental Science from Yale School of Forestry and Environmental Studies in 1994, and her Bachelors in 1986 from the University of California Santa Barbara**.**

**Keynote Abstract - Operationalising One Health: Putting Knowledge into Practice**

Are we going to see an outbreak of Zika, Dengue, or Ebola again this year? Cholera? More heat waves? Why are those whales dying, and how does that affect me? Why is the water green and can I drink it? How many animals perished in that last drought? Every year seems to bring a new onslaught of weather and climate related health impacts. Imagine a world in which we actually predicted health risks, took measures to reduce or prevent detrimental consequences, and restructured our institutions to better manage those risks? What if the seasonal forecast said “80% risk of Rift Valley Fever outbreak this spring, or 70% chance of more heat waves this year and they will start earlier, or risk of meningitis is 85% higher than normal, or that the local seafood is contaminant free and safe to eat, money was saved and livelihoods were protected?”

Ecological, animal, and human health are intrinsically interconnected—what affects one, affects the other. Intuitively we know this, scientifically we understand this. But what are we actually doing to bring our scientific knowledge to bear on the health of our ecosystems, the animals that live there and upon which we depend, and ourselves? And more importantly, what can we do in the future? The concept of One Health provides a framework that institutionalizes the connection between human, ecosystem and animal health, and offers the opportunity to more systematically address this intersection in order to protect human, animal and ecological health, prevent surprises, and promote both health and economic stability. As our population increases and our environment faces increasing natural and human stresses, the capacity of the scientific community to understand and predict those risks is also increasing. This talk will provide an overview of the One Health concept as it applies to the work of the biometeorology community, and will highlight some examples of the use of climate and weather forecasting and earth observations more generally for health including cholera, heat waves and other air, water, and vector-borne diseases. This presentation is intended to illuminate a path for integration of the biometeorology, ecology and health communities and inspire the path forward to protect our ecosystems, the animals that live there, and ourselves.

**Prof. Dr. Dr. Peter Hoeppe (Keynote Speaker 2)**

*Head Geo Risks Research/Corporate Climate Centre, Munich Re, Germany*

Prof. Hoeppe joined Munich Re in 2004 as Head of the Geo Risks Research Department. Currently he heads the Munich Re division “Geo Risks Research/Corporate Climate Centre”.Before joining Munich Re, Prof. Hoeppe worked in different institutes at the Ludwig-Maximillian’s-University in Munich and as a post doc at Yale University (USA). His academic education is in meteorology (Masters and PhD) and human biology (PhD).

His main areas of research have been the effects of atmospheric processes (heat/cold, UV radiation, air pressure fluctuations) and air pollutants (ozone, particles) on humans and the general assessment of environmental risks. Currently his research focus is on trends of natural catastrophes and their drivers and on strategies to increase the resilience of societies against these perils. A further major topic of interest is the analysis of the effects of climate change on insurance and the development of strategies on how this industry can contribute solutions for adaptation to and mitigation of global warming.

Prof. Hoeppe is scientific member of a number of scientific societies; from 1999 to 2002 was the President of the International Society of Biometeorology. He has held expert positions in different UN organisations. He is the Chairman of the Munich Climate Insurance Initiative, which he founded in 2005. In 2007 Prof. Hoeppe was appointed as the Global Warming Advisor of the Bavarian State Government and Chair of the “Finance-Forum: Climate Change” of the high-tech Strategy group of the German Federal Government. In 2009 he was one of the initiators of the Desertec Industrial Initiative. In 2014 he became Chairman of the “Münchener Universitätsgesellschaft”, the sponsoring association of the “Ludwig-Maximillian’s-University”.

**Keynote Abstract - Increasing losses caused by natural disasters: what are the drivers, what are the risk management options?**

Natural disasters are a major factor influencing the balance sheet of insurers, especially reinsurers. This is why they have built up expertise in managing those risks. The NatCatSERVICE database of Munich Re clearly shows that losses caused by extreme events have increased tremendously worldwide in the last decades. The main drivers have been changes in the exposure of values, i.e. growth of population and wealth in affected regions. In order to make historical loss data better comparable and adjust them for such socio-economic changes Munich Re has developed a very sophisticated method for a normalisation of losses. After the normalization a still residual loss trend can be either driven by changes in the vulnerability of assets or on the hazard side. Such analyses suggest that weather related hazards already have changed for some perils and in some regions. So e.g. the data show a significant trend to increasing normalized losses caused by convective events in North America and Europe. This is associated with proof that due to climate change the absolute humidity of the lower atmosphere already has increased, which is a driver to more and more intense convective storms.

Many climate research studies imply that due to global warming such trends will further increase in the coming decades. This would increase the climate change signal in the loss data and would drive them further up. This trend, however, can be broken at least partly by smart investments into risk prevention measures, which in general amortise in relative short periods of time. Some of the natural disaster risks, however, cannot be prevented in an economically sensible way. In this case insurance can step in to make individuals and societies more resilient after large shocks.

**Professor Tim Sparks**

*Professor in Environmental Change, School of Computing, Electronics and Maths, Coventry University, United Kingdom*

Tim Sparks is Professor in Environmental Change at Coventry University. After working in agricultural research I moved to ecological research at the Monks Wood Research Station in 1991 and stayed there until it was closed in 2009. I am currently a visiting professor at the Poznañ University of Life Sciences and at the University of Liverpool, and have close ties with the Department of Zoology, University of Cambridge, and Ecoclimatology, Technische Universität München.

I have an unfortunate fascination with the detection and attribution of change. I am interested in a wide range of topics, ranging from ancient woodlands to farmland biodiversity. In recent years my research has focused on the detection of climate impacts from long-term data. Much of this concerns the study of phenology, the timing of naturally recurring events as diverse as ice-melt, bear hibernation, bird migration, insect flight, plant flowering and lawn cutting. My research interests are widespread, driven by a fascination with data and what they help tell us.

**Keynote Abstract - Phenology: a pastime with a considerable history**

In the last 25 years there has been a resurgence in the study of the timing of seasonal events, known as phenology. In part this is a consequence of the availability of observational data covering decades, sometimes centuries, but also driven by the fact that the seasonal timing of many biological phenomena closely mirrors climatic variables, particularly temperature. This has been enormously beneficial in demonstrating evidence of the impacts of a changing climate to those (including me!) who cannot comprehend what a 0.85⁰C increase looks like. In addition to the traditional methods of collecting data there has been a marked increase in the use of images, whether photographs, remote sensing, or satellite observation, and of museum specimens.

Phenology, as a topic, has had to mature rapidly. Historically, analysis was largely limited to basic summaries but has now become much more sophisticated. It has (to misquote my father) “made great strides, some of them forwards”.

As a community, we have shown numerous clear examples of climate change impacts. We know that species have responded at different rates, but are we in a position to be able, confidently, to state what the consequences of these different responses will be? Are species at risk from a changed phenology? Are all changes bad? Can we mitigate impacts? I will attempt to address at least some of these questions.



**Professor Martin Williams**

*Department of Analytical & Environmental Sciences, Environmental Research Group, MRC-PHE Centre for Environment & Health, King’s College London*

I was until recently head of the air quality programme in Defra responsible for air quality policy and research to inform it. Until recently I chaired the Executive Body of the UNECE Convention on Long Range Transboundary Air Pollution, and I chair the Modelling Review Steering Group for Defra. I am lead author of policy section of the UNEP Assessment of Short Lived Climate Forcers.

My interests lie in the application of atmospheric science to policy on air quality, the relationship between air quality and health, and on the linkages between air quality and climate change. I have a particular interest in the effectiveness of air quality policies on urban and regional air quality as evidenced by measurement. Recent studies on NOx trends are a good example.

Further interests include the establishment of more detailed relationships between air quality and health in the UK as part of projects funded by the MRC at the MRC-HPA Centre at King's College. Prior to joining Defra I carried out air quality impact assessments prior to developments at three major UK airports – Heathrow, Gatwick and Stansted, and have maintained an interest in the impact of aviation on air quality.

I have a continuing interest in ozone as a pollutant and was the first to demonstrate the impact of stratospheric air on ground level concentrations in the UK. I developed a simple, fast but accurate model used in the daily government air quality forecast for ozone.

**Keynote Abstract - Air pollution: how bad is it and what can we do about it?**

In the last few years air pollution has become a popular subject in the media. This has arisen for several reasons; firstly the evidence has been increasing regarding the adverse effects of air pollution, especially on public health. The evidence on the harmful effects of fine particle pollution (mainly on PM2.5) has strengthened to the extent that estimates can be made of the number of premature deaths associated with exposure to PM2.5. The evidence on the harmful effects of nitrogen dioxide (NO2) is also now stronger, although the extent to which these effects are actually due to PM2.5 exposure is still a matter of debate.

Another reason for the increased interest in air pollution is the fact that the UK is failing to meet legally binding limits on NO2 set in an EU Directive and is consequently facing action in Europe through the infraction process carried out by the European Commission. Within the UK, the government has been instructed by judgements in the Supreme Court and High Court to produce an acceptable action plan to meet the NO2 limits.

Solutions to these problems, while technologically feasible, are often difficult to achieve in practice. One of the most important sources of these harmful pollutants is transport and progress is being made through the use of ‘after-treatment’ on vehicle exhausts such as catalytic converters and particle filters. However, the more effective technologies especially for diesel vehicles apply only to the newer vehicles and there is still a large number of older more polluting vehicles in the fleet. One way of reducing the impact of such vehicles, and one which forms a basis of the recent NO2 action plan produced by Defra, is to set up ‘Clean Air Zones’ where older vehicles face a discouraging financial charge to enter or even in more extreme cases a ban.

The agriculture sector has an important role to play in improving air quality, not just in the UK but more widely in Europe and in the rest of the world. Emissions of ammonia from fertiliser use and animal excreta play an important role in forming PM2.5 and transporting it many hundreds of kilometres across Europe. Technologies are available to reduce these emissions of ammonia but they have yet to be implemented on a wide enough scale to make much impression on PM2.5 concentrations in the UK and beyond. Synergies with climate change policies to achieve the goals of the UK Climate Change Act also offer a potentially large improvement in air quality in the UK. Energy efficiency measures, the use of renewables, nuclear power and electric cars can all be win-win measures for both climate and air quality. However there are antagonistic measures which can act in the opposite direction. The widespread burning of wood in small-scale appliances can lead to large emissions of PM2.5, and likewise the introduction of combined heat and power plants into central urban areas essentially imports pollution back into cities from the larger rural power stations which currently provide the UK’s energy.

**Professor Nicola Lacetera**

*Department of Agriculture and Forestry Science (DAFNE), University of Tuscia, Viterbo, Italy*

Prof. Lacetera joined the University of Tuscia (Viterbo, Italy) in 1990 as Assistant Professor at the Institute of Animal Science. Currently he heads the Department of Agriculture and Forestry Sciences in the same University.

Before joining the University of Tuscia, Prof. Lacetera graduated in Veterinary medicine at the University of Perugia (Italy). His academic education continued in the same university with a PhD program in veterinary immunology.

His main areas of research are the interactions between metabolism, immune response and health in dairy ruminants and the effects of heat stress on physiology, health and performance of dairy cows. Immunology, disease resistance and risk of death have been and still are the main topics of his research in the field of animal biometeorology.

Prof. Lacetera is a scientific member of many scientific societies. Within the International Society of Biometeorology he is Chair of the Commission on Animal Biometeorology and was field editor of the International Journal of Biometeorology for more than 10 years. He is member of the Task Force on Agriculture and Climate Changes operating within the Italian Minister of Agriculture and Forestry; member of the Technical Working Group of the European action on Integrated Pollution Prevention and Control (IPPC) in charge of the revision of the BREF (best available techniques reference document) concerning the intensive rearing of poultry and pigs, consultant for collaborative projects carried out in China and funded by the Italian Minister of Foreign Affairs, Chinese Academy of Animal Science, Veterinary Medicine and Grassland, and European Union; external reviewers for the United States-Israel Bi-national Agricultural Research and Development Fund, University of Veterinary and Animal Science of Lahore (Pakistan), University of Queensland (Australia), Deutsche Forschungsgemeinschaft (Bonn, Germany) and the French National Research Agency (ANR).

Prof. Lacetera is co-author of more than 200 publications.

**Keynote Abstract: Weather information for risk management in livestock operations**

Summer temperatures may cause heat stress and decline of welfare and productive efficiency in farm animals. This is responsible for significant economic losses in the livestock industries. Weather information may play a crucial role in preventing problems due to extreme events. This contribution will focus on thermal environment and in particular, it will review dairy cow studies providing information on thresholds based on temperature humidity index (THI) values. The THI combines temperature and humidity into a single value and may be calculated by utilizing several formulas. Different authors calculated thresholds for a number of parameters, which go from the risk of death to the quality of milk. A pluriannual field study indicated THI values of 80 and 70 as the maximum and minimum THI, respectively, above which the number of deaths in dairy farms starts to increase significantly. A similar study carried out in the same geographic area demonstrated a positive correlation between THI and milk somatic cell count and total bacterial count, and indicated a significant change in the slope at 57.3 and 72.8 maximum THI, respectively. The same model demonstrated also a negative correlation between THI and milk fat % and protein % and provided break points in the pattern at 50.2 and 65.2 maximum THI, respectively. Finally, the exposure of primiparous cows to THI values >79 was associated with a higher risk to develop clinical mastitis. This information, in association with weather forecast and further achievements in the field of adaptation of farm animals to climate change, will help farmers to set up emergency interventions, which may counteract the decline of animal welfare and the economic losses due to heat stress.

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| **21st International Congress of Biometeorology** | | |
| **September 3 – 7, 2017** | **Durham University** | **Durham, UK** |

**ICB Programme Committee**

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Camila Caiado, Isabella Bovolo, Sheila Seal, Judith Aird

**Monday**

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| **Sunday, September 3rd** | |
| **09:30 – 17:00** | **Executive Board Meeting**  *Senate Room, Durham Castle* |
| **09:30 – 17:00** | **Student and New Professionals Workshop** - *E005, Engineering* |
| **17:00 – 19:00** | **Registration Opens** |
| **19:00 – 21:00** | **Icebreaker & Welcome**  *Great Hall, Durham Castle* |

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| **Monday, September 4th** | |
| **08:30 – 09:00** | **Welcome & Opening** |
| **10:00 – 10:30** | **Coffee Break** |
| **12:00 – 13:30** | **Lunch Break** |
| **12:30 – 13:30** | **ISB Commission Meetings** |
| **14:30 – 16:00** | **Poster Sessions with Coffee** *ES228-231, Earth Sciences* |
| **07:30 – 17:00** | **Registration Continues throughout conference** |
| **18:00 – 19:30** | **SNP Meeting**  *Kingsley Barrett Room, CLC* |

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| **08:30 – 10:00** *(Arnold Wolfendale Room, CLC)*  **Welcome and Opening Session** |
| **Chair:** Glenn McGregor |
| **08:30**  Welcome to **ICB 2017**  **09:00 KN1** *Operationalising One Health: Putting Knowledge into Practice.* **Juli Trtanj,** NOAA, USA.  **09:30 KN2** *Increasing losses caused by natural disasters: what are the drivers, what are the risk management options?* **Peter Hoeppe,** Head Geo Risks Research/Corporate Climate Centre, Munich RE, Germany |
| **10:30 – 12:00** *(Arnold Wolfendale Room, CLC)*  **Session 1A: General Biometeorology** |
| **Chair(s):** Kristie Ebi, University of Washington, USA |
| **10:30** **1A.1** *Sixty Years of the International Journal of Biometeorology*. **Scott Sheridan**, Kent State University, USA; Michael Allen.  **10:45 1A.2** *:Health as a key focus in Sendai*. **Virginia Murray**, Public Health England, UK; Rishma Maini, Lorcan Clarke, Kevin Blanchard.  **11:15** **1A.3** *21st Century Technologies for Biometeorology*. **Hamed Mehdipoor**, University of Twente, Netherlands; Jennifer Vanos, Raul Zurita-Milla, Guofeng Cao.  **11:30** **1A.4** *Population vulnerability to heat over space and time - lessons for climate change adaptation*. **Sotiris Vardoulakis**, Institute of Occupational Medicine, UK; Clare Heaviside, Helen Macintyre, Katherine Arbuthnott, Shakoor Hajat, Roberto Picetti, Jonathon Taylor, Phil Symonds, Anna Mavrogianni, Ross Thompson, Angie Bone, Antonio Gasparrini, Paul Wilkinson, Mike Davies. |

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| **10:30 – 12:00** *(Rosemary Cramp Room, CLC)*  **Session 1B: Climate Change I** |
| **Chair(s):** Krzysztof Blazejczyk, Polish Academy of Sciences, Poland; Andrew Leung, University of Toronto, Canada |
| **10:30** **1B.1** *Estimates of Heat Related Work Capacity Loss due to Climate Change at Country and Sub-Country Level*. **Tord Kjellstrom**, Centre for Technology Research and Innovation, Cyprus; Bruno Lemke, Matthias Otto, Lauren Lines, David Briggs, Chris Freyberg.  **10:45** **1B.2** *Modelling Future Soil Temperature in Northern Environment*. **Andrew C.W. Leung**, University of Toronto Scarborough, Canada; William A. Gough, Tanzina Mohsin.  **11:00** **1B.3** *Predictions of climate related diseases in Poland to the year 2100*. **Krzysztof Blazejczyk**, Polish Academy of Sciences, Poland; Jaroslaw Baranowski, Anna Blazejczyk.  **11:15** **1B.4** *The energy system costs associated with mitigating heat stress in Africa under climate change*. **Jennifer Cronin**, UCL, UK;Ben Parkes, Jennifer Cronin, Olivier Dessens, Benjamin Sultan.  **11:30** **1B.5** *Assessment of global warming impact on ski fields in Ehime Prefecture, Japan - A combined approach with climate simulations and field surveys –*. **Asuka Suzuki-Parker**, RIssho University, Japan; Yoshika Miura, Hiroyuki Kusaka, Masaaki Kureha.  **11:45** **1B.6** *Comparison of adaptation modelling methods used in climate change impact assessments for heat-related mortality*. **Simon N. Gosling**, University of Nottingham, UK; David M. Hondula, Aditi Bunker, Dolores Ibarreta, Junguo Liu, Xinxin Zhang, Rainer Sauerborn. |

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| **12:30 – 13:30** *(E005, Engineering)*  **Phenology Commission Meeting** |
| **Chair:** Mark Schwartz, University of Wisconsin, USA |

**Monday**

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| **12:30 – 13:30** *(E101, Engineering)*  **Animal Biometeorology Meeting** |
| **Chair:** Nicola Lacetera, University of Tuscia, Italy |

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| **12:30 – 13:30** *(E102, Engineering)*  **Climate and Human Health Commission Meeting** |
| **Chair:** Pablo Fernández de Arroyabe Hernáez, Universidad de Cantabria, Spain |

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| **13:30 – 14:30** *(Arnold Wolfendale Room, CLC)*  **Session 2A: Human Health I** |
| **Chair(s):** Simon Gosling, University of Nottingham, UK; Asuka Suzuki-Parker, Rissho University, Japan |
| **13:30** **2A.1** *Short-term specific humidity effect on mortality in Japan*. **Yasushi Honda**, University of Tsukuba, Japan; Tran Ngoc Dang, Xerxes Tesoro Seposo.  **13:45** **2A.2** *Modeling weather impacts on human mortality using non-linear autoregressive models with exogenous input (NARX models)*. **Scott Sheridan**, Kent State University, USA; Cameron C. Lee.  **14:00** **2A.3** *The Impact of Weather Conditions on Childhood Injury Risk in Akron, Ohio, USA*. **Scott Sheridan**, Kent State University, USA; Jacqueline Curtis, Andrew Curtis, Heather Trnka, Eric Hutzell, Mary Infantino, Beth Kuckuck, Sherry Blair.  **14:15** **2A.4** *Investigating the Spatiotemporal Relationships Between Heat Metrics and Emergency Response Calls During the 2015 Pan American Games in Toronto, Canada*. **Alexandria Herdt**, Texas Tech University, USA; Jennifer Vanos, Ian Scott-Fleming, Dave Henderson. |
| **13:30 – 14:30** *(Rosemary Cramp Room, CLC)*  **Session 2B: Agriculture & Forestry I** |
| **Chair(s):** Dirk Schindler, University of Freiburg, Germany; Budong Qian, Agriculture and Agri-Food Canada, Canada |
| **13:30** **2B.1** *Agronomic Modifications of Maize Production to Minimize Climate Risk and Optimize Productivity in the Southern USA.*. **W. Brien Henry**, Mississippi State University, USA; L. Jason Krutz, Normie Buehring, Chris Fuhrmann.  **13:45** **2B.2** *Simulation of different cultivars of rice responding to elevated carbon dioxide and temperature in the cold region of China*. **Fengmei Yao**, Academy of Sciences, China; Jiahua Zhang.  **14:00** **2B.3** *Simulating regional rice yield with a process-based model and remote sensing information in the typical area of southern China*. **Jiahua Zhang**, Academy of Sciences, China; Fengmei Yao.  **14:15** **2B.4** *Use of weather information to assist farmers in their farm decisions: Case study of Maluti-a Phofung municipality of South Africa*. **M. E. Moeletsi**, Agricultural Research Council, South Africa; T. E. Masupha, K. M. Nape. |

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| **13:30 – 14:30** *(Ken Wade Room, CLC)*  **Session 2C: Human Thermal Comfort I** |
| **Chair(s):** Yasushi Honda, University of Tsukuba, Japan; Sookuk Park, Jeju National University, Rep. Korea. |
| **13:30** **2C.1** *Modelling a combination of urban heat mitigation strategies to improve human thermal comfort in Melbourne, Australia*. **Stephanie Jacobs**, Monash University, Australia; Ailie Gallant, Nigel Tapper.  **13:45** **2C.2** *Effect of summer-time indoor/outdoor temperature difference on office work productivity*. **Asuka Suzuki-Parker**, Rissho University, Japan; Shohei Aiba, Asuka Suzuki-Parker, Hiroyuki Kusaka, Yuki Asano.  **14:00** **2C.3** *Environment of venues at Japanese summer events*. **Michihiko Tonouchi**, Japan Meteorological Business Support Center, Japan; Yuki Tateishi, Hiroshi Yokoyama, Kiichi Sasaki. |

**Monday**

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| **14:30 – 16:30** *(ES228 – 231, Earth Sciences)*  **Formal Poster Viewing** |
| **Chair:** Isabella Bovolo, Durham University, UK |
| **P1** *The effect of vitamin E, L-carnitine and ginger in reversing heat stressed induced damage to antioxidant status and immune response in two broiler strains*. **Zia ur Rehman**, The University of Agriculture, Pakistan; Naila Chand, Rifat Ullah Khan.  **P2** *Physiological responses and adaptive characters in Bonsmara-Hereford crosses vs. Hereford purebred on environment stress.*. **Paula Batista**, University of Republic, Uruguay; Ana Espasandin, Celmira Saravia.  **P3** *Assessment of thermal comfort around sotetsubate “field with cycas hedge” in Amami-Ohshima, Japan*. **Jin Ishii**, Meijo University, Japan; Tsuyoshi Hashimoto, Shinichi Watanabe, Kosuke Kurihara, Ayu Tachikawa.  **P4** *The Impact of Environmental Risk Factors on Cardiovascular and Respiratory Mortality over Multiple Decades - Orange County, California (1975-2005)*. **F. L. T. Gonçalves**, University of São Paulo, Brazil; S. L. Pinheiro, J. R. Gonzales, S. C. Sheridan.  **P5** *Carbon dioxide fertilization offsets negative impacts of climate change on Arabica coffee yield in Brazil*. **Fabian Y. F. Verhage**, Wageningen University, Netherlands; Paulo C. Sentelhas, Niels P. R. Anten.  **P6** *Comparison of the suitability of thermal comfort for different types of farrowing house*. **Priscilla Ayleen Bustos Mac Lean**, São Paulo State University, Brazil; Douglas D’Alessandro Salgado, Isabela Garcia Mendes de Araújo, Vinicius Bonomo Valderramas, Fernanda Andrucioli, Tainara Ribeiro Parreira, Tainara Ribeiro Parreira.  **P7** *Cutaneous evaporation of hostein cows exposed to solar radiation*. **Patric André Castro**, São Paulo State University, Brazil; Alex Sandro Campos Maia, Vinícius de França Carvalho Fonsêca, Gustavo André Bernado Moura, Sérgio Faustini Campos, Marcelo Simão da Rosa, Charles Henrique Ribeiro.  **P8** *UTCI as a prediction tool for heatwave-induced health hazards in Europe*. **Claudia di Napoli**, University of Reading, UK; Anna Mueller-Quintino, Florian Pappenberger, Hannah L. Choke.  **P9** *Numerical modelling of weather conditions during the wildfires*. **Visnja Vucetic**, Meteorological and Hydrological Service, Croatia; Branimir Omazic.  **P10** *Comparison of the 2003 and 2015 heat waves in South-West Germany - Meteorological situation, boundary conditions, and health impacts.*. **Stefan Muthers**, Deutscher Wetterdienst, Germany; Andreas Matzarakis.  **P11** *Study of relations between the Emergency Medical Service data and selected weather and bioweather factors in Ústí nad Labem area*. **Martin Novák**, Czech Hydrometeorological Institute, Czech Republilc.  **P12** *Heat stroke risk for aging society in Japan – a case study of Saitama City from 2006 to 2016*. **Fujino Takeshi**, Saitama University, Japan; Sunuwar Dipenra.  **P13** *Extreme heat events associated to respiratory diseases in children up to 10 years old in São Paulo city*. **Sara Lopes de Moraess**, University of São Paulo, Brazil; Emerson Galvani.  **P14** *Estimation of fatigue by air temperature increase and reduction by air conditioners in Jakarta, Indonesia*. **Tomohiko Ihara**, The University of Tokyo, Japan; Ren Kusama.  **P15** *Calculating disability-adjusted life years (DALYs) for heat related illnesses due to urban heat island in Japan*. **Yuki Hashimoto**, The University of Tokyo, Japan; Tomohiko Ihara.  **P16** *The Climate Perception of Men and Women and Thermal Comfort in Santa Maria - RS*. **João Paulo Assis Gobo**, Universidade de São Paulo, Brazil; Emerson Galvani, Fabio Luiz Teixeira Goncalves.  **P17** *Changing Rainfall Regime and its Implications for Human Comfort in Sokoto State, Nigeria (1926-2015)*. **Umar Aliyu Tambuwal**, Usmanu Danfodiyo University, Nigeria; Aliyu Ismaila.  **P18** *Definition of climatic classification method based in thermal human comfort.*. **Carlos Javier Esparza López**, University of Colima, México; Jorge Armando Ojeda Sánchez, Carlos Escobar del Pozo, Adolfo Gómez Amador.  **P19** *Climate change impact on ecosystems at the East edge of European Russia*. **Oleg Askeyev**, Tatarstan Academy of Sciences, Russia; Arthur Askeyev, Igor Askeyev.  **P20** *Variability of Climatic Elements in Nigeria over Recent 100 Years*. **T. Salami**, Nigerian Meteorological Agency, Nigeria; O. S. Idowu, N. J. Bello.  **P21** *Impacts of recent climate change on meteorological wildfire danger in the Czech Republic*. **Martin Mozny**, Czech Hydrometeorological Institute, Czech Republic; Lenka Hajkova, Tomas Vrablik.  **Monday**  **P22** *Vine and hops as indicators of climate change in the Czech Republic*. **Martin Mozny**, Czech Hydrometeorological Institute, Czech Republic; Lenka Hajkova, Lenka Bartosova, Miroslav Trnka.  **P23** *Pan evaporation trends from 1971 to 2015 in the Czech Republic*. **Martin Mozny**, Czech Hydrometeorological Institute, Czech Republic; Radim Tolasz, Miroslav Trnka.  **P24** *Forest drought monitored by the SPI*. **Jaroslav Vido**, Technical University in Zvolen, Slovakia; Paulína Nalevanková, Katarína Strelcová.  **P25** *Variability of Malaria prevalence in Kano In Relation To Climate Variability*. **A. Akinbobola**, Federal University of Technology, Nigeria; E. C. Okogbue, J. Bayo Omotosho.  **P26** *Spatial Analysis of Malaria Risks in Akure, Ondo State, Nigeria*. **Sikiru Bayo Abdulkareem**, Federal University of Technology, Nigeria; Balogun Ifeoluwa Adebowale, Suleiman Abdulazeez Adegboyega.  **P27** *Silo opening dates: Another source of phenological data?*. **Marie R. Keatley**, University of Melbourne, Australia; Irene L. Hudson.  **P28** *Developing applicable climate science for agriculture and hydrological sectors in Argentina*. **Olga C. Penalba**, Universidad de Buenos Aires, Argentina, CONICET, Argentina; María Laura Bettolli, Vanesa C. Pántano, Mercedes Poggy, Juan A. Rivera.  **P29** *Grapevine phenology in Croatia under climate change*. **Marko Vucetic**, Meteorological and Hydrological Service, Croatia; Visnjica Vucetic, Petra Cicek Pomper.  **P30** *Advances in biometeorological studies in China learned from publications in Journal of Geographical Sciences*. **Xin Zhao**, Chinese Academy of Sciences, China; Yunjia Xu, Junhu Dai, Zexing Tao.  **P31** *Online questionnaire on sunlight as an interior design element*. **Naoko Matsuda**, Osaka Sangyo University, Japan; Kazuo Nagano.  **P32** *An agro-climatic approach to determine citrus postbloom fruit drop risk in Southern Brazil*. **Ana Raquel Soares-Colletti**, University of São Paulo, Brazil; Paulo Cesar Sentelhas, C. A. Alvares.  **P33** *Vertical temperature distribution measured with a drone at locations adjacent to the edge of the forest and the lake in summer*. **Naoshi Kakitsuba**, Meijo University, Japan.  **P34** *Simulation of long-term solar UV effects on surface plant litter decomposition*. **Wei Gao**, Colorado State University, USA; Maosi Chen.  **P35** *Circadian variation of methane emission and metabolic heat production of Nellore Cattle*. **Cíntia Carol de Melo Costa**, São Paulo State University, Brazil; Alex Sandro Campos Maia, Vinicius de Franca Carvalho Fonsêca, Rodrigo Simão, Patric André Castro, Eric de Andrade Culhari.  **P36** *Tourism climate potential in Hungary in the light of climate change*. **Attila Kovács**, University of Szeged, Hungary; János Unger, Noémi Kántor.  **P37** *Sigmoid relationship between surveyed clothing insulation and thermal index in outdoor spaces*. **Kazuo Nagano**, Kyoto Prefectural University, Japan; Kumika Sumisato.  **P38** *Tree growth dynamics as indicator of tree reaction to environmental stress*. **Adriana Leštianska**, Technical university in Zvolen, Slovakia; Peter Fleischer, Katarína Strelcová.  **P39** *Phenological Networks in the Pacific: Development and Community Engagement*. **Lynda E Chambers**, Australian Bureau of Meteorology, Australia; Roan D. Plotz, Siosinamele Lui.  **P40** *Sustainability of Croatian tourism in changing climate*. **Ksenija Zaninovic**, Meteorological and Hydrological Service of Croatia, Croatia; Lidija Srnec, Grigory Nikulin, Ivan Güttler, Renata Sokol Jurkovic.  **P41** *The effect of winter tropical urban climate upon the human body*. **Yoshihito Kurazumi**, Sugiyama Jogakuen University, Japan; Jin Ishii, Kenta Fukagawa, Emi Kondo, Ariya Aruninta.  **P42** *Heat and cold wave in Russia as the uncomfortable factor of the environment*. **Vera Vinogradova**, Russian Academy of Sciences, Russia; Alexandr Zolotokrylin, Alexey Vinogradov.  **P43** *Change of plant phenophases explained by survival modeling*. **Barbara Templ**, Zentralanstalt für Meteorologie und Geodynamik, Austria; Stefan Fleck, Matthias Templ.  **P44** *Effects Of Environment On The Behaviour Of Holstein Cows*. **Sheila Tavares Nascimento**, Universidade de Brasilia, Brazil; Caroline Silva Gonzaga Bueno, Alessandra Aparecida Silva, Claudete Regina Alcalde.  **P45** *Livestock Thermal Balance Simulator RGS 2000*. **Eric de Andrade Culhari**, São Paulo State University, Brazil; Alex Sandro Campos Maia, Vinícius de França Carvalho Fonsêca, Bruno Rodrigo Simão, Patric André Castro.  **P46** *Multivariate approach of adaptive chacteristics in locally adapted sheep*. **Débora Andréa Evangelista Façanha**, UFERSA, Brazil; Wilma Emanuela da Silva, Jacinara Hody Gurgel Morais Leite, Josiel Borges Ferreira, Wallace Sostenes Tavares da Silva, Renato Diogenes Macedo Paiva.  **P47** *Climate impact on vegetation: the case of the ecological zones of Nigeria*. **Folasade O. Oderinde**, Tai Solarin University of Education, Nigeria.  **P48** *Bee and willow phenology – using historical data to study species’ phenology drivers and synchrony*. **Sandra Stålhandske**, Stockholm University, Sweden; Kjell Bolmgren.  **P49** *Circadian pattern of physiological traits of Jersey dairy cows*. **Sheila Tavares Nascimento**, Universidade de Brasilia, Brazil; Alex Sandro Campos Maia, Vinícius França Carvalho Fonsêca, Marcos Davi de Carvalho.  **P50** *Thermal equilibrium of Morada Nova sheep in a tropical semiarid environment*. **Vinícius de França Carvalho Fonsêca**, Sao Paulo State University, Brazil; Alex Sandro Campos Maia, Bruno Rodrigo Simão, Carolina Cardoso Nagib, Severino Guilherme Caetano Gonçalves dos Santos, Mikael Leal Cabral Menezes de Amorim, Edilson Paes Saraiva, Antonio da Costa Pinheiro.  **P51** *A way to measure surface area in animals*. **Bruno Rodrigo Simão**, Sao Paulo State University UNESP, Brazil; Alex Sandro Campos Maia, Marcos Chiquitelli Neto, Eric de Andrade Culhari, Patric André Castro, Vinícius de França Carvalho Fonseca. |

**Monday**

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| **16:00 – 18:00** *(Arnold Wolfendale Room, CLC)*  **Session 3A: Human Health II** |
| **Chair(s):** Alexandria Herdt, Texas Tech University, USA; Adam Kalkstein, United States Military Academy, USA |
| **16:00** **3A.1** *Impact of air temperature on London ambulance response times*. **John E. Thornes**, University of Birmingham, UK; Francis Pope, Paul Fisher.  **16:15** **3A.2** *Heat wave effects on daily excess mortality in 14 Korean cities during the past 20 years (1991-2010): an application of the spatial synoptic classification approach*. **Dae-Geun Lee**, National Institute of Meteorological Sciences, Rep. Korea; Kyu Rang Kim, Chun-Ho Cho, Scott C. Sheridan, Laurence S. Kalkstein, Ho Kim, Seung-Muk Yi.  **16:30** **3A.3** *Short-term Weather Changes, Seasonality, and Respiratory Hospital Admissions*. **Robert E. Davis**, University of Virginia, USA; Kyle B. Enfield.  **16:45** **3A.4** *An exploratory analysis of the impact of the 2015-16 El Nino event on health in the Southwest pacific: The case of diarrhoea*. **Glenn McGregor**, Durham University, UK; Camila C. S. Caiado, Isabella Bovolo, Oliver Jackson, Jesus E. Bustamante-Fernandez.  **17:00** **3A.5** *Changes in Heat and Cold Related Mortality in Finland since the 1970s*. **Reija Ruuhela**, Finnish Meteorological Institute, Finland; Kirsti Jylha, Timo Lanki, Pekka Tiittanen, Otto Hyvärinen, Andreas Matzarakis.  **17:15** **3A.6** *Preliminary results of the assessment of excess mortality during the 2015 and 2016 heatwaves in France: a fine scale analysis by age, sex and place*. **Aymeric Ung**, French National Public Health Agency, France; Karine Laaidi, Mathilde Pascal, Vérène Wagner, Sébastien Denys, Pascal Beaudeau.  **17:30** **3A.7** *The impact of distinct atmospheric pathways on winter mortality in 2 regions of England: An environment-to-circulation approach*. **Pavlos Kassomenos**, University of Ioannina, Greece; Anastasia Paschalidou, Glenn McGregor, Panagiotis Tsanas.  **17:45** **3A.8** *Exploring the Use of Emergency Response Data Related to Extreme Heat in Large City Centers*. **Daniel J. Vecellio**, Texas A&M University, USA; Jennifer Vanos, Steven M. Quiring, Alexander H. Garza. |
| **16:00 – 18:00** *(Rosemary Cramp Room, CLC)*  **Session 3B: Agriculture and Forestry II** |
| **Chair(s):** Marie Keatley, University of Melbourne, Australia; Liang Liang, University of Kentucky, USA |
| **16:00** **3B.1** *Empirical modelling of forest storm damage in Southwest Germany*. **Dirk Schindler**, University of Freiburg, Germany; Christopher Jung.  **16:15** **3B.2** *Inter-annual variability in net ecosystem CO2 exchange during leaf development in a temperate mixed forest*. **Alison Donnelly**, University of Wisconsin-Milwaukee, USA; Rong Yu, Amelia Caffarra, Jonathan Hanes, Liang Liang, Ankur R. Desai, Lingling Liu, Mark Schwartz.  **16:30** **3B.3** *Modelling Spatiotemporal Variations in autumn leaf coloration of Ulmus pumila throughout China based on underground observations*. **Zexing Tao**, Chinese Academy of Sciences, China; Huanjiong Wang, Junhu Dai, Quansheng Ge.  **16:45** **3B.4** *Canola production in Canada facing climate change*. **Budong Qian**, Agriculture and Agri-Food Canada, Canada; Xuebin Zhang, Qi Jing, Alex Cannon, Denise Neilsen, Guilong Li, Brian McConkey, Barrie Bonsal.  **17:00** **3B.5** *Early warning system for bird-cherry oat aphid migrations based on the atmospheric dispersion model SILAM*. **Pilvi Siljamo**, Finnish Meteorological Institute, Finland; Matti Leskinen, Erja Huusela-Veistola, Seppo Neuvonen.  **17:15** **3B.6** *A Degree Day model for durum wheat (Triticum durum, Desf.) across the Italian peninsula under proven linear temperature response*. **Arianna Di Paola**, Euro-Mediterranean Center on Clmate Change, Italy. |

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| **16:00 – 18:00** *(Ken Wade Lecture Theatre, CLC)*  **Symposium 1: Urban Heat and Thermal Comfort: Measurement and Models** |
| **Chairs(s):** Jennifer Vanos, University of California San Diego, USA; David Hondula, Arizona State University, USA |
| **16:00 S1.1** *Actual and Perceived Thermal Sensation of Children during Outdoor Physical Activity in Two Seasons.* **Jennifer Vanos,** University of California; Alexandria Herdt; Marc Lochbaum.  **16:15 S1.2** *Comparison of popular measurement techniques in determining mean radiant temperature – a case study from Shanghai.* **Noémi Kántor,** University of Szeged; Liang Chen.  **16:30 S1.3** *Towards high-resolution heat-stress maps for Seoul, Korea: Hazard, risk and vulnerability.* **Britta Jänicke**, National Institute of Meteorological Sciences; Achim Holtmann; Misun Kang; Kyu Rang Kim; Dieter Scherer.  **16:45 S1.4** *Quantifying and classifying personal heat exposure for health risk assessment.* **David Hondula,** Arizona State University; Evan Kuras; Benjamin Ruddell; Sharon Harlan.  **17:00 S1.5** *Examination of personal heat exposure among grounds management workers at three university campuses.* **Chris Fuhrmann,** Mississippi State University; Maggie Sugg; Jen Runkle; Scott Stevens.  **Tuesday**  **17:15 S1.6** *The application of High Density Street-Level Air Temperature Observations Network (HiSAN): The movement of urban heat island in different period case study in Tainan, Taiwan.* **Yu-Cheng Chen,** National Cheng Kung University; Chun-Kuei Yao; Tzu Ping Lin; Tsuyoshi Honjo.  **17:30 S1.7** *Comfort-Map: dynamic visualizations of children’s thermal sensation in the outdoor environment.* **Silvia Coccolo,** Ecole Polytechnique Federale de Luasanne; Jennifer Vanos, Jerome Kaempf; Jean-Louis Scartezzini. |

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| **Tuesday, September 5th** | |
| **10:00 – 10:30** | **Coffee Break** |
| **10:30 – 12:00** | **Keynote Speakers** |
| **12:00 – 14:00** | **Lunch Break** |
| **12:30 – 14:00** | **General Members Meeting**  *Arnold Wolfendale, CLC* |
| **15:30 – 16:00** | **Coffee Break** |
| **18:00 – 18:30** | **Global Heat Health Information Network: Open Dialogue**  *(Rosemary Cramp Room, CLC)* |
| **18:00 – 19:00** | **International Journal of Biometeorology Editorial Board Meeting**  *Derman Christopherson Room, CLC* |
| **19:30 – 22:30** | **Conference Dinner** |

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| **08:30 – 10:00** *(Arnold Wolfendale Room, CLC)*  **Session 4A: Human Health III** |
| **Chair(s):** Pavlos Kassomenos, University of Ioannina, Greece; Pablo Fernández de Arroyabe, Universidad de Cantabria, Spain |
| **08:30** **4A.1** *Effect of high night-time temperature on all cause and cause specific mortality in London*. **Peninah Murage**, London School of Hygiene and Tropical Medicine, UK; Shakoor Hajat, Sari Kovats.  **08:45** **4A.2** *Association between high temperature and work-related injuries in Guangzhou, China*. **Rongrong Sheng**, Sun Yat-sen University, China; Changchang Li, Cunrui Huang.  **09:00** **4A.3** *Confounding effects of extreme heat duration and community vulnerability on intra-urban cardiovascular mortality*. **Hung Chak Ho**, Chinese University of Hong Kong, Hong Kong; Meng Cai, Alan Lai, Chao Ren, Kevin Ka-Lun Lau, Edward Ng.  **09:15** **4A.4** *Soaking in bathtub filled with artificial CO2-hot spring water may suppress a progress of muscle fatigue during continual resistance exercise after bath*. **Masaaki Hashimoto**, Teikyo University of Science, Japan; Nriyuki Yamamoto.  **09:30** **4A.5** *Modified Risk associated with heat and cold events (1975 – 2004)*. **Michael J. Allen**, Old Dominion University, USA.  **Tuesday**  **09:45** **4A.6** *From Santa Ana Winds to Monsoons: The Role of Local Climate on Heat-Health Relationships in the Southwest United States*. **Adam J. Kalkstein**, United States Military Academy, USA. |

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| **08:30 – 10:00** *(Rosemary Cramp Room, CLC)*  **Session 4B: Urban Green Infrastructure & Heat Management** |
| **Chair(s):** Jennifer Vanos, University of California San Diego, USA; Jennifer Cronin, UCL Energy Institute, UK |
| **08:30** **4B.1** *Urban human-biometeorology meets urban planning: potential of urban green to maintain outdoor thermal comfort at building sites during severe summer heat*. **Hyunjung Lee**, Office for Environmental Protection, City of Stuttgart, German; Rainer Kapp, Ulrich Reuter, Helmut Mayer.  **08:45** **4B.2** *Improvement outdoor thermal comfort by various arbor characteristics in hot and humid regions*. **Shing-Ru Yang**, National Cheng-Kung University, Taiwan; Chia-Chun Chen, Tzu-Ping Lin.  **09:00** **4B.3** *Impact of blue spaces on urban microclimate – a biometeorological assessment*. **Jana Fischereit**, University of Hamburg, Germany; K. Heinke Schlünzen.  **09:15** **4B.4** *Relevance of urban trees and sun shades regarding summertime heat stress reduction – a field surveys from Pécs, Hungary*. **Noémi Kántor**, University of Szeged, Hungary; Ágnes Gulyás, Csilla V. Gál.  **09:30** **4B.5** *Strategic shading of public transportation stops in Phoenix, AZ*. **David M. Hondula**, Arizona State University, USA; Lance Watkins, Mckenzie Murphree, Tamara Dunbarr, Ariane Middel.  **09:45** **4B.6** *Tree shade effects on human thermal environments in summer*. **Sookuk Park**, Jeju National University, Rep. Korea; Stanton E. Tuller. |

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| **10:30 – 12:00** *(Arnold Wolfendale Room, CLC)*  **Keynote Speakers** |
| **Chair(s):** Glenn McGregor, Durham University, UK |
| **10:30**  **KN3** *Phenology: a pastime with a considerable history.* **Tim Sparks,** School of Computing, Electronics and Maths, Coventry University, UK  **11:00**  **KN4** *Air Pollution, how bad is it and what can we do about it?* **Martin Williams,** Department of Analytical & Environmental Sciences, Environmental Research Group, MRC-PHE, Centre for Environment Health, King’s College London, UK  **11:30**  **KN5** *Weather information for risk management in livestock operations,* **Nicola Lacetera**, Deparment of Agriculture and Forestry Science, University of Tuscia, Viterbo, Italy. |

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| **12:30 – 14:00** *(Arnold Wolfendale, CLC)*  **General Membership Meeting** |
| **Chair(s):** Mark Schwartz, University of Wisconsin, USA. |
| * Welcome from 2014 – 2017 President * Announcement of ISB Exec Board elections * Update on International Journal of Biometeorology * Update on Student and New Professionals activities Tromp Award presentation * AOB |

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| **14:00 – 15:30** *(Arnold Wolfendale Room, CLC)*  **Session 5A: Climate Information I** |
| **Chair(s):** Joanne Robbins, Met Office, UK; Joy Shumake-Guillemot, World Meteorological Organisation. |
| **14:00** **5A.1** *Using Teleconnections to Explain Variation in Phenotype and Fitness of White-tailed Deer in a Temperate Location*. **P. Grady Dixon**, Fort Hayes University, USA; Bronson K. Strickland.  **14:15** **5A.2** *To develop optimized drought index for detecting drought events by using multi-sources satellite information*. **Jiahua Zhang**, Academy of Sciences, China; Fengmei Yao.  **14:30** **5A.** **3** *Progress Report on GNSS Based Mobile Flood Early Warning System (GNSS\_MFEWS) for Lagos, Nigeria*. **Balogun Ifeoluwa Adebowale**, Federal University of Technology, Nigeria; Temidayo Oniosun.  **14:45** **5A.4** *Quantifying climate risks to support effective strategic decision-making*. **Richard Hewston**, Verisk Maplecroft, UK.  **15:00** **5A.5** *UMEP - An integrated tool for city-based climate services*. **Fredrik Lindberg**, University of Gothenburg, Sweden; C. S. B. Grimmond, Andrew Gabey, Bei Huang, Christoph W. Kent, Ting Sun, Natalie E. Theeuwes, Leena Järvi, Helen Ward, Y. Y. Chang, Per Jonsson, Niklas Krave, David Meyer, Frans Olofson, J. G. Tan, Dag Wästberg, Lingbo Xue, Zhe Zhang.  **15:15** **5A.6** *Grass species respond differently to climate change*. **Aseel Mahdi**, University of Reading, UK; Julie Hawkins. |

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| **14:00 – 15:30** *(Rosemary Cramp Room, CLC)*  **Session 5B: Heat Stress** |
| **Chair(s):** Robert Davis, University of Virginia, USA. |
| **14:00** **5B.1** *Using a simple city model for heat stress exposure modelling*. **Peter Hoffman**, University of Hamburg, Germany; Jana Fischereit, Stefan Heitmann, K. Heinke Schlünzen, Ingeniun Gasser.  **14:15** **5B.2** *Application of wet bulb globe temperature activity modification guidelines in secondary school athletics*. **Yuri Hosokawa**, University of Connecticut, USA; Nicole Robinson, Delaney Dowden, Ashley Hagen, Matt Durrstein, Fean Wagner, Douglas J. Casa.  **14:30** **5B.3** *Considering varying clothing, activities and exposure times with the Universal Thermal Climate Index UTCI*. **Peter Bröde**, IfADo, Germany; Dusan Fiala, Bernhard Kampmann.  **14:45** **5B.4** *Validation of the human thermoregulation model to predict physiological impact of a heat wave*. **Agnes Psikuta**, Swiss Federal Laboratories for Materials Science and Technology, Switzerland; Barbara Koelblen, Simon Annaheim.  **15:00** **5B.5** *Projected Heat Stress along the 2020 Olympic Marathon Route in Tokyo, Japan and the Role of Microclimatic Design*. **Jennifer Vanos**, University of California San Diego, USA; Robert Brown, Eichi Kosaka, Akiko Iida, Makoto Yokohari.  **15:15** **5B.6** *The cabin air temperature of parked vehicles in summer conditions: a dynamic model of a life-threatening environment for children and pets*. **Günther Schauberger**, University of Veterinary Medicine, Austria; Johannes Horak, Ivo Schmerold, Kurt Wimmer. |

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| **14:00 – 15:30** *(Ken Wade Lecture Theatre, CLC)*  **Session 5C: Pollen** |
| **Chair(s):** Paul Beggs, Macquarie University, ,Australia; Tim Sparks, Coventry University, UK. |
| **14:00** **5C.1** *Does the increase in ambient CO2 concentration elevate allergy risks by oak pollen?*. **Kyu Rang Kim**, National Institute of Meteorological Sciences, Rep. Korea; Jae-Won Oh, Su-Young Woo, Yun Am Seo, Hyun-Seok Kim, Wi Young Lee, Baek-Jo Kim.  **14:15** **5C.2** *New approach to an emission determination in a numerical pollen dispersion modelling*. **Changbum Cho**, National Institute of Meteorological Sciences, Rep. Korea; Tae Hee Kim, Kyu Rang Kim, Yun Am Seo, Baek-Jo Kim.  **14:30** **5C.3** *Developing a validation procedure for numerical pollen forecast models*. **Helfried Scheifinger**, Zentralanstalt für Meteorologie und Geodynamik, Austria; Stefano Natali, Heinz Gallaun, Barbara Templ.  **14:45** **5C.4** *The Melbourne Thunderstorm Asthma Epidemic of 21-22 November 2016*. **John Nairn**, Bureau of Meteorology, Adelaide, Australia; Tarini Casinader, Louise Minty, Beth Ebert, Ed Newbigin, Danny Csutoros, Sandra Falconer, Vikki Lynch, Cenk Suphioglu, Paul Torre.  **15:00** **5C.5** *Circadian patterns of airborne allergenic pollen concentrations: a role for meteorological factors?*. **Athanasios Damialis**, Technical University of Munich and Helmholtz Zentrum München, Germany; Franziska Häring, Kostas Karatzas, Claudia Traidl-Hoffmann.  **15:15** **5C.6** *Relationships between allergic symptoms and airborne pollen concentrations: forecasts and driving factors*. **Athanasios Damialis**, Technical University of Munich and Helmholtz Zentrum München, Germany; Franziska Häring, Gertrud Hammell, Megan Fleming, Andreas Philipp, Stefanie Gilles, Claudia Traidl-Hoffmann. |

**Tuesday**

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| **16:00 – 18:00** *(Arnold Wolfendale Room, CLC)*  **Session 6A: Climate Information II** |
| **Chair(s):** John Thornes, University of Birmingham, UK; Fredrik Lindberg, University of Gothenberg, Germany |
| **16:00** **6A.1** *Storm Track and Landfall Location of Southwest Indian Ocean Tropical Cyclones: Historical Perspective*. **Jennifer M. Fitchett**, University of the Witwatersrand, South Africa.  **16:15** **6A.2** *Climate Services for Health –Overcoming barriers to uptake of climate and weather information*. **Joy Shumake-Guillemot**, WMO/WHO Climate and Health Office, Switzerland.  **16:30** **6A.3** *Climatology of tourism indices TCI and CIT at Lithuanian seaside*. **Justas Kažys**, Vilnius University, Lithuania; Simona Dalinkeviciute.  **16:45** **6A.4** *Global return level estimation of the most severe tropical cyclones and European winter storms in the last decades*. **Christopher Jung**, University of Freiburg, Germany; Dirk Schindler.  **17:00** **6A.5** *The Climate of Fukushima Prefectures and Temporary Housing after Great East Japan Earthquake*. **Masatoshi Tanaka**, Fukushima Medical University, Japan.  **17:15** **6A.6** *Urbanisation influence on bioclimatic conditions and potential health risks: a report from a hot-humid tropical city*. **Balogun Ifeoluwa Adebowale**, Federal University of Technology, Nigeria.  **17:30** **6A.7** *Comparison of the measurements of two different weather stations in Akure, Nigeria*. **Ahmed A Balogun**, Federal University of Technology, Nigeria; Nick van de Giesen, John Selker, Frank Annor, Sunusi Usman Yerima.  **17:45** **6A.8** *Bioclimate and climate tourism conditions of Ondo State, Nigeria*. **Akinyemi Gabriel Omonijo**, Federal University Oye-Ekiti, Nigeria. |

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| **16:00 – 18:00** *(Rosemary Cramp Room, CLC)*  **Session 6B: Heatwaves & Heat Information Systems** |
| **Chair(s):** Scott Sheridan, Kent State University, USA; Christina Koppe, German Meteorological Service, Germany. |
| **16:00** **6B.1** *Building Resilience to Extreme Heat: The National Integrated Heat Health Information System (NIHHIS)*. **Hunter M. Jones**, National Oceanic and Atmospheric Administration, USA; Juli Trtanj, George Luber, Wayne Higgins.  **16:15** **6B.2** *Iterative management of heat early warning systems in a changing climate*. **Kristie L. Ebi**, University of Washington, USA; Jeremy J. Hess.  **16:30** **6B.3** *Challenges for verifying global heatwave and coldwave forecasts: Can emerging technology help?*. **Joanne Robbins**, Met Office, UK; John Nairn, Grant Williamson, Amanda Wheeler, Sharon Campbell, David Bowman, Fay Johnston.  **16:45** **6B.4** *Heat Wave Temporal Structure, and its Implications for Heat Stress Vulnerability with Global Warming*. **Jane Baldwin**, Princeton University, USA; Jay Dessy, Gabriel Vecchi, Michael Oppenheimer.  **Wednesday**  **17:00** **6B.5** *An update to the German Heat health warning system: A focus on the elderly population and urban areas*. **Stefan Muthers**, Deutscher Wetterdienst, Germany; Gudrun Laschewski, Andreas Matzarakis.  **17:15** **6B.6** *Impacts of the 2015 heat wave on mortality in the Czech Republic: A comparison with previous major heat waves*. **Aleš Urban**, Czech Academy of Sciences, Czech Republic; Hana Hanzlíková, Jan Kyselý, Eva Plavcová.  **17:30** **6B.7** *Managing increasing heatwave severity, Australia's national heatwave service*. **John Nairn**, Bureau of Meteorology, Adelaide, Australia; Bertram Ostendorf, Peng Bi.  **17:45** **6B.8** *Building climate services for extreme heat in Bangladesh*. **Hannah Nissan**, Columbia University, USA; NA, Hannah Nissan. |

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| **16:00 – 18:00** *(Ken Wade Lecture Theatre, CLC)*  **Symposium 2: Observing & Managing Diverging Ecological Responses to Climate Change** |
| **Chair(s):** Kjell Bolmgren, Swedish University of Agricultural Sciences, Sweden. |
| **16:00 S2.1** *Pursuing Coherence from Multiple Spring and Autumn Phenological Measures.* **Mark Schwartz,** University of Wisconsin-Milwaukee, USA.  **16:15 S2.2** *Temporal coherence of phenological and climatic rhythmicity in Beijing.* **Xiaoqiu Chen,** Peking University, China**;** Weiqi Zhang.  **16:30 S2.3** *Spatial simulation of autumn land surface phenology in the temperate deciduous broadleaf forest of China.* **Weiguang Lang,** Peking University, China; Xiaoqiu Chen.  **16:45 S2.4** *The phenology of seabirds in a changing climate: are birds adjusting their breeding season?* **Katharine Keogan,** University of Edinburgh, UK; Sarah Wanless; Richard A Phillips; Francis Daunt; Ally Phillimore; Sue Lewis.  **17:00** **S2.5** *Modelling Variability of White Ash Populations in Spring and Autumn Phenology.* **Liang Liang,** University of Kentucky, USA.  **17:15 S2.6** *Variations in autumn phenological seasons in Northern China over the past 50 years and its relationship with climate.* **Junhu Dai,** Chinese Academy of Sciences, China; Zexing Tao; Huanjiong Wang; Quansheng Ge.  **17:30 S2.7** *Asymmetric effects of daytime and nighttime warming on spring leaf phenology.* **Yongshuo H Fu,** Beijing University, China and University of Antwerp, Belgium.  **17:45 S2.8** *A Euorpean phenological database, PEP725, www.pep725.eu*. **H. Scheifinger**, Zentralanstalt für Meteorologie und Geodynamik, Austria; T. Hübner, E. Koch, A. Paul, . Ungersböck. |

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| **Wednesday, September 6th** | |
| **10:45 – 11:15** | **Coffee Break** |
| **12:00 – 13:30** | **Lunch Break** |
| **12:00 – 13:30** | **New ISB Executive Committee Meeting**  *Derman Christopherson Room, CLC* |
| **15:45 – 16:15** | **Coffee Break** |
| **16:15 – 17:00** | **Closing Ceremony** |
| **17:15 – 19:00** | **Symposium 3 Follow-up: Roundtable Discussion**  *Kingsley Barrett Room, CLC* |

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| **09:15 – 10:45** *(Rosemary Cramp Room, CLC)*  **Session 7A: Human Thermal Comfort II** |
| **Chair(s):** Stephanie Jacobs, Monash University, Australia; Michikiko Tonouchi, Japan Meteorological Business Support Center, Japan. |
| **09:15** **7A.1** *UTCI assessment of cold stress suffered from the local wind ‘Hijikawa-Arashi’ in Ehime, Japan.* **Yukitaka Ohashi**, Okayama University of Science, Japan; Takumi Katsuta, Haruka Tani, Taiki Okabayashi.  **09:30** **7A.2** *The thermal comfort range of UTCI and its application on the long-term climate in hot and humid regions*. **Shing-Ru Yang**, National Cheng Kung University, Taiwan; Tzu-Ping Lin.  **09:45** **7A.3** *Neutral temperature ranges of Korean human thermal sensation in urban and beach areas*. **Sookuk Park**, Jeju National University, Rep. Korea; Stanton E. Tuller.  **10:00** **7A.4** *A comparative analysis of outdoor thermal comfort in Hong Kong and Melbourne during summer,* **Cho Kwong Charlie Lam,** Sun Yat-sen University, China; Kevin Ka-Lun Lau.  **10:15** **7A.5** *Effect of Radiation Environment on Outdoor Thermal Sensation*. **Atsumasa Yoshida**, Osaka Prefecture University, Japan; Dalki Hayashi, Shinichi Kinoshita.  **10:30** **7A.6** *Study of the Fabrication Process of EVA/Starch Foams Using Subcritical CO2 and Ultrasound*. **Rebeca Delatore**, São Paulo State University, Brazil; Daniel Velasco, Miguel Angel Rodríguez-Pérez. |
| **11:15 – 12:00** *(Arnold Wolfendale Room, CLC)*  **Session 8A: Vector Borne Disease** |
| **Chair(s):** Lynda Chambers, Bureau of Meteorology, Australia |
| **11:15** **8A.1** *Determining malaria hotspot using climatic variables and geospatial technique in central urban area of Ibadan, Southwest, Nigeria*. **A Akinbobola**, Federal University of Technology, Nigeria; J. Bayo Omotosho, E.C. Okogbue, John Oludare.  **11:30** **8A.2** *Present Day and Future Population Dynamics of the Dengue Vector Mosquito Aedes aegypti Using a Water Container Energy Balance Model*. **Daniel F. Steinhoff**, National Center for Atmospheric Research, USA; Andrew J. Monaghan.  **11:45** **8A.3** *Spatial-temporal Distributions of Several Infectious Diseases in Different Climate Zones in Western China*. **Yuxia Ma**, Lanzhou University, China; Yuxin Zhao, Sixu Yang, Jianding Zhou, Xiaodong Zheng. |

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| **11:15 – 12:00** *(Rosemary Cramp Room, CLC)*  **Session 8B: Air Pollution** |
| **Chair(s):** Pilvi Siljamo, Finnish Meteorological Institute, Finland. |
| **11:15** **8B.1** *Climate variability and change as elements modulating air pollution and behavior of Acute Infection disease*. **Pablo Fernández de Arróyabe**, Cantabria University, Spain; Daysaríh Tápanes Robau, Paulo Ortíz Bultó, Pablo Fernández de Arróyabe,.  **11:30** **8B.2** *Air Pollution Episodes Associated with Prescribed Burns in Sydney Australia*. **Melissa Hart**, University of New South Wales, Australia; Giovanni Di Virgilio, Ningbo Jiang.  **11:45 8B.3** *An analysis of the impact of climate change on the air pollution in Beijing–Tianjin–Hebei region, China*. **Xiakun Zhang**, National Meteorological Center of China Meteorological Administration, China; Shuyu Zhang. |

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| **11:15 – 12:00** *(Ken Wade Lecture Theatre, CLC)*  **Session 8C: Forecasting** |
| **Chair(s):** John Nairn, Bureau of Meteorology, Australia; Helfried Scheifinger, Zentralanstalt für Meteorologie und Geodynamik, Austria |
| **11:15** **8C.1** *Developing the second generation of biometeorological forecasts: the methods and fundaments.*. **Luis B. Lecha Estela**, University of Havana, Cuba; Luis Monteagudo Lima.  **11:30** **8C.2** *An Evaluation of Intraseasonal to Interannual Climate Forecasts and Forecasting Tools for Use in Agriculture; Decision Making in the South East United States.*. **Fergus J. D. Keatinge**, The University of Florida, USA; Peter R. Waylen, Jane Southworth, Ray G. Huffaker, Gerrit Hoogenboom.  **11:45** **8C.3** *Enhancing Resilience to Heat Extremes:Multi-model Forecasting of Excessive Heat Events at Subseasonal Lead Times*. **Augustin Vintzileos**, University of Maryland, USA. |

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| **13:30 – 15:45** *(Arnold Wolfendale Room, CLC)*  **Session 9A: Animal Biometeorology II** |
| **Chair(s):** Grady Dixon, Fort Hays State University, USA. |
| **13:30** **9A.1** *A panting score index for sheep*. **J. B. Gaughan,** The University of Queensland, Australia; A. M. Lees, M. L. Sullivan, A. J. Cawdell-Smith, J. B. Gaughan.  **13:45** **9A.2** *Global climate change is going to affect beef cattle performance in Turkey: Performance of beef cattle determined by comprehensive climate index for different climate models.*. **H. Koknaroglu**, Suleyman Demirel University, Turkey; J.A. Harrington Jr, T.L. Mader.  **14:00** **9A.3** *Circadian variations in rectal temperature responses of packed donkeys deprived of feed and water administered with ascorbic acid during the cold-dry (harmattan) season*. **Victor O. Sinkalu**, Ahmadu Bello University, Nigeria; Joseph O. Ayo, Salka N. Minka, Jecintha N. Umekesiobi.  **Wednesday**  **14:15** **9A.4** *Impact assessment of climate change on intensive pig and poultry production by the simulation of the indoor climate of livestock buildings*. **G. Schauberger**, University of Veterinary Medicine, Austria; R. Vitt.  **14:30** **9A.5** *Estimating the Climatic Energy Demands (Feed and Water) of Dromedary Camels Fed at the Maintenance Level: A Theoretical and Practical Aspect*. **Emad M. Samara**, King Saud University, Saudi Arabia; Khalid A. Abdoun, Ahmed A. Al-Haidary.  **14:45** **9A.6** *Enteric methane emission of Jersey dairy cows: an investigation on circadian pattern*. **Alex Sandro Campos Maia**, São Paulo State University, Brazil; Sheila Tavares Nascimento, Marcos Davi de Carvalho, Vinícius de França Carvalho.  **15:00** **9A.7** *Thermoregulation in different coat coloured locally adapted brazilian sheep*. **Jacinara Hody Gurgel Morais Leite**, UFERSA, Brazil; Wallace Sostene Tavares da Silva, Wilma Emanuela da Silva, Renato Diógenes Macedo Paiva, Josiel Borges Ferreira, José Ernandes Rufino Sousa, Luis Alberto Bermejo Asensio, Débora Andrea Evangelista Façanha.  **15:15** **9A.8** *Acid-Base Equilibrium in Locally Adapted Brazilian Sheep Under Natural Heat Stress*. **Débora Andrea Evangelista Façanha**, UFERSA, Brazil; Fabrício Xavier Morais, José Moreira de Oliveira Filho, Chromacio Calafange Medeiros, Josiel Borges Ferreira, Wilma Emanuela Silva, José Ernandes Rufino de Sousa.  **15:30** **9A.9** *Relationship between body weight and respiratory traits of livestock bred in tropical environment*. **Carolina Cardoso Nagib Nascimento**, Universidade Estadual Paulista, Brazil; Vinícius de França Carvalho Fonsêca, Cintia Carol de Melo Costa, Leandro Zucheratto Camerro, Marcos Chiquitelli Neto, Alex Sandro Campos Maia |
| **13:30 – 15:45** *(Rosemary Cramp Room, CLC)*  **Session 9B: Weather Sociology** |
| **Chair(s):** Hunter Jones, NOOA, USA; Glenn McGregor, Durham University, UK |
| **13:30** **9B.1** *Hot under the collar: the relationship between temperature and crime in Australia*. **Paul J. Beggs**, Macquarie University, Australia; Heather R. Stevens, Petra L. Graham.  **13:45** **9B.2** *Multi-dimensional social vulnerability and flood disadvantage assessment to support socially just flood risk management*. **Gina Cavan**, Manchester Metropolitan University, UK; Aleksandra Kazmierczak, Sarah Lindley, Angela Connelly.  **14:00** **9B.3** *Assessing the effect of weather on human outdoor perception using Twitter*, **Hanna Leona Lokys**, University of Muenster, Germany; Laura Giuffrida, Otto Klemm.  **14:15** **9B.4** *Communication of Heat Stress PInformation for Risk Management*. **Matthias Otto**, Nelson Marlborough Institute of Technology, New Zealand; Bruno Lemke, Tord Kjellstrom.  **14:30** **9B.5** *Heatwave risk perception and its management in the field : a study among the local stakeholders of the French National Heatwave Plan*. **Aymeric Ung**, French National Public Health Agency, France; Karine Laaidi**,** Christophe Perrey, Mathilde Pascal, Sébastien Denys, Pascal Beaudeau.  **14:45** **9B.6** *Nocturnal tornadoes in Tennessee, USA: An interdisciplinary approach to understanding public safety challenges*. **Kelsey N. Ellis**, University of Tennessee, USA; Lisa Reyes Mason, Kelsey N. Gassert, Mary E. Winchester.  **15:00** **9B.7** *Biometeorological Data Infrastructures and Human Vulnerability definition based on a Citizens Science Approach*. **Pablo Fernandez de Arroyabe**, University of Cantabria, Spain; Dominic Royé. |

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| **13:30 – 15:30** *(Ken Wade Lecture Theatre, CLC)*  **Symposium 3: Integrating Climate Information & Individual Physiology for Improved Heat Warning** |
| **Chair(s):** Lars Nybo, University of Copenhagen, Denmark. |
| **13:30** **S3.1** *Overview of climatological aspects of forecasting heat waves over Europe*. **Christina Koppe**, Deutscher Wetterdienst, Germany.  **13:45** **S3.2** *Challenges in linking climate services and European-scale heat warnings*. **Christoph Spirig**, Federal Office of Meteorology and Climatology MeteoSwiss, Switzerland; Ana Casanueva, Sven Kotlarski, Jonas Bhend, Pascal Noti, Mark A. Liniger.  **14:00** **S3.3** *Physiological responses and human health aspects of heat stress*. **Glenn P. Kenny**, University of Ottawa, Canada.  **14:15** **S3.4** *Epidemiological analyses of environmental heat factors related to mortality*. **Andreas D. Flouris**, University of Thessaly, Greece.  **14:30** **S3.5** *Impact of individual and integrated environmental heat stress factors on physical exercise performance*. **Lars Nybo**, University of Copenhagen, Denmark; George Havenith.  **14:45** **S3.6** *Clothing modulated heat stress in the context of climate change*. **Chuansi Gao**, Lund University, Sweden.  **15:00** **S3.7** *Heat-health warning systems: integrating physiological knowledge and climate information into operational advices for occupational purposes*. **Marco Morabito**, Institute of Biometeorology, Italy; Alfonso Crisci, Alessandro Messeri, Simone Orlandini.  **15:15** **S3.8** *Climate change and working life: linking stakeholders for risk assessment and management.* **Tord Kjellstrom**, Centre for Technology Research and Innovation CETRI, Cyprus; Lucka Kajfez-Bogatat.  **Wednesday** |

**Wednesday**

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| **16:15 – 17:00** *(Arnold Wolfendale Room, CLC)*  **Closing Ceremony** |
| * Closing comments from 21st ICB Chair * The Lantern Ceremony * Comments from 2017 – 2020 ISB President |

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| **17:15 – 19:00** *(Kingsley Barrett, CLC)*  **Symposium 3 Follow-up: Roundtable Discussion** |
| **Chair(s):** Lars Nybo, University of Copenhagen, Denmark |

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| **Thursday, September 7th**  **Optional Excursions** | |
| **07:30** | **Holy Island**  *Marriot Hotel pick-up* |
| **07:45** | **Holy Island**  *Collingwood College pick-up* |
| **08:30** | **Hadrian’s Wall**  *Collingwood College pick-up* |

**21st International Congress of Biometeorology**

**Abstracts – Oral Presentations**

**1A.1**

*Sixty Years of the International Journal of Biometeorology*

**Scott Sheridan1, Michael Allen2 (1Kent State University, USA, 2Old Dominion University, USA)**

The International Journal of Biometeorology has continuously evolved since its first publications in 1957. In this paper, we examine these changes using a database that includes all manuscript titles and author information. A brief history considers the development of the journal and shifts over time. With an interdisciplinary focus, publications draw on a wide array of subdisciplines. Using content analysis, we evaluate the themes found within IJB. Some research themes have maintained prominence throughout the journal’s history, while other themes have waxed or waned over time. Similarly, the most influential manuscripts throughout the past 60 years reveal that human biometeorological papers, particularly regarding thermal comfort, have been influential throughout the journal’s history, with other themes, including phenology and animal biometeorology, more concentrated in specific periods. Dominated by North America and Europe in the early years, publication authorship has shifted over the last decade to be more globally representative. Recent inclusion of special issues devoted to regional biometeorological issues, as well as to Students and New Professionals, offer insight into the future direction of the IJB.

**1A.2**

*Health as a key focus in Sendai*

**Virginia Murray, Rishma Maini, Lorcan Clarke, Kevin Blanchard (Public Health England, UK)**

Effective response and recovery to disasters can reduce health risks and improve health outcomes. The Sendai Framework recognises this and places a strong emphasis on ensuring resilient health systems through the integration of disaster risk manage­ment into health care provision. Four out of the seven global targets stated in the Sendai Framework are directly related to health, namely: reducing disaster mortality and the number of affected people, and reducing disaster damage to critical infrastructure and disruption of basic services such as health facilities.

However, health indicators can be difficult to measure. Baseline data may not be available and there is a lack of comparable disaster damage and loss data due to differences in data recording and standards. Attributing morbidity and mortality to disasters can be complex given the multiple direct and indirect pathways. For instance, with slow-onset hazards such as droughts, health effects may be mediated through the disruption to basic health care and communicable diseases. Furthermore, time periods between the exposure to hazards and subsequent health outcomes can vary widely, particularly concerning impacts on mental health, which raises questions around the setting of temporal dimensions within which to measure the effects of disasters.

Setting the right targets and indicators requires detailed thinking, time and consultation with a diverse range of stakeholders. Ultimately, the indicators need to be useful, useable and used; minimising the reporting burden to countries whilst also empowering countries to use data more effectively and ensuring its applicability locally and nationally as well as at the global level. As Sendai is furthest ahead in developing its indicators compared to all other UN Landmark agreements passed in 2015, it will be incumbent upon it practitioners within disaster risk reduction to share its learning and experiences of best practice in this area globally.

**1A.3**

*21st Century Technologies for Biometeorology*

**Hamed Mehdipoor1, Jennifer K Vanos2, Raul Zurita-Milla1, Guofeng Cao3 (1University of Twente, Netherlands, 2University of California San Diego, USA, 3Texas Tech University, USA)**

The first decade of the 21st century saw remarkable technological advancements for biometeorology. These emerging technologies have allowed the collection of new data and further emphasized the need for specific and/or changing systems for efficient data management, data processing, and advanced representations of new data by using digital information management systems. The state-of-the-art forms of biometeorological observations and processing capabilities will be of utmost importance as we face new, highly complex and interconnected challenges into the future. Solutions to worldwide issues that fall within the realm of biometeorology (energy use, health, poverty and food, agriculture, water, climate change adaptation, etc.) will increasingly rely upon technology. As a community of researchers, keeping abreast of the technological advances will allow biometeorology to arise as a field prepared to deal with challenges within the air, water, and land as they connect to living biological organisms. For example, progress towards finer scales of meteorological data in urban and rural areas is at the forefront of understanding the potential for impacts of heat waves on humans, plants, and animals as one of the main hazards of a changing climate. Moreover, routine collection, processing, and visualization of personal exposure data (‘big data’) will shift paradigms from place-based distribution of environmental. This study provides an overview of new hardware and software technologies that support biometeorologists in representing and understanding the influence of atmospheric processes on living organisms.

**1A.4**

*Population vulnerability to heat over space and time – lessons for climate change adaptation*

**Sotiris Vardoulakis1, Clare Heaviside2, Helen Macintyre2, Katherine Arbuthnott3, Shakoor Hajat3, Roberto Picetti3, Jonathon Taylor4, Phil Symonds4, Anna Mavrogianni4, Ross Thompson2, Angie Bone2, Antonio Gasparrini3, Paul Wilkinson3, Mike Davies4 (1Institute of Occupational Medicine, UK, 2Public Health England, UK, 3London School of Hygiene & Tropical Medicine, UK, 4UCL, UK)**

Climate change has led to an increase in mean temperatures in most parts of world since pre-industrial times, and to more frequent and intense heatwaves particularly in temperate climatic zones, affecting human health, wellbeing and productivity.

However, some evidence suggests that population vulnerability to heat and heatwaves has decreased over time across a number of different settings. This is potentially due to general improvements in healthcare and living standards, and the wider use of cooling devices and heat-health warning systems in high-income countries.

Vulnerability to heat also varies with geographical location across climatic zones and continents, and even within the same country or region. This can be influenced by population characteristics, e.g. the elderly are typically more vulnerable to heat than younger adults, and the adaptive capacity of different societies, e.g. community resources and heat risk reduction programmes. Heat risk may also depend on characteristics of the built environment, e.g. housing type and population density. The urban heat island (UHI) effect can exacerbate heat-related health impacts in urban areas compared to surrounding rural areas. Mitigation of the UHI through redesign and increase of urban green and blue spaces can alleviate the impacts of heat, and provide additional public health benefits, such as improved air quality and increased physical activity.

We have critically appraised the scientific literature to identify the key characteristics of population vulnerability to heat, including variability over space and time. This variability has important implications for the assessment of current and future heat-related health impacts, as well as for adopting effective health protection measures in the context of environmental and demographic change.

**1B.1**

*Estimates of Heat Related Work Capacity Loss due to Climate Change at Country and Sub-Country Level*

**Tord Kjellstrom1,2, Bruno Lemke3, Matthias Otto3, Lauren Lines4, David Briggs4, Chris Freyberg4 (1Centre for Technology Research and Innovation, Cyprus, 2Australian National University, Australia, 3Nelson- Marlborough Institute of Technology, New Zealand, 4Ruby Coast Research Centre, New Zealand)**

It is well known in physiology that high heat exposure of a working person causes serious health risks and reductions of work capacity or labour productivity. Such a reduction is related to the natural actions for heat effect prevention that the working people take if they can "self-pace". If the work intensity continues without self-pacing a risk of exertional heat stroke develops. Exposure-response relationships for the heat induced reduction of work capacity based on a few epidemiological studies, as well as guidelines for safe hourly work intensity (need for rest periods) can be used to estimate the likely future loss of work capacity as climate change progresses.

We have developed a new method to calculate heat related work capacity loss at grid cell level (0.5 x 0.5 degrees) and can combine the impact on all grid cells in a country or intra-country region to produce impact assessments in different time periods. These assessments use publicly available climate modelling outputs and the results depend on the model and pathway used in the modelling. Examples from the different continents indicate that for moderate intensity work (at 300W) the work capacity reduction expressed as the percent of annual daylight work hours lost currently is 1-2% in India, Cambodia, Nigeria and Burkina Faso, and 0.2-0.3% in China, Tunisia, Mexico and USA. These reductions will increase at the end of this century up to 7-11% for the first group of countries and up to 2% for the second group, based on the current global climate change policies. These reductions will affect the economic outputs of individuals, communities, enterprises, regions and countries. The analysis methods are being developed to incorporate economic impact estimates. Initial examples will be presented.

**1B.2**

*Modelling Future Soil Temperature in Northern Environment*

**Andrew C.W. Leung, William A. Gough, Tanzina Mohsin (University of Toronto Scarborough, Canada)**

Climate modelling is often used to project future temperature under various emission and policy scenarios. While remote sensing offers an accurate picture of soil temperature over a large area, this approach is only capable of measuring near-surface soil temperature and is less precise than actual instruments placed within the soil. Using long term historical soil temperature records in northern Canada, the Canadian Second Generation Earth System Model (CanESM2) and Statistical Downscaling Model (SDSM) software, we calibrated and assessed the performance of model. The model was found to be relatively accurate in replicating historic soil temperatures. Higher modelling accuracy was achieved with mean temperature and less for maximum and minimum temperature. We created future projections (up to year 2086) under three IPCC AR5’s RCP scenarios (RCP 2.6, 4.5 and 8.5) for soil temperature at 5 cm to 150 cm. Soil temperatures at all depths were projected to rise to above 0oC by 2057-2086 period under the highest emission scenario (RCP 8.5). This could affect the safety of aircraft operations in the region due to the melting of the permafrost. Lower emission scenarios (RCP 2.6 and 4.5) would keep the soil temperature below 0oC. We successfully demonstrated that even though the SDSM software was not originally created to project future soil temperatures, the software was capable of such projection with high accuracy.

**1B.3**

*Predictions of climate related diseases in Poland to the year 2100*

**Krzysztof Błażejczyk1, Jarosław Baranowski1, Anna Błażejczyk2 (1Polish Academy of Sciences, Poland, 2Laboratory of bioclimatology and Environmental Ergonomics, Poland)**

In spite of great progress in medicine the health of individuals and societies still strongly depends on atmospheric factors which influence humans in direct and indirect ways. Clinical research proved that some atmospheric factors influence human body. The short-term changes of weather could induce subjective ailments in healthy humans, intensify some objective symptoms of many illnesses and even a death within the groups of higher risk (elders, convalescent, small children).

The aim of the paper is to present predictions of some climate related diseases (CRD) typical for the temperate climatic zone of Poland. It is characterized by great seasonal changes of the air temperature and other climate elements. The following CRD are taken into consideration: *Salmonellosis* intoxications, *Lyme* *boreliosis*, skin cancers (morbidity and mortality), influenza, weather caused deaths, mortality caused by dysfunctions of respiratory and circulatory systems.

The research consisted of two stages: statistical modelling basing on past data (climatological and epidemiological for the longest available period) and predictions of CRD for three climate change SRES scenarios (A1B, A2, B1) to the year 2100.

Several simple and multiply regression models were found for the relationships between mortality and morbidity rates and climate variables. The models were applied to predict future levels of CRD. First we predicted climate variables used in the models using the of METEONORM 7 software package. Next we calculated standardised morbidity and mortality rates per 100 000 inhabitants. At the end of 21st century we should expect significant changes in CRD levels. We must expect increase in: heat stress mortality, cardiovascular mortality, *Lyme boreliosis* infections and skin cancer morbidity and mortality. There is also predicted decrease in: cold stress mortality, respiratory mortality, overcooling mortality and influenza. However, in *Salmonellosis* intoxications predictions show slight fluctuations during the century without any clear tendencies.

**1B.4**

*The energy system costs associated with mitigating heat stress in Africa under climate change*

**Ben Parkes1, Jennifer Cronin2, Olivier Dessens2, Benjamin Sultan1 (Sorbonne Universités, France, 2UCL, UK)**

Heat stress occurs when a person is unable to cool themselves sufficiently to maintain a healthy body temperature. High temperature and water vapour pressure reduces the efficacy of sweating and can lead to serious productivity and health impacts. To prevent the increasing heat stress caused by climate change, the energy system will need to supply more electricity to power cooling devices such as fans and air conditioning units, which will incur costs.

We use an ensemble of CORDEX-Africa simulations, which are derived from a set of CMIP5 climate simulations with the RCP8.5 scenario, to calculate two heat stress indices (Apparent Temperature and Humidex) for the current and future climates: the 1986-2005 control period and two specific warming levels, +2K (2020-2049) and +4K (2062-2091). The increased temperatures and changes to the precipitation distribution under climate change are projected to increase the intensity of heat stress events in Sahelian Africa and introduce new heat stress events in Northern and Central Africa.

The cooling demand to turn a heat stress event into a non-heat stress event is computed for each grid cell in Africa. These values are weighted by the population in each grid cell to find the total cooling required to prevent heat stress over Africa. We use TIAM-UCL, a bottom-up global optimisation model, to explore the least-cost future energy system that meets the projected increase in demand and thereby derive the increase in investment and operational costs of the system. Preventing heat stress in Africa under climate change is found to increase the cost of the energy system by 0.26% up to 2035 and by 0.60% up to 2076. This additional cost accounts for 0.03% and 0.06% of the cumulative African GDP up to 2035 and 2076 respectively.

**1B.5**

*Assessment of global warming impact on ski fields in Ehime Prefecture, Japan: A combined approach with climate simulations and field surveys*

**Asuka Suzuki-Parker1, Yoshika Miura2, Hiroyuki Kusaka2, Masaaki Kureha2 (1RIssho University, Japan, 2University of Tsukuba, Japan)**

This study aims to assess the impact of global warming on ski fields with ensemble high-resolution climate simulations and field surveys. The study targets three ski fields in Ehime Prefecture, the southern limit of snow accumulation in Japan.

We conducted field surveys to investigate means of snow supply and number of days open for each field. Field A, located at altitudes of 1200m and above, depends solely on natural snowfall, whereas field B, located below 1000m, receives no natural snowfall and depends solely on snow machines. Field C is a mix of the two, depending both on natural and artificial snow supplies. While field B has the most number of days open (105 days per season) in part owing to artificial snow supplies, the number of open days for fields A and C is relatively less, with 86 and 82 days respectively.

With the differences in means of snow supply in mind, we performed future projections for number of days open for the end of 21st century. For fields B and C, number of days open was defined as days with daily average temperature below 0 ℃ (threshold for retaining snowpack by snow machines). For field A, number of days open was defined as days with average snow depth (from natural snowfalls) greater than 30cm. We used high-resolution (5km) ensemble regional climate model simulations for current (1980-2000) and future (2076-2096, IPCC-AR5 RCP8.5 scenario) periods (Murata et al. 2015). Projection results indicated that compared to current climate, number of days open for fields B and C would reduce by 48% and 36% respectively. For field A, a 99% reduction was projected for future climate, resulting in almost no possible days open. However, if snow machines are introduced, field A may retain the current actual number of days open in future climate.

**1B.6**

*Comparison of adaptation modelling methods used in climate change impact assessments for heat-related mortality*

**Simon N. Gosling1, David M. Hondula2, Aditi Bunker3, Dolores Ibarreta4, Junguo Liu5, Xinxin Zhang6, Rainer Sauerborn2 (1University of Nottingham, UK, 2Arizona State University, USA, 3University of Heidelberg, Germany, 4European Commission, Joint Research Centre, IPTS, Spain, 5South University of Science and Technology of China, China, 6Beijing Forestry University, China)**

Many different methods have been used to model the potential for populations to adapt to a warming climate in climate change impact studies for heat-related mortality. We address the longstanding requirement for a comprehensive and systematic comparison of the sensitivity of impact estimates to each method. We also develop an understanding of the relative sensitivity of impacts to climate model uncertainty, emissions uncertainty and “adaptation uncertainty” (i.e. the inclusion/exclusion of adaptation modelling). We compare the effect of employing six different statistical adaptation modelling methods on projected impacts in 2070-2099, for 14 European cities. Impacts are estimated with climate projections from five climate models, run under two emissions scenarios to explore the relative effects of climate modelling and emissions uncertainty. We find that adaptation uncertainty is a source of uncertainty that can be greater than emissions and climate modelling uncertainty. In 13 of 14 cities the ranges in projected impacts due to adaptation uncertainty are larger than those associated with climate modelling and emissions uncertainty. In addition, the inclusion/exclusion of adaptation significantly effects the impact estimates. The range of the difference (%) in impacts between including and excluding adaptation, irrespective of climate modelling and emissions uncertainty, can be as low as 28% with one method and up to 103% with another (mean across 14 cities). Thus, we recommend that future assessments account for adaptation uncertainty in their approach.

**2A.1**

*Short-term specific humidity effect on mortality in Japan*

**Yasushi Honda, Tran Ngoc Dang, Xerxes Tesoro Seposo (University of Tsukuba, Japan)**

Background: Humidity has been regarded as one of the weather factors that affects health. However, there has been no study that has evaluated the geographical difference simultaneously controlling for temperature and its lag effect. We show the results for 47 prefectures in Japan.

Data and Methods: Anonymous death certificate data were obtained by permission of Ministry of Health, Labour and Welfare, and weather data were obtained from Japan Meteorological Agency. We evaluated the relation between all-cause mortality and weather variables using distributed lag non-linear models. In the evaluation, we evaluated specific humidity and its lag effect, controlling for daily maximum temperature and its lag effect, time trend and day of week.

Results: We found two types of pattern for the overall specific humidity effect on mortality; V-shaped and monotonous risk decline. In other words, in almost all the cases, very low humidity had a significant risk, whereas very high humidity showed elevated risk only in some of the prefectures. The V-shaped pattern appeared to be observed more frequently in south-western region, but the difference was not clear.

Discussion: The specific humidity effect evaluated here are for after controlling for temperature. Therefore, the results should not be confounded by temperature. However, as with low the temperature effect, the risk elevation by low humidity would also be related to season, not by day to day variation of humidity per se. Further studies are necessary to provide a clear conclusion.

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**2A.2**

*Modelling weather impacts on human mortality using non-linear autoregressive models with exogenous input (NARX models)*

**Cameron C. Lee, Scott Sheridan (Kent State University, USA)**

Many previous studies have shown the relationship between human mortality and atmospheric conditions – temperature in particular – to be highly nonlinear, as extreme conditions tend to impact human health in an increasingly exponential manner. Due to this characteristic, various nonlinear time-series modelling frameworks have been utilized to describe this association, such as distributed lag nonlinear models and generalized additive models, among others. The current research utilizes a novel artificial neural network-based time series model known as nonlinear autoregressive models with exogenous input (NARX models) to quantify the relationship between weather and mortality in 45 different cities in the United States from 1979-2010. Preliminary results show that weather-forced NARX models can explain over 60% of mortality variability in some locations, representing an improvement of over 20 percentage-points in explained variance compared to the simple 1-day autocorrelation of mortality in some locations, with model performance being best in winter and worst in summer. Models generally improve when the number of lags in daily mortality incorporated into the model are increased, however, increasing model complexity and/or lagged weather variables have widely varying impacts on model performance. While direct comparisons to other modelling techniques utilized in the biometeorological literature base were not undertaken, this research presents a promising first-take on the efficacy of an alternative method for weather-mortality research.

**2A.3**

*The Impact of Weather Conditions on Childhood Injury Risk in Akron, Ohio, USA*

**Scott Sheridan1, Jacqueline Curtis1, Andrew Curtis1, Heather Trnka2, Eric Hutzell3, Mary Infantino4, Beth Kuckuck3, Sherry Blair2 (1Kent State University, USA, 2Akron Children’s Hospital, USA, 3Summit County ADM Board, USA, 4Akron Police Department, USA)**

While much research has examined the connection between extreme weather and broad-scale mortality and morbidity outcomes, far less is known about how they might influence injury, especially among children. Therefore, this study analyses a broad range of injury and risk outcomes collected from disparate data sources over a three-year period (2013-2015) for the city of Akron, Ohio. Days with extreme weather events (temperature and precipitation) are compared to days without extremes. These comparisons enable us: 1) to identify the spatial pattern of all-cause injuries and risk of injury among children that are unique to days with temperature and precipitation extremes and 2) to create a model for public health practitioners to integrate these otherwise siloed data as an evidence base for geographically targeting prevention and intervention activities for extreme weather events in their communities. Child injury data and injury risk data are drawn from a variety of sources including trauma registry, police calls for service, and police incidents of juvenile victimization. Days were defined as being extreme in terms of temperature if the daily mean apparent temperature was above the 90th percentile (hot) or below the 10th percentile (cold) of the historical distribution. Extreme precipitation events are defined as any day in excess of the 90th percentile of daily precipitation, or any incidence of frozen precipitation. Cluster analysis is performed on locations of child injury and risk data based on classifications of age, and injury and risk types for each extreme weather day and on a matched sample day representing weather norms. Incidence of outcomes are compared between the extreme and normal days, as are the spatial patterns of these outcomes. Findings from this study suggest that specific extreme weather events produce differential injury outcomes and injury risks for children and that these are geographically variable.

**2A.4**

*Investigating the Spatiotemporal Relationships Between Heat Metrics and Emergency Response Calls During the 2015 Pan American Games in Toronto, Canada*

**Alexandria Herdt1, Jennifer Vanos1, Ian Scott-Fleming1, Dave Henderson3 (1Texas Tech University, USA, 2University of California San Diego, USA, 3Environment Canada, Canada)**

Weather has a profound effect on human health and well-being, with heat being one of the greatest causes of human morbidity, specifically at large gatherings such as sporting events. Various univariate, bivariate, and multivariate heat stress metrics are used to identify episodes of oppressive weather that are detrimental to human health. In an attempt to better understand weather variations in the Greater Toronto Area (GTA), Environment Canada deployed a mesonet system of 53 weather stations during the summer of 2015 and throughout the Pan American games during which thousands of tourists and athletes visited Toronto. The unique combination of fine-scale mesonet weather data with EMS data, as opposed to applying a single station’s data across the whole city, allows for a more detailed exploration of the effects of heat on human health than is traditionally possible. Spatiotemporal analyses are completed through statistical comparisons between three heat stress metrics ‒ Humidex, Wet Bulb Globe Thermometer, or COMFA human energy budget model – as well as emergency medical service (EMS) calls. Preliminary spatial maps across the GTA demonstrate variations by heat metric, identifying different areas of escalated risks for heat-related illness.

These maps can be used to inform public health officials and/or urban planners of areas of increased heat exposure at a finer intra-urban scale. Further results will determine which heat stress has the strongest relationship with heat-related EMS calls within the city limits using statistical regression modelling and three spatial exposure proxies (airport, averaged city, and station-specific), with a case study focused on thermal comfort at Pan American Games venues.

Results will provide new information on the potential benefits and uses of mesonet systems during large-scale events and will improve our understanding of the variability among common heat metrics in relation to intra-urban heat- health burden to enhance Toronto’s resilience to extreme heat.

**2B.1**

*Agronomic Modifications of Maize Production to Minimize Climate Risk and Optimize Productivity in the Southern USA*

**W. Brien Henry, L. Jason Krutz, Normie Buehring, Chris Fuhrmann (Mississippi State University, USA)**

Weather patterns resulting in excessive heat and drought often affect farmers negatively. Recent improvements in climate modelling and consolidation within the agriculture and weather industries result in farmers altering their cropping strategies and risk exposure in response to relatively short-term weather patterns. Our work in the Mid-South USA region suggests that there are potential moisture and economic savings with minor changes to existing irrigation and agronomic practices. Data from over 14 farmer fields and four research stations over the 2013 to 2016 growing seasons suggest that by implementing minor irrigation modifications, we can improve yield by approximately 3 to 5% and reduce the amount of water applied by 40% all while increasing profitability. Planting date, hybrid selection, and soil moisture sensors were used to optimize and improve the profitability of the maize production system. By planting earlier with improved, stress tolerant hybrids, the critical reproductive phase of corn development occurs in a historically wetter and cooler portion of the growing season. These conditions improve maize production and increase the probability of naturally occurring precipitation while reducing farmer dependence upon supplemental irrigation. Preserving water resources and taking advantage of our wet climate all while reducing farmer risk exposure enhances environmental stewardship and economic sustainability.

**2B.2**

*Simulation of different cultivars of rice responding to elevated carbon dioxide and temperature in the cold region of China*

**Fengmei Yao, Jiahua Zhang (Academy of Sciences, China)**

The impacts of increasing temperature and CO2 concentration on different rice cultivars production in the cold region of China was studied in this paper. Three rice varieties with different maturity types were selected according to the accumulated temperature to perform the simulation experiments. Daily weather data and Open Top Chamber (OTC) test yield data in 2013 were used to initialize CERES-Rice model parameters. the CERES-Rice model was used to simulate the influence of climate change on early-mature, mid-mature and late-mature rice production in the study area under fixed weather scenarios, which consisted of three CO2 concentration (i.e., 390, 450 and 550μmol.mol-1) and four temperature rise levels (i.e., 1, 2, 3 and 4℃). Simulations were performed with and without considering the enhanced CO2 fertilization effects, respectively. Results showed that with CO2 concentration rising, rice yield showed an increase. With temperature rising, early-mature rice yield declined significantly, but mid-mature and late-mature rice yield increased at first and then gradually declined. Without considering the effect of CO2 fertilization, except for the medium and late varieties in 1oC warming would have slightly increased by 3.06% and 0.27%, yields under other treatments would reduce. The most serious reduction occurs to early-mature rice, which decreased up to 57.70% with an increase of temperature by 4oC, while mid-mature rice and late-mature rice yields decreased about 10%. With considering the effect of CO2 fertilization, mid-mature and late-mature rice yields still increased 0.75% and 3.23% at 2oC warming under 450μmol·mol-1CO2, respectively. Mid-mature rice yield also increased 4.49% at 3oC warming and late-mature rice yield increased 0.39% at 4oC warming under 550μmol·mol-1CO2. However, whether considering the effect of CO2 fertilization or not, early-mature rice yield always obviously decreased with temperature increasing.

**2B.3**

*Simulating regional rice yield with a process-based model and remote sensing information in the typical area of southern China*

**Jiahua Zhang, Fengmei Yao (Academy of Sciences, China)**

Rice is one of the main crops in China, and rice planting area accounts for 20% of the world’s rice planting area, and the production ranks first in the world, which accounts for 30% of the world’s rice production. Rice has played an important role for China and the whole world in terms of food security, so it is very crucial to estimate timely and accurately the rice yield for agriculture and food security. We developed a process-based crop model (RS-P-YEC) to estimate crop yield with regional scale based on a BEPS model, which was derived by climate data, soil data, experiment data and remote sensing information. This study has analysed the applicability of the RS-P-YEC (the remote-sensing-photosynthesis-yield estimation for crops) model for the rice yield simulation over the Middle and Lower Reaches of Yangtze River (MLRYR) in a typical region of Southern China. The simulated rice yield was compared with the actual statistical dataset, so as to obtain the accuracy of the model results. The results showed that the correlation coefficients (R) between simulated rice yield and statistical data is 0.708 (P=0.01), the average relative errors were 9, 6.5, 7.2%, and the root mean square errors were 777.5, 606.4, 693.4 kg/ha in 2007, 2008 and 2009, respectively. It indicated that the RS-P-YEC model can be used to estimate rice yield in the MLRYR region of China.

**2B.4**

*Use of weather information to assist farmers in their farm decisions: Case study of Maluti-a-Phofung municipality of South Africa*

**M. E. Moeletsi, T. E. Masupha, K. M. Nape (Agricultural Research Council, South Africa)**

Climate variability, climate change and food security are the most puzzling problems currently being faced by most developing countries in Africa. Agricultural activities in Southern Africa are vulnerable to weather and climate variability and thus agricultural decision-makers should utilize available weather forecast information to their benefit. In this project, weather information was conveyed to the farmers of the Maluti-a-Phofung municipality of the Free State province in the view to assist them in their day-to-day agricultural/farm management decisions. Two forms of dataset namely seasonal forecast and weekly were deemed necessary for the farming community in the Free State province. Seasonal forecast was conveyed to farmers in the form of workshops before planting and its updates during the growing season. Weekly rainfall forecast was sent on a biweekly basis in the form of short messaging system. The importance of this information was evaluated through a questionnaire at the end of the season. Farmers were highly satisfied with the information on weather and climate presented to them with over 90% of the farmers stating that their decisions were highly influenced by the rainfall forecasts. The farmers also alluded that most significant rainfall periods were captured by the forecasts in time for their benefit. Hence, the results of the study demonstrated the importance of packaging agrometeorological information appropriately and timeously for the benefit of the farming societies.

**2C.1**

*Modelling a combination of urban heat mitigation strategies to improve human thermal comfort in Melbourne, Australia*

**Stephanie Jacobs, Ailie Gallant, Nigel Tapper (Monash University, Australia)**

Heatwaves are the most dangerous natural disaster to occur in Australia causing more fatalities than all other natural disasters combined. People in urban areas, where the majority of Australia's population resides, are at a higher risk of heat stress caused by heatwaves due to factors such as the urban heat island effect that makes cities warmer than their surroundings.

We model a climatology of heatwaves (from 1990-2014) for Melbourne and measure the effectiveness of two urban heat mitigation techniques separately and in combination. We model an increased vegetation fraction and the implementation of white roofs across the city. We investigate how the two urban heat mitigation techniques affect the near surface temperature, wind speed, humidity, sensible heat, latent heat and apparent temperature, a 'feels like' index. White roofs reduce the temperature and the apparent temperature in the city during the day, while an increase in vegetation reduces the temperature at night. The combination of multiple urban heat mitigation techniques creates the largest cooling effect in the city. This study determines the most effective combination of urban heat mitigation strategies for creating a safer and more comfortable city during heatwaves.

**2C.2**

*Effect of summer-time indoor/outdoor temperature difference on office work productivity*

**Shohei Aiba1, Asuka Suzuki-Parker2, Hiroyuki Kusaka1, Yuki Asano1 (1University of Tuskuba, Japan, 2Rissho University, Japan)**

Authors conducted subject experiments and meteorological observations to examine the effect of summer-time indoor/outdoor temperature differences on office work productivity. Office work productivity was assessed by paper calculation tests of adding two-digit numbers. Subjects were asked to take this test before and after 15 minutes of exposure to their assigned environment and/or behaviour. Subjects were divided into three groups. Group A remained in an air-conditioned room in a sitting position. Groups B and C were exposed to outdoor environment for 15 minutes; group B remained in a sitting position, and group C was asked to walk at their own pace.

Experiments were conducted for seven days (all in August 2016) in three suburban cities around Tokyo, Japan. The number of subjects for each experiment ranged from 9 to 17, totalling 96 subjects (ages 21.8±2.0, 65 males, 31 females). It was generally sunny for the first 5 days of experiments, with an average temperature > ~30oC and an indoor/outdoor temperature difference > ~5oC during outdoor exposure time. The latter two days were relatively cooler.

Test score changes (before and after outdoor exposure of groups B and C) from group C for sunny experiment days showed a 2% reduction (statistically significant at 95%), whereas other groups showed no significant changes. Test score changes from group C for cool days also did not show significant changes. Further analysis of group C for sunny days showed that subjects with short sleep hours (less than 270 min) had significantly larger test score reduction rates compared to those with sufficient sleep hours (more than 450 min). These results indicate that exposure to outdoor/indoor temperature difference added with physical stress and insufficient sleep lead to an increased risk in a reduction of office work productivity.

**2C.3**

*Environment of venues at Japanese summer events*

**Michihiko Tonouchi1, Yuki Tateishi2, Hiroshi Yokoyama, Kiichi Sasaki (1Japan Meteorological Business Support Center, Japan, 2The Ministry of Environment, Japan)**

Japanese summer is hot and humid, however, lots of events are held in summer. In 2020 Tokyo Olympic Games will be held in the hottest season of Japan. In order to reduce risks of heat stroke at event venues, observations at fields, i.e. soccer stadiums, a firework festival, traditional summer festivals, were implemented. WBGT observed in sunny areas is 2 to 3 degree (Celsius) higher than in shaded areas. And if the area is a small and poorly ventilated space, WBGT becomes 1 degree higher additionally. In order to reduce such risks, event organizers direct queues to shaded areas or deliver number tickets for pre-collection. On the other hand, when people assemble in a small place, WBGT becomes 1 to 2 degrees higher compare to uncongested areas. Such a situation was observed at an entrance of a station by people returning home, behind stadiums (e.g. toilets) at half time, after the game and the congestion of audiences before starting games and around souvenir shops. The WBGT increase from congestion is mostly brought on by the rise of dry-bulb temperature.

**3A.1**

*Impact of air temperature on London ambulance response times*

**John E Thornes, Francis Pope, Paul Fisher (University of Birmingham, UK)**

Ambulance services are in operation continuously (24/7) around most of the world and yet, until recently, ambulance data has only been used for operational purposes rather than for assessing public health. In England in 2014/15 more than 9 million emergency 999 calls were received, an increase of 6.1% over the previous year. Ambulance call-out data offers a new and valuable (near) real-time source of public health information that can also be used to assess the impact of environmental conditions, such as temperature, upon human health. A detailed analysis of London ambulance data (2003-2014) will be presented and compared to London temperature data. Ambulance services are susceptible to disruptions due to both hot and cold weather due primarily to the increased number of emergency calls. In London, the speed of ambulance response begins to suffer when the mean daily air temperature drops below ca. 2 °C or rises above ca. 20 °C. This is explained largely by the increased number of calls past these threshold temperatures. The degradation in response times is more rapid, at lower temperatures compared to higher temperatures due to road conditions in snow and ice which results in three distinct temperature regimes (<2, 2-20, >20°C). The baseline relationships established in this work will inform the prediction of likely changes in ambulance demand (and illness types) that may be caused by seasonal temperature changes and increased frequency and intensity of extreme/severe weather events, exacerbated by climate change, in the future.

**3A.2**

*Heat wave effects on daily excess mortality in 14 Korean cities during the past 20 years (1991-2010): an application of the spatial synoptic classification approach*

**Dae-Geun Lee1, Kyu Rang Kim1, Chun-Ho Cho1, Scott C. Sheridan2, Laurence S. Kalkstein3, Ho Kim4, Seung-Muk Yi4 (1National Institute of Meteorological Sciences, Rep. Korea, 2Kent State University, USA, 3University of Miami, USA, 4Seoul National University, Rep. Korea)**

The aim of this study is to explore offensive summer weather type classified by the Spatial Synoptic Classification (SSC) and to evaluate its impacts on excess mortality in 14 Korean cities. Daily all-caused deaths for the entire population were examined over the summer (May - September) months of 1991-2010. Daily deaths were standardized to account for long-term trend of subcycles (annual, season and week) on mid-latitude. As a result, Dry Tropical (DT) in early summer caused excess mortality due to non-acclimatization of inhabitants, and Moist Tropical (MT) plus and double plus exhibited greater spike of excess mortality due to extremely hot and humid conditions. Among the 14 Korean cities, the high elderly excess mortality was observed in Incheon (23.2%, 95%CI: 5.6), Seoul (15.8%, 95%CI: 2.6), and Jeonju (15.8%, 95%CI: 4.6). No time-lag effect was observed, and excess mortality gradually increased by days in a sequence of hot weather. To implement Heat-Health Warning System a synoptic climatology based, mortality prediction model was constructed by multiple stepwise regression. The model performance showed weak predictability by overestimation of the model during the validation period. Nevertheless, the result reveals efficiency of relative and multiple variable approach, rather than absolute and single variable approach. These results demonstrate that the SSC could be a suitable methodology for uncovering the heat-vulnerability in South Korea, when hot summer weather could be a significant risk factor.

**3A.3**

*Short-term Weather Changes, Seasonality, and Respiratory Hospital Admissions*

**Robert E. Davis, Kyle B. Enfield (University of Virginia, USA)**

A recent emphasis in bioclimatological research is how short-term changes in weather might be related to human morbidity. Rapid weather changes can result in physiological strain, primarily through the respiratory system. These changes might also account for the observed differences in spring vs. autumn mortality that have been observed in some midlatitude climates.

Daily tallies of elective hospital admissions for respiratory-related morbidity were acquired for the University of Virginia Medical Center in Charlottesville, Virginia from 1997–2015. The dataset includes 3815 unique daily admissions. Hourly weather data from Charlottesville Airport were used to compute two physiological indices developed to examine weather changes: the Acclimatization Thermal Stress Index (ATSI) and the Partial Oxygen Deficit of Air (PODA) Index.

Admissions were smoothed using centred moving average filters of varying lengths and were compared to smoothed ATSI and PODA index values at differing lags to account for latency between the presumptive weather impact and resulting respiratory distress. Preliminary results indicate statistically significant inverse relationships between the daily PODA index and standardized respiratory admissions in late summer and autumn and overall negative associations for PODA “watch” values and admissions at a 3 - 4 week lag. ATSI relationships indicate a greater morbidity impact in the autumn warm-to-cold transition than in spring’s cold-to-warm transition.

Indices like these that emphasize daily-to-weekly weather changes have the potential to be useful in uncovering avenues for understanding the underlying physiological underpinnings of seasonal morbidity and mortality patterns.

**3A.4**

*An exploratory analysis of the impact of the 2015-2016 El Niño event on health in the Southwest Pacific: The case of diarrhoea*

**Glenn McGregor, Camila C. S. Caiado, Isabella C. I. Bovolo, Oliver W. Jackson, Jesus E. Bustamante-Fernandez (Durham University, UK)**

El Niño has a strong and varied impact on environmental conditions across the Pacific region leading to a range of climate extremes. Such extremes possess the potential to exact a heavy toll on Pacific Island Countries (PICs), especially in relation to population health. This is of utmost concern as PICs are amongst those most vulnerable to variations in climate because of a high burden of ill-health and the limited capacity of health systems to respond and adapt to climate risks as posed by events such as El Niño. Given this, the potential impacts of the recent 2015-2016 El Niño on people's health in PICs, as affected by a range of possible diseases (e.g. diarrhoea and dengue fever) could be significant. The overarching aim of this paper therefore is to present the outcome of an exploratory analysis of the health impacts in PICs of the 2015-2016 El Niño event by exploring whether significant anomalies of disease incidence across a number of PICs are related to unequivocal departures of a range of health sensitive climate fields from the “normal” climate state. In doing so, the paper will assess the utility of disease incidence data collected via the Pacific Syndromic Surveillance System (PSSS; weekly data) and the Health Information and Intelligence Platform (HIIP; daily data) for establishing El Niño related health impacts and describe some of the methodological and analytical challenges confronted in assembling an integrated climate and health data set for establishing climate related health impacts.

**3A.5**

*Changes in Heat and Cold Related Mortality in Finland since the 1970s*

**Reija Ruuhela1, Kirsti Jylha1, Timo Lanki2, Pekka Tiittanen2, Otto Hyvärinen1, Andreas Matzarakis3 (1Finnish Meteorological Institute, Finland, 2National Institute for Health and Welfare, Finland, 3German Meteorological Service, Germany)**

Climate change is altering the characteristics of heat and cold waves, and exposure of the population to heat and cold stress, as well. When assessing climate change impacts on mortality, one needs to take into account the extent of acclimatization and the fact that potential changes in population health and other socio-demographic factors are likely to affect the sensitivity of the population to temperature extremes.

Mortality related to high temperatures and heat waves has been an underrated problem in Finland, in northern Europe. Our study indicates that mortality increases more notably due to hot extremes than due to cold extremes, when compared to a seasonally-varying baseline mortality with higher mortality in winter than in summer. On the other hand, our study in the Helsinki-Uusimaa hospital district in southern Finland shows that the sensitivity of the population to temperature extremes has decreased over the period 1972-2014. This applies especially to hot extremes but to some extent also to cold extremes. The sensitivity has decreased even among the very elderly, 75 years and older.

In our presentation, we will show also meteorological case studies on heat wave events. During the most severe heat wave in 1972 more than 800 extra deaths took place in Finland. In heat waves 2003 over 200, and 2010 over 300 extra deaths occurred especially among the very elderly.

Since Finland is more than 1100 km long in the south-north direction, the climatic normal values clearly differ between the southern and northern parts of the country, and so does the exposure of people to heat and cold stress. In our presentation, we will show how mortality-temperature relationships vary in different parts of the country.

**3A.6**

*Preliminary results of the assessment of excess mortality during the 2015 and 2016 heatwaves in France: a fine scale analysis by age, sex and place*

**Aymeric Ung, Karine Laaidi, Mathilde Pascal, Vérène Wagner, Sébastien Denys, Pascal Beaudeau (French National Public Health Agency, France)**

Background: After 2003, a French National Heatwave Plan has been implemented to limit the adverse impacts of heatwaves on health. In 2015 and 2016, France experienced record-breaking heatwaves. We assessed the excess mortality during those episodes.

Methods: Heatwaves were defined as at least three days with minimum and maximum observed temperatures above the 99,5th percentiles of the distribution of minimum and maximum temperatures 3-days moving average. The excess mortality was estimated as the difference between observed and expected number of deaths during the heatwave and the three subsequent days to take into account possible delayed effect of heat. The expected number of deaths was computed as the mean observed mortality during different reference periods up to the five preceding years. We reported the mean excess mortality computed for these reference periods and the interval of the excess mortality defined as the minimum and maximum of these values within this period.

Results: We estimated 1,739 [1,620; 1,832] excess deaths during the 47 heatwaves days of 2015 and 378 [327;394] excess deaths during the 24 heatwave days of 2016 episodes. We observed an excess mortality in most of the French departments which experienced heatwaves: 45 out of 50 in 2015 and 20 out of 24 in 2016. Mortality increase was slightly higher among women compared to men (respectively 19 vs 16% in 2016 and 14 vs 12% in 2015) Mortality increase was higher among the elderly for both years.

Discussion / conclusions: The excess mortality during the 2015 and 2016 heatwaves remains high and underlines the need of carrying on the efforts to limit the impact of heatwaves. Further local investigation, and epidemiological models taking into account the duration and the earliness of the heatwave and including intervention variable, are needed to gain insights on the efficiency of the prevention.

**3A.7**

*The impact of distinct atmospheric pathways on winter mortality in 2 regions of England: An environment-to-circulation approach*

**Kassomenos Pavlos1, Anastasia Paschalidou2, Glenn McGregor3, Panagiotis Tsanas1 (1University of Ioannina, Greece, 2Democritus University of Thrace, Greece, 3Durham University, UK)**

This study presents an alternative methodology for analysing the relationship between low temperatures and human health by studying the atmospheric pathways related to the occurrence of daily high mortality levels during the cold season in 2 regions of England for the 26-year period between 1974-1999. Specifically, an environment-to-circulation approach is applied through the use of backward air mass trajectories reaching the (a) West Midlands and (b) Northeast regions. On the whole, the analysis sheds light on the associations between increased levels of mortality and specific atmospheric pathways and highlights, on the one hand, the importance of synoptic climatology in understanding excess winter mortality in England, and on the other, that although cold-related health outcomes can be fatal, they can also be predictable and preventable.

**3A.8**

*Exploring the Use of Emergency Response Data Related to Extreme Heat in Large City Centers*

**Daniel J. Vecellio1, Jennifer K. Vanos2, Steven M. Quiring3, Alexander H. Garza (1Texas A&M University, USA, 2University of California San Diego, USA, 3Ohio State University, USA, 4Saint Louis University, USA)**

Heat stress is one of the largest drivers of heat-related illnesses, particularly amongst children and the elderly, as well as urban dwellers. Numerous heat indices have been developed to quantify heat stress during extreme heat events (EHEs), but there is no consensus on the most suitable index for identifying and quantifying heat-health risk and specific health outcomes. Two commonly used indices in North America are the Heat Index (United States) and the Humidex (Canada). Both of these indices account for the combined effect of temperature and humidity to quantify heat stress and to issue extreme heat watches and warnings. However, although over 100 various heat indices have been created, there is a paucity of data that associates heat exposures (risk factors) to heat-health illness or injuries. This study will statistically compare the relationship of select heat indices with emergency medical service (EMS) information obtained for FirstWatch® in four North American Cities. The two-step process first involves calculating hourly index values for 10-20 common heat indices using hourly meteorological data during summer EHEs. These will be evaluated to determine their covariance with the standard heat indices (Heat Index and Humidex) versus the unique information provided during the EHEs. Second, those indices displaying the greatest variance from the HX and HI will be applied in Poisson regressions, with heat-related EMS calls as the dependent variable to test performance. The information derived from the final analysis will allow for improved prediction of human response during EHEs, with added information of location and item of occurrence. This study will help identify the most suitable heat indices (and the associated thresholds) for to guide emergency response to improve preparedness and response time during EHEs in North America.

**3B.1**

*Empirical modelling of forest storm damage in Southwest Germany*

**Dirk Schindler, Christopher Jung (University of Freiburg, Germany)**

Empirical models were used to simulate endemic and catastrophic damage resulting from winter storms in the forests of the south-western German federal state Baden-Württemberg (size: 35,752 km2). The storm damage models were built based on (1) wind and gust speed records routinely measured at the stations of the German Meteorological Service and (2) routinely collected booking records of salvaged timber in the period 1979-2008. The application of the ensemble learning methods random forests and bagged classification trees allowed for the calculation of storm damage probability, proportions of storm damaged timber and endemic storm damage risk at the landscape scale. Results from model evaluation demonstrate that the most important predictor variables for both endemic and catastrophic storm damage were forest type (conifer forest, deciduous forest, mixed forest), soil moisture and a newly developed gust speed model with a spatial resolution of 50 m × 50 m. The inclusion of the new gust speed model in the storm damage model development clearly improved model accuracy in comparison to previous studies. Including gust speed, ROC-curve evaluation yielded cross-validated AUC-values between 0.70 and 0.86 for the predictive accuracy of the applied models. Moreover, the proposed methodology allows for embedding of damage caused by exceptional storms into the regional chronic storm pattern causing endemic forest damage. This is an important achievement in the field of empirical-statistical simulation of forest storm damage, because consideration of individual catastrophic storm events always introduces bias into the estimation of storm damage predictor importance due to the unique nature of storms.

**3B.2**

*Inter-annual variability in net ecosystem CO2 exchange during leaf development in a temperate mixed forest*

**Alison Donnelly1, Rong Yu2, Amelia Caffarra3, Jonathan Hanes1, Liang Liang4, Ankur R. Desai5, Lingling Liu6, Mark Schwartz (1University of Wisconsin-Milwaukee, USA, 2University of Nebraska-Lincoln, USA, 3ITK, France, 4University of Kentucky, USA, 5University of Wisconsin-Madison, USA, 6South Dakota State University, USA)**

Determining the potential for forests to sequester CO2 is fundamental to facilitate the accurate calculation of carbon budgets. Carbon uptake in temperate mixed forests begins as bud burst starts and increases as leaves develop and mature. However, the duration of leaf development and subsequent rate of carbon uptake, is species specific. Here, we propose to examine the relationship between spring phenological duration and net ecosystem exchange (NEE). We will examine 3 phenophase categories (bud-burst, leaf-out, full-leaf unfolded) from a community of species in a mixed forest in northern Wisconsin, USA over a 5-year period for comparison with carbon fluxes from a nearby AmeriFlux tower. We hypothesis that during warmer springs an early start to bud-burst coupled with a fast rate of phenological progression will be reflected in an earlier start to carbon uptake and a faster rate.

**3B.3**

*Modelling Spatiotemporal Variations in autumn leaf coloration of Ulmus pumila throughout China based on underground observations*

**Zexing Tao, Huanjiong Wang, Junhu Dai, Quansheng Ge (Chinese Academy of Sciences, China)**

Autumn phenology plays a critical role in regulating climate-biosphere interactions and net primary production of ecosystem in autumn. However, modelling spatiotemporal variation of autumn leaf coloration (LCD) remains deficient, especially for species-specific phenology on a continental scale. In this study, we take advantage of underground observations acquired from China Phenological Observation Network during 1963-2012 to establish three leaf colouring models aimed at simulating the spatiotemporal variations of LCD in elm (Ulmus pumila) throughout China. Subsequently, Empirical Orthogonal Function (EOF) analysis is used to identify the most extensive and influential spatial modes of LCD variability and how they change with time. We also test the effect of geographical factors (e.g. latitude, longitude and altitude) on LCD through multiple regression analysis. The results reveal that: (1) the spring-influenced autumn model (SIAM), which considers both the effects of climatic factors (accumulated cold temperature and photoperiod) and spring phenology, gives the best fit to the observations (*r*2=0.70, RMSE=10.9, *p*<0.01). (2) the simulated mean LCD ranges from day of year 256 to 326 with the earliest LCD occurs at the border area of Tibetan Plateau in the southwest and Tianshan Mountain in the northwest, and the latest LCD occurs at North China Plain and Tarim Basin. (3) the first EOF mode, which accounts for 31.1% of the variance, shows a nearly unidirectional pattern throughout China. While, the second EOF mode exhibits opposite weights in north and south China. In general, the LCD of Ulmus pumila presents a delaying interannual trend, although the trend is weak and statistically nonsignificant (0.075 days/decade). (4) each of the three geographical factors has significant influence on mean LCD and trend in LCD (*p*<0.01). The sensitivity of mean LCD to latitude, longitude and altitude are -0.65 days/°, -0.18 days/°, and -0.01 days/m, respectively. These results can provide a quantitative understanding on the phenological process in autumn and how it responds to climate change.

**3B.4**

*Canola production in Canada facing climate change*

**Budong Qian1, Xuebin Zhang2, Qi Jing1, Alex Cannon2, Denise Neilsen1, Guilong Li2, Brian McConkey1, Barrie Bonsal2 (1Agriculture and Agri-Food Canada, Canada, 2Environment and Climate Change Canada, Canada)**

Canadian canola production is critical to the global market as Canada has a 22% share of the global area growing canola/rapeseed and exports 90% of its production. The projected future warmer climate is suspected to be unfavourable to canola. Therefore, assessing climate change impacts on canola growth and yield is essential for developing adaptation strategies for canola production in Canada. A well-evaluated crop model, the CSM-CROPGRO-Canola model in the Decision Support System for Agrotechnology Transfer (DSSAT) v4.6 was used to simulate canola growth and yield, under a set of climate scenarios based on 20 climate models and two Representative Concentration Pathways (RCPs) 8.5 and 4.5. Climate scenarios used to drive the crop model were developed with a bias correction method of multivariate quantile mapping. Simulations were conducted for all 50 agricultural regions in the Canadian Regional Agricultural Model (CRAM) on the Canadian Prairies and in eastern Canada. Results show that future climate in some areas north of the current agricultural extent could become suitable for growing canola, especially under RCP8.5 and the distant future (2070-2099) as the risk of crop failures associated with the shortage of heat units would be lower than the baseline climate. The simulated potential yield (no nitrogen and water stresses) would mostly increase in the near term (2010-2039) and near future (2040-2069) but likely decrease in the distant future due to heat stresses from the projected increasing temperatures. The simulated water-limited yield (no nitrogen stress) indicated a larger decrease associated with increasing heat and water stresses, especially in the distant future under RCP8.5. An overall negative impact of climate change was projected for canola production in Canada, especially in the distant future under RCP8.5. Adaptation strategies, such as developing new heat resistant and drought tolerant cultivars and improving agronomic management practices, are required.

**3B.5**

# *Early warning system for bird-cherry oat aphid migrations based on the atmospheric dispersion model SILAM*

**Pilvi Siljamo1, Matti Leskinen2, Erja Huusela-Veistola3, Seppo Neuvonen3 (1Finnish Meteorological Institute, Finland, 2University of Helsinki, Finland, 3Natural Resources Institute Finland Luke, Finland)**

In Finland, the occurrence of some pests is affected by immigration from warmer areas, which might increase in a warming climate. The development, as well as the intensity of increase of pest insects in the source areas is controlled by temperature. Climate warming may increase the growth of agriculturally important plants in exceptionally northern areas as in Finland, but at the same time the conditions may get better for insects pests and plant pathogens. In addition, some of the most important pest insects - vectors of the diseases as well - are long-range migrants. The immigrants increase the infestation risk, especially as they attack the plants early in a more vulnerable state.

The presentation shows the first results of the SAPID (a novel approach to predict Source areas and Atmospheric transport of plant Pathogens and pest Insect migration using atmospheric Dispersion models) –project (9/2016-8/2019) funded by the Academy of Finland. The target of the project is an operational warning system for some pest insects migrations and dispersion of a plant pathogen. The model will be European wide, but the most important target areas are Finland and the UK.

The SILAM model is a mathematical-physical atmospheric composition model ([http://silam.fmi.fi](http://silam.fmi.fi/)) capable, e.g., pollen dispersion forecasts. Its pest insect migration warning system will be based on habitat maps of the host plants, temperature sum and suitable weather conditions for uplift, transport in the air and removal processes. Small insects - like aphids - mainly follow air flows. Thus, in the first pest insect model version, the transport of the insects will be computed like small particles and their landing is not yet treated separately, but like small particles. Especially the model’s capability to predict early bird-cherry oat aphid migrations in Finland in years 2002, 2010 and 2016 will be discussed.

**3B.6**

*A Degree Day model for durum wheat (Triticum durum, Desf.) across the Italian peninsula under proven linear temperature response*

**Arianna Di Paola (Euro-Mediterranean Center on Climate Change, Italy)**

A great deal of crop models predict plant development by means of the Degree Days (DD) algorithm, according to which simplest definition crop development can be predicted by the accumulation of specific quantity of heat (growing degree days) above a certain threshold base temperature, below which plant development stops.

The accuracy of the DD method to predict crop development mostly depends on *i*) the strength of the linear relationship between developmental rate and air temperature and *ii*) the accuracy of the base temperature. However, proven linear relation between developmental rate and temperature is poorly ascertained from crop model users whilst base temperatures are often predefined, leading to a lot of variability among results that ultimately makes the DD method site- and season- specific. Nevertheless, understanding and identifying site-independent relationships between plant development and climate drivers is crucial to obtain models suitable for regional simulations.

As explicative case study, phenological field observations on durum wheat (*Triticum durum*, Desf.), collected during the three-year PHENAGRI project (http://phenagri.entecra.it), were used to parameterize and test a Degree Day model for durum wheat across the Italian peninsula. Data come from different experimental fields located in northern, central and southern Italy and encompass scalar sowing dates, allowing to check the model performances both at different latitudes and sowing dates. To assure the basic assumption of the DD method, wheat subphases were identified to enable the best linear relationship (less data dispersion and higher coefficient of determination) between developmental rates and average air temperature. Under proven linear temperature responses, the model gave satisfactory simulations of wheat phenology over different locations and sowing period (R2 = 0.96; RMSE = 8,4 days; no bias, minimal complexity), even if the growing degree days counted from the common predefined base temperature of 0°C was not constant.

**S1.1**

*Actual and Perceived Thermal Sensation of Children during Outdoor Physical Activity in Two Seasons*

**Jennifer Vanos1, Alexandria Herdt2, Marc Lochbaum2 (1University of California San Diego, USA, 2Texas Tech University, USA)**

Outdoor thermal comfort (TC) is an important parameter used to assess the value and health utility of a space. Given the public health significance of effective physical activity in children to improve health and lessen obesity, there is a paucity of studies addressing heat balance of children during outdoor activity. Furthermore, TC indices were created for adults, and no research has attempted to create adaptive models for children in outdoor environments or during exercise. The current research addresses children’s perceived and actual thermal sensation (PTS and ATS, respectively) in connection with microclimate conditions. We test and adapt the outdoor TC model, COMFA\*, for applicability to children during physical activity under various weather conditions. Surveys of ATS, overall TC, and perceived change (PC) were collected from 30 children (aged 9–13) during 60-min exercise sessions on 8 spring and 11 autumn days in 2016 in the semi-arid climate of Lubbock, Texas. Approximately 2–3 surveys were performed per child per session. All radiant fluxes and weather data were collected with a portable high-end microclimate station. Subjects worechest monitors for accelerometery and heart rate. Activity, psychological, and metabolic skewing factors were applied to the model and energy budget ranges in various combinations. Preliminary results demonstrate a significant relationship between ATS and PTS votes (Spearman’s *rho*=0.504\*) and between PTS and PC (*rho*=–0.607\*). ATS votes present the strongest correlation with absorbed radiation (*r*=0.536\*). In hot conditions, 40% of children stated preference to be ‘A lot cooler’ in conjunction with perceived ‘thermal comfort’. This implies that children’s psychological response may differ to that of adult’s. This study is this first to evaluate outdoor TC in children during exercise, and has implications for the applicability of TC and heat indices to children and for the suitable design of children’s spaces for physical activity.

**S1.2**

*Comparison of popular measurement techniques in determining mean radiant temperature – a case study from Shanghai*

**Noémi Kántor1, Liang Chen2 (1University of Szeged, Hungary, 2East China Normal University, China)**

Mean radiant temperature (Tmrt [°C]) – a parameter which combines all long-wave and short-wave radiant flux densities reaching the human body into a single value in °C dimension – has primary importance in the field of human-biometeorology. However, up to this day there is no standard method to determine this parameter for the purpose of outdoor thermal comfort researches. Several studies obtained Tmrt by different radiation simulation software, while other studies relied on different field measurement techniques including radiometers and/or various globe thermometers. As the number of outdoor thermal comfort studies increases, there is an emerging need to assess the reliability of the different methods generally used to obtain Tmrt.

This paper compares three measurement based Tmrt-techniques relying on a 25h-long field survey conducted on a clear summer day at the East China Normal University campus in Shanghai. Three survey points were selected: an open point with artificial surface cover, an open point on grassy surface, and a shaded point under the rows of medium-sized plane trees. Small human-biometeorological stations were set up at each survey points, equipped with thermometer, anemometer and two globe thermometers made of 40 mm acrylic globes: a black and a grey-painted one. Tmrt values were calculated from the measured air temperature, wind speed and globe temperature values according to different empirical equations. Beside the three stationary stations equipped with globe thermometers, an expensive net-radiometer set was used to obtain Tmrt according to the most accurate way as well. Three net-radiometers in perpendicular arrangement recorded separately the short- and long-wave radiation flux densities reaching the human body from the upper and lower hemisphere, as well as from the four cardinal directions. The outcomes of this study underline the importance of standardisation in the field of outdoor thermal comfort measurements.

**S1.3**

*Towards high-resolution heat-stress maps for Seoul, Korea: Hazard, risk and vulnerability*

**Britta Jänicke1, Achim Holtmann2, Misun Kang1, Kyu Rang Kim1, Dieter Scherer2 (National Institute of Meteorological Sciences, Rep. Korea, Berlin Institute of Technology, Germany)**

Heat stress threatens human health, particularly in cities. For understanding and reducing the impacts on human health in cities, heat-stress maps are important. The aim of this study is to create high-resolution heat-stress maps for the megacity Seoul, South Korea. In contrast to many other studies, we estimated heat-stress hazard and risk as well as vulnerability. Thus, we seek to bridge the gap between vulnerability- and hazard-focused heat-stress studies. We simulated heat-stress hazards (air temperature/mean radiant temperature) for the whole area of Seoul at high resolution (25 m) using numerical and geo-statistical models representing an average heat day. A time-series (2000-2014) of air temperature and mean radiant temperature at a reference site served to established linear regression models with heat-related excess mortality. Using the regression models and the spatially-resolved hazard data, we produced heat-stress risk maps for Seoul. Heat-stress vulnerability was quantified at district level using an index based on several factors, such as age over 65 years, diabetes or low education. With these three maps, we identified the vulnerable, hazardous and risky areas regarding heat stress in Seoul. Moreover, we discuss how intra-urban variability of heat-stress hazard, risks and vulnerability influence each other and to which extend quantifying all three elements instead of just one leads to a more comprehensive and coherent assessment of heat stress in cities.

**S1.4**

*Quantifying and classifying personal heat exposure for health risk assessment*

**David M. Hondula1, Evan Kuras2, Benjamin L. Ruddell3, Sharon Harlan4 (1Arizona State University, USA, 2University of Massachusetts, USA, 3Northern Arizona University, USA, 4Northeastern University, USA)**

Personal heat exposure involves contact between a person and an indoor or outdoor environment that increases the risk of perceived discomfort and/or adverse health outcomes. In recent years personal heat exposure research has accelerated due in part to the increasing availability of small, low-cost, wearable sensors as well as improvements in computational data resources. There is little guidance in the literature regarding how personal heat exposure data can be summarized into meaningful metrics to assess health risks at the scale of individuals. We explored the sensitivity of individual level heat-health risk assessment to the choice of summary metric, drawing from nearly two dozen different options proposed in the literature for characterizing exposure to other hazards. The analysis was based on personal heat exposure data gathered simultaneously from 80 individuals in greater Phoenix, Arizona, USA, over a period of one week. Despite the wide variety in the underlying rationale for each of the metrics examined, many metrics were highly correlated with one another. Two principal components explained 75% of the variance among the original pool of metrics, the first of which was closely related to mean exposure and the second of which was closely related to variance and maximum exposure. Subsequent cluster analysis identified distinctive exposure profiles among the study participants, which may serve as illustrative cases for communicating the different ways in which people experience heat in the city.

**S1.5**

*Examination of personal heat exposure among grounds management workers at three university campuses*

**Chris Fuhrmann1, Maggie Sugg2, Jen Runkle3, Scott Stevens3 (1Mississippi State University, USA, 2Appalachian State University, USA, 3North Carolina State University, USA)**

Ambient heat exposure is a major threat to occupational health, particularly for workers who engage in activities requiring much physical exertion and who spend the majority of their workday in hot and sometimes humid environments. To date, most strategies aimed at reducing occupational heat exposure are based on data obtained from fixed locations across broad geographic areas and are not work place specific. This approach can miss important spatial and temporal variability in the meteorological conditions experienced by workers, as well as details in the physiological, behavioural, and social factors that drive susceptibility to heat-related health outcomes. In this presentation, we discuss results from a study of personal heat exposure among grounds management workers during the summer of 2016 at three U.S. university campuses: Appalachian State University in Boone, NC; North Carolina State University in Raleigh, NC; and Mississippi State University in Starkville, MS. Personal heat exposure was measured using Thermochron iButtons that measure ambient air temperature and Hygrochron iButtons that measure ambient air temperature and relative humidity surrounding the workers as they went about their workday. Specifically, we examine how personal heat exposure varied among outdoor workers at each campus and how the temperature and humidity experienced by these workers compared to official observations at nearby automated weather stations. To better understand the factors that drive differences in personal heat exposure, we linked the iButton measurements to various environmental, physiological, and behavioural characteristics of the workers (e.g. activity level, heart rate, symptoms of heat stress) using daily activity logs and Garmin GPS Smartwatches. By doing so, we can better understand where and why exposure is the greatest, and determine which individuals are most at risk for heat-related health outcomes. These results may be used to inform more targeted occupational health interventions and heat warning systems.

**S1.6**

*The application of High Density Street-Level Air Temperature Observations Network (HiSAN): The movement of urban heat island in different period case study in Tainan, Taiwan*

**Yu-Cheng Chen1, Chun-Kuei Yao1, Tzu-Ping Lin1, Tsuyoshi-Honjo2 (1National Cheng Kung University, Taiwan, 2Chiba University, Taiwan)**

Due to the growing urban heat island effect (UHI) becoming a severe issue this study utilizes a high-density street level air temperature observation network (HiSAN) as the database to observe air temperature at street level for elaborating the UHI phenomenon, including the movement of UHI in different periods, and the effect of various urban characteristics on the air temperature distribution in Tainan. For the measurements, a total of 100 points comprised the network in Tainan city. The average distance between the two nearest points in the rural area was 1.9 km, with is being lower in the metropolitan core area at 0.8 km. The result herein reveals that the centric point of UHI will move from west to east in daytime with a 4.2°C UHI intensity and the opposite at night time with a 3.6°C UHI intensity. The finding indicates that different urban characteristics dominate the thermal condition at various times. The results also indicated urban features are related to air temperature distribution. An analysis of urban morphology parameters, e.g. total floor area, imperviousness ratio and land use land cover, showed that a 200m buffer zone around each measurement point has a better explanation for the UHI phenomenon. The HiSAN system can be useful for the policy maker of urban planning through the urban design review process, and is of benefit to architects during the design scheme, site planning, and materials applied in the construction process.

**S1.7**

*Comfort-Map: dynamic visualizations of children’s thermal sensation in the outdoor environment*

**Silvia Coccolo1, Jennifer Vanos2, Jerome Kaempf3, Jean-Louis Scartezzini (1Ecole Polytechnique Federale de Lausanne, Switzerland, 2University of California San Diego, USA, 3Haute Ecole d'Ingénierie et d'Architecture Fribourg, Switzerland)**

Outdoor thermal comfort (OTC) is an essential factor to quantify the perceived quality of the urban microclimate. Accounting for this dimension prior to the design implementation phase can lead to a more usable outdoor space and holistic view of sustainable urban development. The creation of a thermally comfortable outdoor environment is important for safe recreational activities, and is also a key issue for children’s learning activities because a comfortable microclimate has positive impacts in cognitive and affective domains. Several methods exist to quantify human OTC, but when addressing OTC for children, there are added complexities to assess within the models. The current study applied the COMFA\* model to understand and quantify children’s thermal sensation, and the inclusion of children’s physiological characteristics is proposed within the model. The COMFA\* budget is then coded into the CitySim software, an urban energy modelling tool, in order to provide user’s thermal sensation from the building to the city scale, thus allowing the calculation of Comfort-Maps in any outdoor environment. The Comfort-Maps visualize the hourly thermal sensation of children during a Typical Meteorological Year by including the impact of the outdoor built environment, as well as shading devices, greenery, and ground properties. The model is applied to two case studies: an elementary school located in the city of Lubbock (Texas, United States) and a school campus in Dubai (United Arab Emirates). The new Comfort-Map model is applied to understand the variability in thermal sensations of children and adults throughout the parks/playgrounds, and to propose bioclimatic design strategies to improve the perceived microclimate of both sites. This paper presents the methodology, results, and discussion, as well as the recommendations for sustainable and appropriate bioclimatic designs of the playgrounds in a hot, arid climate (Dubai) and a cool/hot, arid climate (Lubbock).

**4A.1**

*Effect of high night-time temperature on all cause and cause specific mortality in London*

**Peninah Murage, Shakoor Hajat, Sari Kovats (London School of Hygiene and Tropical Medicine, UK)**

Background/Aim:High ambient temperatures have been associated with increase in mortality. Exposure to high night-time temperatures may increase the probability of death due to lack of relief from thermal stresses during the night. Heat effect on health may be exacerbated in urban areas as these areas are likely to remain warmer at night in comparison to surrounding areas, however, the evidence to demonstrate this is limited.

Methods:We obtained daily mortality and hourly temperature data for 1993 to 2015. Primary outcomes were identified as mortality from all causes, disease and age specific mortality. Daily mean temperatures were estimated from 9am-9pm. Night-time temperatures were estimated from 4am-8am, as these hours may be more sensitive to physiological processes related to increase in cardiovascular events. We also examined the heat effect of hot or cool nights preceded by hot days. Time series quasi-Poisson regression was used to model the heat effect for a lag of seven days, and relative risks were estimated to quantify the effect. All models were adjusted for air quality, and, night-time models were additionally adjusted for daily mean temperatures.

Results:The effect of night-time temperatures persisted after adjusting for daily mean temperatures. This residual effect was highest for stroke, heart failure and diseases of the nervous system. Hot days followed by hot nights had a higher mortality risk than hot days followed by cool nights, this difference was highest in cardiovascular diseases.

Conclusions:Extreme night-time temperatures in urban areas may be associated with elevated mortality, which is highest in warmer nights that were preceded by a hot day. The heat health warning system trigger criteria of hot-day followed by hot-night seems justified based on these findings. Patients with cardiovascular and diseases of the nervous system are the most susceptible, this finding may help health services deliver targeted interventions.

**4A.2**

*Association between high temperature and work-related injuries in Guangzhou, China*

**Rongrong Sheng, Changchang Li, Cunrui Huang (Sun Yat-sen University, China)**

Background:Despite increasing concerns about the health effects of climate change, the extent to which workers are affected by temperature increases is not well documented. This study aims to investigate the association between high temperatures and work-related injuries in Guangzhou, China.

Methods:We used workers’ compensation claims to identify work-related injuries occurred in Guangzhou, China during 2011–2012. A time-stratified case-crossover study design was used to examine the association between ambient temperatures and work-related injuries. Workers' compensation claims data were transformed into time series format, merged with meteorological data and analysed using conditional Poisson regression models.

Results:Overall, a 1°C increase in minimum temperature was associated with a 0.9% increase in daily injury claims. Specifically, the incidence rate ratio (IRR) for male workers and workers aged 25-45 were (1.011, 95% CI 1.002 to 1.006), and (1.018, 95% CI 1.014 to 1.022), respectively. Significant associations were also found between daily minimum temperature and risk of injury for fractures injuries, lower degrees of disability, manufacture, outdoor industries combined and small-sized enterprises, and between maximum temperature and injury for workers aged 25-45 and indoor industries combined. Larger effects were observed in the warm season for Guangzhou (1 June–31 October).

Conclusions: There is a significant association between injury claims and temperature in Guangzhou, China, for certain industries and groups. This study provides valuable epidemiological evidence for policy-makers and relevant stakeholders for reducing the potential effects of the projected increase in global average temperature due to climate change.

Keywords:Case-crossover study; Climate change; Temperature; Occupational health; Work-related injury

**4A.3**

*Confounding effects of extreme heat duration and community vulnerability on intra-urban cardiovascular mortality*

**Hung Chak Ho, Meng Cai, Alan Lai, Chao Ren, Kevin Ka-Lun Lau, Edward Ng (Chinese University of Hong Kong, Hong Kong)**

Heat mortality has been observed in subtropical cities under climate change. However, previous studies have not investigated the spatial variability of extreme heat duration on mortality, although a spatial difference of heat exposure has found to be one of the significant factors that can influence mortality risk. We developed an ecological study to estimate the added effect of extreme heat duration on cardiovascular mortality. We also estimated the added effect of community vulnerability during the days with heat warning for comprehensively investigating the confounding effects on heat mortality. Mortality data (2011 – 2014) at the days with heat warning (Tmax ≥ 33°C or Tmin ≥ 28°C) were grouped to district-level and were compared with mortality data during the days without extreme heat. During a day issued a heat warning, it can be 3.4% higher cardiovascular mortality at both lag 0 and lag 1 days across Hong Kong. In addition, 1% longer night time hot hours across a district can induce 1.2% [0.9%, 1.4%] and 1.0% [0.8%, 1.2%] additional mortality at lag 0 day and lag 1 day. Higher % female, % lower education, and % unmarried of a district can also contribute to larger added effects on cardiovascular mortality. Based on these confounding effects, we can locate the high-risk areas in needed for sustainable urban planning in Hong Kong.

**4A.4**

*Soaking in bathtub filled with artificial CO2-hot spring water may suppress a progress of muscle fatigue during continual resistance exercise after bath*

**Masaaki Hashimoto1, Nriyuki Yamamoto2 (1Teikyo University of Science, Japan, 2Japanese Red Cross Hokkaido College of Nursing, Japan)**

The hot spring water which contains high concentration of CO2 (≥1000ppm, CO2-hot spring) is used for the balneotherapy of the cardiovascular system disease from the old days. When we take a bath with CO2-hot spring water, even at bathtub water temperature below thermoneutral, a remarkable flushing is observed in the skin of the immersed part within a short time of immersion, and also the skin vasodilation increases of the skin blood flow, a decrease of the blood pressure, and a decrease of the catecholamine level have been reported. Since these phenomena in response to CO2-hot spring bathing are reproducible by using artificially made bathtub water which contains the level of CO2 comparable to CO2-hot spring water (CO2-water), these effects are thought to be due to high concentration of CO2. Previous reports suggested that an immersion of the body into the CO2-water evoked both the vasodilation and the increment of blood flow, not only in the skin but also in the skeletal muscles, of the immersed part. Hence, we hypothesized that improvement of a muscular blood flow might influence exercise performance by taking the CO2-water bath in between continual exercise. To evaluate this hypothesis, whether a progress and recovery of muscle fatigue induced by repetitive handgrip exercise was influenced by a CO2-water bath in between the exercise was investigated while measuring muscle blood flow. The effect of CO2-water bath on recovery of muscle fatigue was not apparent but progression of muscle fatigue tended to be suppressed. Muscle blood flow was significantly larger in CO2-water bath compared to tap-water bath of a same temperature. Although the underlying molecular mechanism remains still unclear, the increased muscle blood flow might not facilitate washing-out of the fatigue substances but suppress an accumulation of the substances in agonist muscle of the handgrip exercise.

**4A.5**

*Modified Risk associated with heat and cold events (1975 – 2004)*

**Michael J. Allen (Old Dominion University, USA)**

Thermal exposure is linked to a wide-range of negative health outcomes. Over time, this vulnerability associated with heat and cold has changed. This research considers the changes in vulnerability with respect to thermal exposure from 1975 - 2004. While studies indicate shifts in heat vulnerability because of improved education, heat-health watch warning systems, and the increased use of air conditioning, less attention has focused on the changes to cold-related risk. Using daily mortality (1975 – 2004) for 50 U.S. cities, a distributed lag non-linear model analysed the mortality relationships during heat and cold events. The study considers the impact of both the seasonal (early-late) and duration (short-long) anomalous temperature events. By continuing the evaluate the changes to vulnerability, professionals may be better equipped to cope with additional changes in the climate system and future impacts of heat and cold.

**4A.6**

*From Santa Ana Winds to Monsoons: The Role of Local Climate on Heat-Health Relationships in the Southwest United States*

**Adam J. Kalkstein (United States Military Academy, USA)**

The negative impact of heat on human health is well-established, particularly within the mid-latitudes. However, local climate can have a major impact on these heat-health relationships, often resulting in unusual patterns not found in other locations. Using human mortality records from 1975 through 2010, we examine relationships between heat and human health in Los Angeles, CA and Phoenix, AZ, two cities in the Southwest United States with unique local climates. Los Angeles displays a highly significant heat-health relationship in the *winter*, the first such relationship discovered in a U.S. city and likely the result of Santa Ana winds that can bring infrequent but intense heat waves even during the cool season. Phoenix also displays unusual heat-health relationships, with late-season summer heat being particularly dangerous, possibly due to an increase in humidity associated with the summer monsoon. This finding differs from most U.S. cities, where early-season heat is often more dangerous due to a lack of acclimatization. The discovery of two unique heat-health patterns in the Southwest United States is an important finding and can be used to alert susceptible populations and mitigate risk.

**4B.1**

*Urban human-biometeorology meets urban planning: potential of urban green to maintain outdoor thermal comfort at building sites during severe summer heat*

**Hyunjung Lee1, Rainer Kapp1, Ulrich Reuter1, Helmut Mayer2 (1Office for Environmental Protection, City of Stuttgart, Germany, 2Albert-Ludwigs-University of Freiburg, Germany)**

The presentation concerns the application of a human-biometeorological simulation method in order to quantify the potential of urban green at building sites for maintaining outdoor thermal comfort during severe summer heat. The thermal comfort conditions were analysed for seven different building sites in the city of Stuttgart, the largest in Southwest Germany, whose sizes range from 0.14ha to 4.21ha. They are located in topographically inhomogeneous terrain, which is typical of Stuttgart. For each building site, four different usage scenarios were considered: (A) current state, (B) site completely asphalted, (C) site only covered with grassland and trees, and (D) application of a planning option. Near surface air temperature, mean radiant temperature and physiologically equivalent temperature (PET) as characteristics of human thermal comfort were simulated in a horizontal 2 m and 3 m grid, respectively, by use of the ENVI-met model v4.0 BETA. The numerical simulations were conducted for the meteorological conditions on the heat wave day 4 August 2003. As the simulation results should be applicable in urban planning, they were averaged over the daytime period (10-16 CET) that represents the strongest human heat stress in outdoor spaces of Central European cities. The essential results are as follows: (i) related to scenario A, citizens are exposed to thermal stress in the PET-class "hot" at almost all building sites, (ii) as expected, scenario B shows the strongest human heat stress, (iii) scenario C quantitatively reveals the heat mitigation effect by the selected type of urban green, (iv) each scenario D leads to a slight reduction of PET, however, without a change from the PET-class "hot" to the lower PET-class "warm", (v) each scenario D is incapable of tapping the full heat mitigation potential indicated by the differences between the scenarios B and C.

**4B.2**

*Improvement outdoor thermal comfort by various arbour characteristics in hot and humid regions*

**Shing-Ru Yang, Chia-Chun Chen, Tzu-Ping Lin (National Cheng-Kung University, Taiwan)**

Different species of arbores have different effects on modifying the thermal environment, especially in hot and humid Taiwan. Appropriate plant species should be selected to enhance the user's outdoor thermal comfort. This study measures the air temperature, air humidity, mean radiant temperature and wind speed of multiple tree species, and uses ENVI-met software to conduct the sensitivity analysis. The results show that the variables of tree height, crown diameter and leaf area density have the greatest effect on thermal environment. According to the above mentioned variables, we selected six common arbores in Taiwan to analyse the improvement benefit of these arbores to the thermal comfort of Taiwan in summer. The result indicated that due to the solar angle, the short arbores with wide crown and medium leaf density can shield the sunshine effectively without obstructing the air flow. Although the tall trees can reduce the air temperature effectively, the shifted result in the uncomfortable condition under the trees. In addition, as for the Madagascar almond and Bombax ceiba with low leaf density, the difference between the simulated and actual temperatures is at most 5oC PET, it may due to the leaf density of real plants is subject to wind, the plants with lower leaf density have higher temperature in the model. The results suggest that designers consider the tree type and growth rate of arbores when planning arbores. Furthermore, the local microclimate characteristic and the demand for human thermal comfort should be included for the landscape design in Taiwan.

**4B.3**

*Impact of blue spaces on urban microclimate – a biometeorological assessment*

**Jana Fischereit, K. Heinke Schlünzen (University of Hamburg, Germany)**

In the light of climate change and increasing urbanisation, thermally comfortable design is necessary in order to promote the well-being of urban dwellers. Urban vegetation, often termed green infrastructure, has been intensively studied to achieve this goal. In contrast, the impact of their blue counterparts, urban water surfaces, on the surrounding microclimate has been less explored.

To address this gap, systematic sensitivity studies with the building-resolving MIcroscale TRAnsport and Stream model MITRAS are performed. The model area consists of an idealized urban environment with an open water surface, inspired by the city of Hamburg, Germany with the river Elbe. The impact of this water surface on the surrounding microclimate is investigated for different water surface characteristics, such as extend and temperature, and different adjacent building structures and vegetation. The analysis is performed in human-relevant terms by using two thermal indices, the Physiological Equivalent Temperature (PET) and the Universal Thermal Climate Index (UTCI) as they have been noted to be differently sensitive to changes in meteorological input parameters. Additionally, to changes of these indices in the immediate vicinity of the water surface, the extent of the impacted area is determined to estimate what proportion of the urban population is affected from the developed urban microclimate.

First results indicate that during the summer the relatively warm river Elbe heats the atmosphere during the night and thereby deteriorates important night-time thermal comfort.

**4B.4**

*Relevance of urban trees and sun shades regarding summertime heat stress reduction – a field surveys from Pécs, Hungary*

**Noémi Kántor1, Ágnes Gulyás1, Csilla V. Gál2 (1University of Szeged, Hungary, 2Dalarna University, Sweden)**

Mitigating the impact of summertime heat stress became the central issue of climate-conscious urban planning as a result of rising temperatures and continued urbanization trends. Furthermore, recent EU planning directives gave priority to nature-based solutions (NBS) and hence to re-naturing cities. Within the scope of the international Nature4Cities project fostering the use such solution, an inter- and cross-disciplinary research will be done assessing the performance of archetypal NBSs addressing different urban challenges – in this case, heat mitigation in urban environments.

The objective of this particular study is to compare the effectiveness of natural and artificial shading solutions (urban trees and sun sails) in reducing summertime heat stress and enhancing outdoor thermal comfort of pedestrians. The Physiological Equivalent Temperature (PET), used as performance indicator in this study, was calculated from field data. The measurement campaign utilizing two human-biometeorological stations recorded pedestrian-level radiant flux densities from six perpendicular directions, air temperature, relative humidity and wind speed on three late-summer days. The daytime measurements were conducted at three different urban settings in Pécs, a medium-size Central-European city.

Our research found that mature trees with dense canopy have the highest heat stress reduction potential and could reduce the local PET by up to 10°C. Even though artificial sun sails blocked effectively direct solar exposure, the low-hanging sun sails became the sources of long-wave radiation which made the thermal comfort conditions below them somewhat worse compared to trees. Our study demonstrates the importance of small-scale field measurements, the outcomes of which are directly applicable in the climate-adaptive design of urban spaces.

**4B.5**

*Strategic shading of public transportation stops in Phoenix, AZ*

**David M. Hondula, Lance Watkins, Mckenzie Murphree, Tamara Dunbarr, Ariane Middel (Arizona State University, USA)**

Weather is one of the many variables that impacts people’s decisions to use public transportation systems. In hot cities, the strategic provisioning of shade along access corridors to public transportation stops, as well as at stops themselves, can help ameliorate thermal discomfort among riders during the warm season. As a result, these investments have been suggested as one strategy to encourage public transportation system use. We paired NASA Earth Observations with daily ridership data and local infrastructure attributes from the 4,000 bus stops in the city of Phoenix, Arizona, USA, to understand how heat, shade, and transportation system use are related. Across the entire city, temperature was inversely correlated with ridership in the warm season after accounting for confounding variables. An effect of the same sign was observed at approximately half of the bus stops in the city, and the effect tended to be stronger at stops that were located in certain geographic clusters as well as those that had limited or no shading infrastructure. Contrary to expectations, high temperatures did not suppress ridership in some neighbourhoods with high surface temperatures and low vegetation coverage; the lack of a temperature effect in these neighbourhoods may be attributable to more limited transportation mode choice. Partnership with city staff informed data selection and analysis throughout the project duration. This partnership increased the utility of end-products to help city staff identify the stops where the addition of shade structures would be of greatest benefit.

**4B.6**

*Tree shade effects on human thermal environments in summer*

**Sookuk Park1, Stanton E. Tuller2 (1Jeju National University, Rep. Korea, 2University of Victoria, Canada)**

This study investigated microclimatic effects of different street and single tree species on human thermal sensation in summer. Two broadleaf deciduous and three broadleaf evergreen species planted as street trees and single trees of one broadleaf deciduous, two broadleaf evergreen and one needleleaf species were sampled on Jeju island, Republic of Korea. All trees we**r**e mature with full canopies. Microclimate observations were taken both in the open and tree shade.

Mean air temperature, relative humidity and wind speed were slightly different between sunny and shady locations: 0.1-1.5℃, 0.9-5.3%, 0-0.7ms-1 depending on the tree species, respectively. However, the overall mean radiant temperature (Tmrt) difference between them was large, 21.4-30.9℃ (36.0-47.0%) lower for street tree shade and 15.3-21.8oC (25.4-38.4%) lower for single trees. Shaded locations had cooler computed mean human thermal sensations: 8.9-14.8oC (21.2-31.3%) lower Physiological Equivalent Temperature (PET) and 5.0-8.5oC (12.7-20.0%) lower Universal Thermal Climate Index (UTCI) in street trees’ shade; 6.0-8.3oC (14.8-20.5%) lower PET and mean 3.6-4.8oC (9.2-12.5%) lower UTCI in single tree’ shade, depending on the tree species.

Mean differences are equivalent to 1.5-2.5 heat stress levels in PET and 1-1.5 UTCI levels from the street trees; 1-1.5 levels in PET and around 0.5 in UTCI from the single tree species. The linear group of street trees was more effective on thermal modification in urban areas than single trees. Street tree, evergreen species had 5% more modification effects in PET than deciduous ones. The needle leaf species had the most reduction in Tmrt, but also reduced mean wind speed the most (0.7ms-1) so its modification effects in PET and UTCI were not great. Wind speed and especially Tmrt reductions created by the density of tree crowns were the key controls of trees’ modification in human thermal sensation.

**5A.1**

*Using Teleconnections to Explain Variation in Phenotype and Fitness of White-tailed Deer in a Temperate Location*

**P. Grady Dixon, Bronson K. Strickland (Fort Hays State University, USA)**

Regional and global weather and climate variations have been shown to influence the fitness of large herbivores by thermoregulation, energy expenditure, or indirectly via primary production and plant phenology. These relationships are typically found in locations with “extreme” (very cold, snowy, arid, high latitudes, etc.) climates, but temperate locations have not been included in such findings. However, numerous studies have found significant effects on the weather of the humid, subtropical southeastern USA due to variations in ENSO, the Pacific Decadal Oscillation (PDO), and the North Atlantic Oscillation (NAO). We used hunter-harvest data from the Mississippi Department of Wildlife, Fisheries, and Parks (1991–2015) and compared eviscerated body mass and antler-beam lengths of 2.5-year males to climatic indices previously shown to affect the region’s weather and vegetation. After accounting for trends in the deer data, results suggest that statistically significant changes in deer phenotype that have been shown to affect fitness, even in temperate locations, can be caused by variations in global and regional climate conditions. This is important as 66% of all deer species are found in tropical and subtropical regions.

**5A.2**

*To develop optimized drought index for detecting drought events by using multi-sources satellite information*

**Jiahua Zhang, Fengmei Yao (Academy of Sciences, China)**

Drought is one of the most frequent climate-related disasters occurring in Southwest China. It is very important to detect the comprehensive information of drought from meteorological to vegetation aspects. This study intended to develop the optimized meteorological /vegetation drought index (OMDI/ OVDI) from multi-source satellite data to detect drought in Southwest China. The OMDI and OVDI were integrated with parameters such as precipitation, temperature, soil moisture and vegetation information, which were derived from Tropical Rainfall Measuring Mission (TRMM), Moderate Resolution Imaging Spectro radiometer Land Surface Temperature (MODISLST), AMSR-E Soil Moisture (AMSR-E SM), the soil moisture product of China Land Soil Moisture Assimilation System (CLSMAS), and MODIS Normalized Difference Vegetation Index (MODIS NDVI), respectively. Different sources of satellite data for one parameter were compared with in situ drought indices in order to select the best data source to derive the OMDI and OVDI. The Constrained Optimization method was adopted to determine the optimal weights of each satellite-based index generating combined drought indices. The result showed that the highest positive correlation and lowest root mean square error (RMSE)between the OMDI and 1-month standardized precipitation evapotranspiration index (SPEI-1) was found in three regions of Southwest China, suggesting that the OMDI was a good index in monitoring meteorological drought; in contrast, the OVDI was best correlated to 3-month SPEI (SPEI-3), and had similar trend with soil relative water content (RWC) in temporal scale, suggesting it a potential indicator of agricultural drought. The spatial patterns of OMDI and OVDI along with the comparisons of SPEI-1 and SPEI-3 for different months in one year or one month in different years showed significantly varied drought locations and areas, demonstrating regional and seasonal fluctuations, and suggesting that drought in Southwest China should be monitored in seasonal and regional level, and more fine distinctions of seasons and regions need to be considered in the future studies of this area.

**5A.3**

*Progress Report on GNSS Based Mobile Flood Early Warning System (GNSS\_MFEWS) for Lagos, Nigeria*

**Balogun Ifeoluwa Adebowale, Temidayo Oniosun (Federal University of Technology, Nigeria)**

With the increasing catastrophes induced by climate change, coastal communities are becoming increasingly vulnerable to the risk of damage and danger from flooding. A memory of the impact of Hurricane Sandy on communities in the northeast US reveals the potential damage that a single storm can cause. This project therefore, through the use of data, visualization, citizen engagement, and simulations, aims at assisting people to understand their exposure to coastal inundation hazards and their increased vulnerability; thereby reducing the effect of flooding on lives and properties. Project GNSS\_MFEWS is a tool that will alert communities about flood in coastal areas and notify them of impending weather disaster. It will identify the potential danger of impending coastal inundation risks and also help citizens to protect themselves against a flood event by furnishing them with information such as flood risk warnings, condition of evacuation routes, resilience /vulnerability of their neighbourhoods. Floating GNSS -Position Sensor will be deployed in areas prone to frequent flooding. Galileo's initial services along with GPS will be used for improved accuracy and faster-time-to-first-fix, ground fixed GNSS - SNR Sensor will also be deployed in areas with large water bodies like dams, rivers, estuary where rate of change of flood is relatively low. Since this sensor works on ground reflections, system features such as availability and multipath are of significance. The end product will be a cross platform mobile application aimed at safeguarding lives and properties from impending weather inundations. This paper analyses the progress on the project that bothers on disaster risks and management and also discuss possibilities of project partnership and collaboration.

**5A.4**

*Quantifying climate risks to support effective strategic decision-making*

**Richard Hewston (Verisk Maplecroft, UK)**

Climate change and variability has the potential to significantly affect livelihoods and economies across the globe. Changes in regional climate regimes, including the shifting pattern of extreme climate events, will have implications for ecosystems, human health, physical assets, industrial operations, supply chains and infrastructure. Governments, businesses and societies face major challenges in managing and mitigating the risks posed by climate change. Not least is identifying the appropriate climate data to support strategic decision making.

Verisk Maplecroft responds to these challenges by providing organisations with robust climate data and innovative risk management decision support tools. Here, we present our Climate Change Vulnerability Index (CCVI) which assesses the susceptibility of human populations to the impacts of climate variability and change across 191 countries at the sub-national level. The CCVI evaluates the physical impacts of climate variability and change; the sensitivity of societies to those impacts; and governmental capacity to adapt to climate change. Along with identifying the most vulnerable societies in the world, we analyse the key risk drivers in these cities and countries. Many of these locations are found in sub-Saharan Africa and South-East Asia and are expected to undergo significant economic growth in the coming years. Investment in these markets is therefore accompanied by an increase in business risk exposure to climate change, including to operations, supply chains and consumer bases. We explore some of the barriers organisations face when managing their exposure to climate risk and provide real-life examples of how decision support tools facilitate effective risk management**.**

**5A.5**

*UMEP - An integrated tool for city-based climate services*

**Fredrik Lindberg1, C. S. B. Grimmond2, Andrew Gabey2, Bei Huang2, Christoph W. Kent2, Ting Sun2,Natalie E. Theeuwes2, Leena Järvi3, Helen Ward2, Y. Y. Chang4, Per Jonsson5, Niklas Krave1, David Meyer2, Frans Olofson1, J. G. Tan4, Dag Wästberg5, Lingbo Xue2, Zhe Zhang2 (1University of Gothenburg, Sweden, 2University of Reading, UK, 3University of Helsinki, Finland, 4Shanghai Meteorological Service, China, 5Tyréns AB, Sweden)**

Scientists and practitioners from a wide range of disciplines including architecture, climatology, planning, engineering and geography have long been interested in how weather and climate affect the environment and people within urban areas. However, the development of climate knowledge and climate services for the operation of cities, urban planning and building design is not straightforward. Communication between key stakeholders, academics and practitioners to develop and deliver such services may be poor. To communicate spatial variability, maps and other images are a ‘language’ used by both research and practitioner communities.

Here, the city-based climate service tool UMEP (Urban Multi-scale Environmental Predictor) is introduced. UMEP combines “state of the art” 1-D and 2-D models with processes essential for urban climate assessments. The QGIS extension (or plug-in) can be used for a variety of applications related to outdoor thermal comfort, climate change mitigation, etc. UMEP allows users to integrate atmospheric and surface data from multiple sources; to ‘urbanise’ data; and to compare and visualise scenarios of operational plans for different climate elements (and combinations of these) of particular concern (heat indices, intense precipitations, water/energy demand) at a range of spatial scales.

**5A.6**

*Grass species respond differently to climate change*

**Aseel Mahdi, Julie Hawkins (University of Reading, UK)**

Analysis of herbarium data may provide one route to determine the individual phenological responses of different grasses to changing climate. Our study makes use of abundant herbarium specimens of common UK grasses, both common and well represented the University of Reading Herbarium (RNG). Specimens collected over a period spanning 100 years, between 1900 and 2000 in different areas of the British Isles. Herbarium specimen’s labels record the date and locality of plant collection, and the specimen itself can be examined to determine its phenological stage. In this study, we recorded the flowering stage following a modified BBCH scale. We compiled Gridded temperature and rainfall data from weather stations in closest proximity to the sites of herbarium specimen and sets of three-month averages calculated. Linear regression models were used to determine the associations of the climate parameters on flowering. Comparing extracted climate parameters with flowering stage data using general linear models shows that different plant species respond differently to climate parameters.

These findings are considered in term of grass as important sources of airborne allergens. Predicting pollen load is important, but although different species may respond differently to climate change. Current models do not discriminate between grass species contributing to pollen load.

Keywords: Grass. Herbaria, Phenological change.

**5B.1**

*Using a simple city model for heat stress exposure modelling*

**Peter Hoffmann, Jana Fischereit, Stefan Heitmann, K. Heinke Schlünzen, Ingenuin Gasser (University of Hamburg, Germany)**

The well-being of urban dwellers is largely dependent on the environmental conditions in cities, which can be quite different from those in rural surroundings. One of the stressors that can have a negative effect on the human health and well-being is heat stress. It can lead to an increased risk of cardiovascular and respiratory diseases and even to excess mortality. While the heat stress conditions depend on urban morphology and urban fabric the exposure to heat stress depends also on other parts of the urban system (e.g. traffic system) as well as on the human behaviour (e.g. choice of transport). Therefore, a simple mathematical model of an idealized radial symmetric city is introduced to investigate the exposure of urban commuters to daytime heat stress. This is done by coupling a module of the mean radiant temperature (Tmrt) calculation with a newly developed multi-class multi-mode traffic model. With this coupled model, the dependency of heat stress exposure on idealized city morphologies as well as on albedo can be investigated.

Simulation results with parameters chosen for Hamburg, Germany for a hot summer day show that predominantly part-time workers are affected by heat stress because of the Tmrt maximum in early afternoon. In addition, sensitivity studies with varying urban morphology and varying albedo are conducted. The results of these studies will be presented with respect to impacts on Tmrt within the city, the traffic (e.g. commuting time, time in traffic jams) and therefore on the heat stress exposure. Furthermore, implications on strategies to mitigate the exposure will be discussed in light of the currently proposed climate adaptation measures.

**5B.2**

*Application of wet bulb globe temperature activity modification guidelines in secondary school athletics*

**Yuri Hosokawa, Nicole Robinson, Delaney Dowden, Ashley Hagen, Matt Durrstein, Fean Wagner, Douglas J. Casa (University of Connecticut, USA)**

Activity modification guidelines for physical activity in the heat is recommended by medical organizations, such as the American College of Sports Medicine and National Athletic Trainers’ Association. These guidelines utilize wet bulb globe temperature (WBGT) as an index to evaluate the magnitude of the environmental heat strain, in conjunction with the actions that should be taken to ensure the welfare of athletes conducting physical activity in the heat. At the secondary school level, these guidelines are set forth by state high school athletics associations. However, despite the well-established consensus regarding the use of WBGT based activity modification guidelines, there still remains many states that do not utilize WBGT and/or utilize guidelines that have unrealistic activity modification thresholds, where the policy is not serving its purpose in alerting personnel when modifications needs to take place. In this case report, environmental data from 7 different schools (185 observations) were analysed during their fall pre-seasons of 2015 and 2016, in which the state recommendation for these schools did not meet the previously established WBGT guidelines. Therefore, we aimed to investigate differences in the activity modifications recommended at a given observed environmental condition between their existing guidelines and the WBGT guidelines. All environmental data were collected by a certified athletic trainer (ATC) at each school using the Extech HT30 heat stress WBGT meter. The ATC at each school also documented any practice modifications that they made at their own discretion for safety reasons. The results revealed that the state’s current guidelines did not enact activity modification guidelines for 58% of the observations while the WBGT guidelines recommended activity modifications 83% of the time. Furthermore, actions taken by the ATC resembled the recommendations outlined in the WBGT guidelines. Thus, it should be recommended that the state update their current guidelines and incorporate the WBGT guidelines.

**5B.3**

*Considering varying clothing, activities and exposure times with the Universal Thermal Climate Index UTCI*

**Peter Bröde1, Dusan Fiala2, Bernhard Kampmann3 (1IfADo, Germany, 2ErgonSim, Germany, 3Wuppertal University, Germany)**

The Universal Thermal Climate Index UTCI assesses the outdoor thermal environment based on the multi-node Fiala-model of thermoregulation, which was coupled with a clothing model considering the clothing behaviour of an urban population. The assumed moderate activity level (2.3 MET) and the maximum exposure time of two hours currently impede its applicability to persons exercising outdoors or resting, e.g. at the beach, as well as for occupational settings requiring the consideration of work clothes.

However, the high level of detail devoted to the modelling of the physiological and clothing system allow for expanding UTCI to varying exposure times, clothing and activity levels, as will be demonstrated by this paper.

We calculated UTCI correction values for activity varying from resting to a high (5 MET) level and for exposure duration covering an 8-hour shift length in 30-min steps. Simulations with the UTCI-Fiala model were performed using the adaptive UTCI-clothing model with air temperatures from -50°C to +50°C for UTCI reference climatic conditions (calm air, mean radiant temperature equalling air temperature, and 50% relative humidity, but maximum vapour pressure of 2 kPa). Additional simulations considered light (0.6 clo) and more insulating (1 clo) work clothes.

The correction values indicated that thermal stress decreased with shorter exposure and increased with longer times, and that high activity increased heat stress, whereas low activity increased cold stress. Effect size was moderated by stress category with greater effects of activity and exposure time in the cold compared to moderate or warm climates. The higher insulation of work clothes increased the indicated heat stress levels.

These results demonstrate UTCI's capabilities for a comprehensive assessment of different outdoor activities and of dynamic occupational thermal stress, while remaining consistent within its original scope of application. However, additional simulations covering more combinations of environmental conditions, clothing and activity are mandatory.

**5B.4**

*Validation of the human thermoregulation model to predict physiological impact of a heat wave*

**Agnes Psikuta1, Barbara Koelblen1,2, Simon Annaheim1 (1Swiss Federal Laboratories for Materials Science and Technology, Switzerland, 2Warsaw University of Technology, Switzerland)**

High temperatures in summer with a higher probability of incidence of heat waves in response to climate change may dramatically reduce the thermal comfort of the inhabitants of urban areas. It has been demonstrated that higher daytime temperatures and reduced night-time cooling associated to heat waves can affect human health by contributing to general discomfort, respiratory and cardiovascular difficulties and exhaustion, and higher mortality, especially in sensitive populations, such as children, elderly and those with existing health conditions. This issue can be addressed with simulation tools such as validated models of human thermoregulation to develop effective preventive strategies and to mitigate heat exposure of individuals including its effects on their well-being and health. The major challenge posed on such models is the simulation of the exposure to outdoor conditions with continuous variability of the ambient parameters, which may affect stability and accuracy of the model. The second challenge is the necessity to simulate long-term exposures to capture effect of the heat wave lasting typically for several days, where any inaccuracy of the model algorithms will cumulate over time.

In this study, we have validated human thermo-physiology model by Fiala using human experimental datasets collected during outdoor exposures with ambient conditions changing on a minute basis. Secondly, we have attempted to simulate the long-term exposures to validate parameters critical for human health and well-being using exposures based on the literature survey. The analysis revealed the opportunities of the human thermoregulation modelling in prevention of heat-related risks and showed the model shortcomings that need to be addressed in the further modelling and research endeavours.

**5B.5**

*Projected Heat Stress along the 2020 Olympic Marathon Route in Tokyo, Japan and the Role of Microclimatic Design*

**Jennifer Vanos1, Robert Brown2, Eichi Kosaka3, Akiko Iida3, Makoto Yokohari3 (1University of California San Diego, USA, 2Texas A&M University, USA, 3University of Tokyo, Japan)**

The 2020 Olympic Games marathon will be run through the streets of Tokyo on August 8, a time of year that is typically very hot, sunny, and humid. The Tokyo Olympic Planning Committee would like to avoid heat illness with a course designed as a series of thermally comfortable microclimates within an otherwise hot urban heat island. The goal of the current study is to establish a baseline of conditions and scenarios to estimate the projected thermal comfort and heat stress along the course for both spectators and the athletes. Microclimate data were collected in August 2016 with a mobile high-response microclimate station along the proposed marathon route. Measurements (air and surface temperature, solar radiation, humidity, windspeed) and sky view factors were recorded at one second intervals, and combined with estimated physiological parameters (metabolic heat load, activity speed) for both the athletes and spectators. All parameters are used in energy balance modelling and heat injury estimations, and mapped along the route. Results show spectators to experience comfortable conditions in the early morning (7:30am) (energy budget +/- 50W m-2), with dangerous conditions reached in the last half of the marathon time period (9:00–10:00am). Contrasts in radiation levels along the course present variable situations for the athletes, with noted ‘hot spots’ in open, concrete areas resulting in energy budgets well above 350 W m-2 (‘dangerous’). From baseline data, we model the effect of proposed microclimatic design interventions and optimal route changes and/or spectator locations. This is the first stage of a four-year process whereby modifications will be made to the course landscape and the effectiveness of microclimatic changes will be measured. Information is expected to aid in mitigating human heat loads during the 2020 Olympics, and sustain the cooling into the future in the mega-city to carry on the Olympic Legacy.

**5B.6**

*The cabin air temperature of parked vehicles in summer conditions: a dynamic model of a life-threatening environment for children and pets*

**Johannes Horak, Ivo Schmerold, Kurt Wimmer, Günther Schauberger (University of Veterinary Medicine, Austria)**

In modern vehicles, heating, ventilation, and air conditioning systems are in use to maintain the thermal comfort and air quality inside of the driver cabin while the vehicle is in operation. In vehicles that are parked, no ventilation and/or air conditioning takes place. If a vehicle is exposed to direct solar radiation an immediate temperature rise occurs. The harsh environment inside parked vehicles can cause heat stroke as a life-threatening syndrome observed in human and animals. It may result from exposure to environmental heat stress and is characterised by body core temperatures of > 40°C in a human and > 41°C in dogs, as well as by central nervous system. Not only is the heat stress relevant, but also the duration of exposure. In the US, lethal heat strokes cause a mean death rate of 37 children per year. In addition, temperature-sensitive goods can be adversely affected by high temperatures. To calculate the rise of the cabin air temperature, a dynamic model was developed that is driven by only three parameters: air temperature, global radiation, and wind velocity. The duration of the transient lies in the range of about 60 minutes, which means that even a short exposure time of less than 60 minutes can be live threatening by causing a heat stroke. To assess the thermal load of an organism (humans as well as animals) more complex models are needed to include metabolic heat production and the heat release of the body. This can be used for forensic applications to calculate the point of time reaching uncompensable heating (>37°C) and/or hyperthermia (>40°C). The model output can be applied as well to assess the heat load of temperature-sensitive goods, which are transported and/or stored inside veterinary vehicles or in emergency medical service vehicles.

**5C.1**

*Does the increase in ambient CO2 concentration elevate allergy risks by oak pollen?*

**Kyu Rang Kim1, Jae-Won Oh2, Su-Young Woo3, Yun Am Seo1, Hyun-Seok Kim4, Wi Young Lee, Baek-Jo Kim1 (1National Institute of Meteorological Sciences, Rep. Korea, 2Hanyang University College of Medicine, Rep. Korea, 3University of Seoul, Rep. Korea, 4 Seoul National University, Rep. Korea, 5National Institute of Forest Science, Rep. Korea)**

Oak pollen is one of the major respiratory allergens in Korea. It is expected to increase by ecological succession and climate change. One of the drivers of climate change is CO2 increase, which is known to amplify the allergenicity of weeds pollen. The impact of CO2 concentration on tree pollen is not clearly understood due to the experimental difficulties in CO2 exposure for a long period.

To study the response of oak (*Quercus acutissima*) trees on elevated levels of ambient CO2 concentrations, three open top chambers (OTC, Lee et al. 2012) at National Institute of Forest Science in Suwon, Korea were utilized with daytime (8 am – 6 pm) CO2 concentrations of ambient (~400 ppm, Ch1), 1.4x (~550 ppm, Ch2), and 1.8x (~700 ppm, Ch3). Three trees per chamber were planted in Sept. 2009 but one or two of them bloomed in 2016. Five-six catkins were selected per tree and glassine envelopes were attached to collect pollen grains. Total number of catkins per tree was counted. Counts, weight, and size of pollen grains per catkin were measured. Oak allergen – Que a 1 (Allergen Co., Uppsala, Sweden) – was purified and extracted to make a ELISA kit, which quantified the antigen levels in the pollen samples.

Total pollen counts and weight per tree at Ch1, Ch2, and Ch3 were estimated as 114 x 109, 518 x 109, and 1808 x 109 grains and 1.24, 9.39, and 24.16 g, respectively. Allergen levels were determined as 419.7±27.7 (Ch1), 455.5±54.3 (Ch2), and 459.5±30.7 ng/ml (Ch3).

The trees bloomed in 2016 underwent more than 6 years of the CO2 levels. The CO2 increase induced the amount of pollen by 4.5 to 19.5 times whereas the antigen level by 9%. In summary, oak trees with 1.4x and 1.8x CO2 concentrations will produce 4.9x and 21.3x higher allergenicity, respectively.

**5C.2**

*New approach to an emission determination in a numerical pollen dispersion modelling*

**Changbum Cho, Tae Hee Kim, Kyu Rang Kim, Yun Am Seo, Baek-Jo Kim (National Institute of Meteorological Sciences, Rep. Korea)**

In numerical pollen modelling, most studies have estimated an emission amount based on observed data from receptor regions where it is not close to trees. As this is a receptor-oriented modelling, not only emission amount can be much lower than the actual amount but also the period of pollen emission can be grossly exaggerated. i.e., it can be defined as a normalized ambient concentration, which is diluted throughout dispersion, advection, deposition processes.

In order to implement the actual emission amount of pollen in a numerical modelling system, we conducted observations of phenological stages and hourly concentration of oak pollen over a pure oak forest for 3 years. A simple function of accumulated temperature was derived to describe the pollen generating of oak tree and implemented into the CMAQ (Community Multi-Scale Air Quality) model of US/EPA. The simulation results from a receptor-oriented and this source-oriented approaches to emission determination were compared.

As a result, the source-oriented approach simulates more closely the natural tendency of pollen concentration in the atmosphere. On the other hand, as a receptor-oriented approach shows that the pollen was produced from early of April to end of May, it is an obvious that it is far from true because no tree can generate pollen for as long as 2 months.

**5C.3**

*Developing a validation procedure for numerical pollen forecast models*

**Helfried Scheifinger1, Stefano Natali2, Heinz Gallaun3, Barbara Templ1 (1Zentralanstalt für Meteorologie und Geodynamik, Austria, 2SISTEMA, Austria, 3Digital – Joanneum Research, Austria)**

Evaluating the performance of numerical pollen forecast models requires to take into account some special characteristics, which are unique to the pollen dispersion problem: the pollen season has a distinct shape with a season start, episodes and a season end, which depends on region and elevation and is repeated each year to some extent, the concentration range spreads over several orders of magnitude, time resolution of observed pollen concentrations is usually limited to a day, the observed data show a high level of noise, to cite the most important. Taken together these features make the assessment of the performance of pollen dispersion models difficult. Additionally, it has turned out that validation parameters might provide inconsistent information on the model performance. The idea of a zero-model, like a long-term average for instance, and a best thinkable model help to get a grip on this problem. Preliminary results suggest that current numerical pollen forecast models do hardly outperform zero-models.

**5C.4**

*The Melbourne Thunderstorm Asthma Epidemic of 21-22 November 2016*

**John Nairn1, Tarini Casinader2, Louise Minty2, Beth Ebert2, Ed Newbigin3, Danny Csutoros4, Sandra Falconer4, Vikki Lynch4, Cenk Suphioglu5, Paul Torre6 (1Bureau of Meteorology, Adelaide, Australia, 2Bureau of Meteorology, Melbourne, Australia, 3University of Melbourne, Australia, 4Victorian Department of Health and Human Services, Australia, 5Deakin University, Australia, 6Environment Protection Authority Victoria, Australia)**

Southeastern Australia experienced an epidemic thunderstorm asthma event on Monday 21 November 2016 when late afternoon thunderstorms moved through the metropolitan regions of Geelong and Melbourne as people were making their way home from work. Although the storms themselves were not remarkable, their interaction with very high concentrations of rye grass pollen carried south from agricultural regions led to a profound health emergency. It is estimated that 9,900 people presented at hospitals in metropolitan Melbourne and Geelong of which approximately 4,000 were respiratory related, and there were more than 2300 emergency ambulance calls. Nine deaths occurred that might be attributable to this thunderstorm asthma event and are being investigated by the State Coroner. The event was unprecedented internationally.

In the days immediately following the event, experts from the Victorian Department of Health and Human Services, Bureau of Meteorology, Environment Protection Authority, University of Melbourne and Deakin University formed an Inter-Agency Working Group (IAG) to share knowledge and experience of thunderstorm asthma-associated events and discuss ways to predict future events to inform public health planning. An Interim Agency Response Plan was implemented for the remainder of the pollen season whereby forecasts for high risk days (i.e., days with thunderstorms) prompted a meeting of the IAG to assess the predicted pollen forecast and atmospheric conditions and notify the Chief Health Officer for appropriate public health messaging to relevant patient and health services groups. The State Government of Victoria pledged AUD$1 million to establish new pollen monitoring sites and conduct research to improve the understanding and prediction of the thunderstorm asthma phenomenon in preparation for the upcoming pollen season.

This presentation will describe the 21 November 2016 thunderstorm asthma event in Melbourne, including the environmental and atmospheric conditions leading up to the event, and the collaboration between health, meteorology, and university sectors to work toward improved prediction of thunderstorm asthma to assist relevant agencies and the community to be prepared for such events.

**5C.5**

*Circadian patterns of airborne allergenic pollen concentrations: a role for meteorological factors?*

**Athanasios Damialis1,2, Franziska Häring1,2, Kostas Karatzas3, Claudia Traidl-Hoffmann1,2 (1Technical University of Munich and Helmholtz Zentrum München, Germany, 2Center for Allergy and Research and Education, Switzerland, 3Aristotle University of Thessaloniki, Greece)**

Airborne pollen is implicated in respiratory allergy symptoms worldwide. Hence, seasonal distribution patterns and long-term trends have been well investigated. However, few studies exist on the daily timescale, even though this is closely related to the prophylaxis of allergic patients in everyday practice. The aim was to detect any diurnal pollen distribution patterns and to predict potentially safe periods for allergic patients.

Airborne pollen grains were collected on a bihourly basis in Augsburg, Germany (2015-2016), using Hirst-type volumetric traps. For the first time, the circadian rhythm for the whole spectrum of pollen diversity was studied, both at ground- and rooftop- level sampling height. The causative factors were also investigated, like rainfall and wind components. To do so, time series analysis and dynamic regression modelling were conducted and Artificial Intelligence models were developed.

The salient feature is that in Augsburg airborne pollen are detected in the air throughout the day. Most taxa exhibited clear diurnal pollen distribution patterns. Frequently, pollen peak concentrations occurred in the evening until early in the morning, like in the cases of birch and pine. Fewer taxa displayed their peak daily counts during midday, like grasses. Species-specific differences exist between ground-level and rooftop-level pollen concentrations. Rainfall incidents, even for just a few hours, have an inverse effect on airborne pollen abundance, however, there have been cases of pollen presence despite raining.

Contrary to the widely held assumption that the peak of airborne pollen is during midday (when temperature is higher), results from Germany reveal that more pollen is often observed between evening to early morning. Given the usually short duration of pollen season for many taxa and the very high annual pollen index for some of them, distribution of allergenic pollen for only some hours during the day can have dire effects for allergic patients.

**5C.6**

*Relationships between allergic symptoms and airborne pollen concentrations: forecasts and driving factors*

**Athanasios Damialis1,2, Franziska Häring1,2, Gertrud Hammel1,2, Megan Fleming1,2, Andreas Philipp3, Stefanie Gilles1,2, Claudia Traidl-Hoffmann1,2 (1Technical University of Munich and Helmholtz Zentrum München, Germany, 2Center for Allergy and Research and Education, Switzerland, 3University of Augsburg, Germany)**

Airborne pollen is implicated in respiratory allergy symptoms worldwide. Particularly birch pollen exhibits the direct impact on allergic individuals in boreal and temperate climates. However, the mechanistic effects of airborne pollen abundance on the actual symptoms of allergic individuals have not been clarified and the role of co-factors like local meteorology on real-life human allergic manifestations remains unknown.

Airborne pollen was monitored in Augsburg, Germany in 2016, using Hirst-type volumetric traps, at rooftop and ground level sampling height. Meteorological parameters were collected and ocular, nasal and lung symptoms of birch pollen-allergic and non-allergic human volunteers were registered daily, along with their overall symptom score. Multi-variate and time series analyses and dynamic regression modelling were performed to check for relationships among symptoms, airborne pollen concentrations and meteorological parameters.

The salient feature is that symptoms always correlate positively with higher concentrations of airborne pollen, both for allergic and non-allergic individuals; this relationship is usually stronger for previous day’s pollen atmospheric load (*p*<0.001, *r*=0.61). Lung symptoms seem to be the most important for allergic individuals and nasal symptoms for non-allergic ones. Specific combinations of meteorological factors with pollen concentrations yield higher symptom scores, thus highlighting the importance of local meteorology. Rainfall incidents, even for just a few hours, have an inverse effect on airborne pollen abundance and particularly lung symptoms (*p*<0.001, *r*=0.62).

By investigating the transition from airborne pollen exposure to the actual allergic disease output (symptoms), it was found that pollen exposure alone is not a reliable factor to explain and forecast respiratory allergy symptoms. In some cases, like for lung symptoms, meteorological factors significantly contribute to the determination of safe time points. It is concluded that pollen exposure and consequent respiratory symptoms can be diminished via environmental health services based on real-time pollen monitoring and real-life, well-characterised patient panel studies.

**6A.1**

*Storm Track and Landfall Location of Southwest Indian Ocean Tropical Cyclones: Historical Perspective*

**Jennifer M. Fitchett (University of the Witwatersrand, South Africa)**

Research conducted on tropical cyclones in the southwest Indian Ocean has largely been preoccupied with categorizing the severity of the storm impact, and associating this with regional climatological disturbances. Although there is now broad consensus that there has not been a statistically significant change in the number of storms making landfall in the region, the storm track and landfall destinations remain contested. Much of the uncertainty surrounds regional climate model projects that indicate a northward shift in the formation, trajectory and landfall of these storms. These model outputs are in conflict with historical records for Madagascar and Mozambique that demonstrate a progressive southward trend in the position of landfall of these storms. Although these debates could be resolved theoretically, they highlight the poor spatial resolution of tropical cyclone storm track analyses, whether historical or modelled. This study seeks to address this issue, through a high resolution (sub 1°) analysis of the storm track pattern and landfall location of tropical cyclones affecting Madagascar, Mozambique and South Africa. Results confirm the progressive southward trajectory of tropical cyclones over recent decades, and contest the modelled output indicating a northward trajectory. These findings are consistent with the progressive southward shift in the position of the 26°C and 27°C sea surface temperature isotherms in the southwest Indian Ocean. These findings are critical to improved projections of tropical cyclone landfall probability, and consequently for the disaster-risk management strategies of the affected countries.

**6A.2**

*Climate Services for Health –Overcoming barriers to uptake of climate and weather information*

**Joy Shumake-Guillemot (WMO/WHO Climate and Health Office, Switzerland)**

Health practitioners, researchers, policy-makers and individual citizens today have greater access than ever to relevant and real-time information about hazardous conditions. Climate services for health are an emerging technical field with aims to assist health professionals to enhance the public health toolkit by accessing and using relevant and robust climate and weather information. However, despite new and existing opportunities, expertise, techniques and good practices for the application of climate and weather science in public health -- the process of co-developing climate services remains costly, timely, and challenging.

As part of the Global Framework for Climate Services, the WMO and WHO jointly produced a collection of pioneering case studies of health applications of climate and weather information. This presentation will share common barriers reported throughout these 40 operational country based projects to the uptake of weather and climate information. Five categories of barriers relate to data quality and interoperability; co-production and product development; partnerships and adequate enabling environments; sustainability; and communicating climate information and risks. It will also present the innovative solutions used to enable partners to overcome these challenges, and a six component framework developed to facilitate the co-production and design of climate services.

**6A.3**

*Climatology of tourism indices TCI and CIT at Lithuanian seaside*

**Justas Kažys, Simona Dalinkevičiūtė (Vilnius University, Lithuania)**

The weather “makes weather” while planning your holidays. Usually persons rely on averaged climatic conditions and weather forecasts of the holidays sites, however, the weather conditions in the Baltic Sea Region (mid-latitudes) are not stable for beach tourism activities during the summer. We developed a new methodological approach based on statistical evaluation of climatological data to find the most suitable conditions for summer tourism activity at the Lithuania coastal line. We use the Tourism Climate Index (TCI), originally conceptualized by Mieczkowski (1985), and the Climate Index for Tourism (CIT) created by De Freitas (2005). For the calculations of TCI and CIT values we gather data from 3 meteorological stations (Klaipėda, Nida and Palanga) situated at the coastal area for the period 1993 to 2016. We evaluate conditions of tourism indices for past, present and future using different time periods (1-, 3-, 7-, 15- and 30-days). We ranked TCI and CIT values to determine best conditions during May-September period by making moving-averages. The results show that variation of weather conditions during the summer were mostly determined by the chosen time period. The conditions vary a lot for 1-day period and they are very close to averaged values for a 30-day period.

**6A.4**

*Global return level estimation of the most severe tropical cyclones and European winter storms in the last decades*

**Christopher Jung, Dirk Schindler (University of Freiburg, Germany)**

Storms are among the most catastrophic disasters around the world. From the North American east coast, Europe, East Asia to the Bay of Bengal many countries regularly suffer from their high impact. For instance, in August 2005 hurricane ‘Katrina’ caused the loss of 1,800 lives and insured losses of 108 billion US-dollars. A memorable high-impact European winter storm event in the last century was storm ‘Lothar’, which caused 110 deaths and a total damage of 11.5 billion US-Dollars on 26 December 1999. Accurate estimation of storm-related return levels would enable better adaptation of infrastructure and sophisticated disaster management, which could reduce losses. Thus, the return levels of the most severe tropical cyclones and European winter storms in the period 1979-2015 were systemically estimated by using ERA-Interim gust speed and precipitation data. A detailed extreme value analysis based on the block-maxima method for a large number of theoretical distributions of empirical gust speed distributions was carried out. The goodness-of-fit of the theoretical distributions was tested by the Anderson-Darling and the Kolmogorov-Smirnov statistic. It was found that the five parameter Wakeby distribution generally provides the best goodness-of-fit. By applying the Wakeby distribution, gust speed- and precipitation-related return levels were estimated. Furthermore, the combination of high gust speed and precipitation was evaluated by applying extreme value copulas. As an important result, this study points at areas where storms led to great losses but return levels were comparatively low.

**6A.5**

*The Climate of Fukushima Prefectures and Temporary Housing after Great East Japan Earthquake*

**Masatoshi Tanaka (Fukushima Medical University, Japan)**

Fukushima area is divided into 3 parts; the seaside area where the ocean climate is rather comfortable, the basin area surrounded by hills and mountains where it is moist and hot in summer and cold in winter, and mountainous areas where there is lots of snow in winter. After the earthquake on 11th March 2011 in the northeast area, many of the evacuees came from near the Fukushima nuclear plant accident area near the seaside. Temporary houses were built at first in basin areas and mountain areas with similar housing structures. The basic material of temporary housing structures is lightweight steel. Spaces for usage are a living room, bedroom, kitchen, bathroom and toilet. All houses are equipped with one air conditioner, refrigerator, etc. We carried out a survey regarding housing conditions, families etc., measuring indoor air conditions; room air temperature, humidity in summer and winter, and carbon dioxide in winter in some temporary houses in the Fukushima City basin area. Regarding significant problems of temporary housing in summer, the results of the questionnaire survey showed that heat, humidity, narrowness of living area, etc. were the significant problems. In many houses, an air-conditioner and double windows were added to prevent coldness in winter. The results of the questionnaire survey showed that rooms were comfortable with the use of the air-conditioner and uncomfortable with no use of the air-conditioner in summer. In winter, the houses were refitted or repaired for coldness. Thermal conditions inside the houses are not so uncomfortable, but carbon dioxide levels were rather high. Air pollution occurs frequently inside the house, due to for example using oil heaters or gas ring within narrow and air tight living spaces. Ventilation is important for safety during daily life.

**6A.6**

*Urbanisation influence on bioclimatic conditions and potential health risks: a report from a hot-humid tropical city*

**Balogun Ifeoluwa Adebowale (Federal University of Technology, Nigeria)**

The impact of weather on human health has become an issue of increased significance in recent times, considering the increasing rate of urbanisation and the much associated heat island phenomenon. This study examines the urbanisation influence on human bioclimatic conditions in Akure, a medium sized hot- humid tropical city in Nigeria, utilising data from measurements at urban and rural areas in the city. Differences in the diurnal, monthly and seasonal variation of human bioclimatic characteristics between the urban and rural environments were evaluated and tested for statistical significance. The study also integrates geographic information system to examine day-to-day time variation of physiologic comfort of the people living in the urban environment using physiological equivalent temperature (PET) at strategic points across different land use types. Results showed that thermal stresses are found spatially and temporally across different land uses within the study area. Higher frequencies of high temperatures observed in the city centre suggest a significant heat stress and health risk in this hot humid city. Analysis of the responses from sampled population across the land uses depicted that many of the respondents have low understanding of climate change and thermal stress. The study recommended that policies that will support urban greenery, full awareness of climate change and thermal comfort should be implemented.

**6A.7**

*Comparison of the measurements of two different weather stations in Akure, Nigeria*

**Ahmed A Balogun1, Nick van de Giesen2, John Selker3, Frank Annor2, Sunusi Usman Yerima1 (1Federal University of Technology, Nigeria, 2Delft University of Technology, Netherlands, 3Oregon State University, USA)**

The realisation that the very low density of weather stations in Africa is negatively impacting agricultural yields in the hostile African climate and leading to serious food security challenges. Scientists at the Delft University of Technology (TU Delft), Netherlands and the Oregon State University (OSU), USA initiated the Trans-African Hydro-Meteorological Observatory (TAHMO). The goal of TAHMO is to develop a dense network of hydro-meteorological measurement stations throughout sub-Saharan Africa. On average, there will be one station per 1000 km2. The stations will be cost-effective through the use of new sensor and communication technologies. The station design is robust and aims at minimizing maintenance. Special attention will be paid to data quality assessment and control. Through public–private partnerships, the system will be made financially self-sustaining. Education will play an important role as many stations will be placed at schools, where they will play a role in the curriculum.

The first of the TAHMO stations in Nigeria was installed and co-located with a research grade Campbell Sci Inc, BREB system at the meteorological observatory of the West African Science Service Centre for Climate Change and Adaptive Land Use (WASCAL), Department of Meteorology and Climate Science, Federal University of Technology, Akure, Nigeria. This situation provides the opportunity to compare weather data and results between the two types of stations. Multiple comparisons between the weather stations measurements of different weather variables will be presented.

Study results based on actual sensor data comparisons in Akure for hundreds of hourly observations clearly illustrate that there is little statistical difference in the measured variables between the Campbell Sci Inc (control) versus the Tahmo station (measured) as they were found to be significantly correlated in all cases for temperature, dew point, precipitation and, in most cases, relative humidity and wind direction.

**6A.8**

*Bioclimate and climate tourism conditions of Ondo State, Nigeria*

**Akinyemi Gabriel Omonijo (Federal University Oye-Ekiti, Nigeria)**

Weather and the influences of climate frequently emerge as important factors for choosing a tourism destination as they help in determining the appeal of a location in absolute or relative terms. The tourism industry is particularly sensitive to weather conditions and climate variability. Therefore, weather and climate can act both as resource and constraint to tourism industry. The goal of this paper is to present in a useful and understandable way how thermal atmospheric environment can be interpreted for tourism and recreation in Ondo State, Nigeria so that the potential of the unique characteristics of the tourists’ attractions site in Ondo State can be developed to become one of the biggest tourist centres in Nigeria. The tourist attractions in Ondo State include the following: Cave of Ashes, Coast Creek and Canal, Ebomi Lake (Mysterious Lake), Idanre Hill, Igbo Irunmole and Igbo Olodumare (The Forest of the Almighty), Oke Maria, Owo Museum of Antiquities, Palace of the Deji of Akure among others. The physio-climatic indices such as temperature humidity index (THI), cooling power (CP) and physiologically equivalent temperature (PET) were used for the assessment of human thermal conditions in this study. The study equally used Climate-Tourism-Information-Scheme (CTIS) model to detailed climate information of Ondo State which can be used by tourists to anticipate thermal environmental conditions for planning for their holidays. The outcome of the physiologically equivalent temperature derived from the human energy balance which was used to describe the effect of climate both in terms of thermal sensation and physiological stress level on human beings in this study indicate that thermal sensations range from period of comfortable to hot and physiological stress levels range from no thermal stress to strong heat stress.

**6B.1**

*Building Resilience to Extreme Heat: The National Integrated Heat Health Information System (NIHHIS)*

**Hunter M. Jones1, Juli Trtanj1, George Luber2, Wayne Higgins1 (1National Oceanic and Atmospheric Administration, USA, 2Centers for Disease Control and Prevention, USA)**

Communities across the United States and the globe are increasingly facing more extreme heat events. The Intergovernmental Panel on Climate Change states that heat waves will be more frequent, last longer, and start earlier. It’s not too soon to start planning --across time scales, with new partners, and stimulating innovation to support longer term sustainability and community resilience to extreme heat.

Many cities and counties in the US and worldwide have heat/health warning systems. Many of these systems are near stand-alone sentinels or systems born of need and organic creation, use different methods and models, and are largely at weather and emergency response time scales. How do we mine the wealth of knowledge already learned from existing heat health early warning systems and the practitioners who use them, and apply it to other systems and at different time scales?

In June of 2015 NOAA and the Centers for Disease Control and Prevention (CDC) launched the National Integrated Heat Health Information System (NIHHIS). NIHHIS is comprised of two pillars: inter-agency engagement to combine the efforts and resources of all agencies with a focus on this issue, and regional pilots across the United States that establish connections to local, interdisciplinary heat-health practitioners and share best practices. NIHHIS developed framework questions for all pilots to consider, including consideration of: institutional capacity and partnerships, heat-health parameters and monitoring, data and forecast product needs, and engagement & communication strategies. This presentation will highlight NIHHS framework and demonstrate its implementation in pilots. We will update participants on inter-agency activities, including a White House webinar and the rollout of the NIHHIS web portal in 2016, and integrated social media communications, articles, and press briefings being planned for 2017. Finally, we will place NIHHIS within the context of the emerging Global Heat Health Information Network (GHHIN).

**6B.2**

*Iterative management of heat early warning systems in a changing climate*

**Jeremy J. Hess, Kristie L. Ebi (University of Washington, USA)**

Background:Extreme heat is a leading weather-related cause of morbidity and mortality, with exposures becoming more widespread, frequent, and intense with climate change. Heat early warning and response systems (HEWS) that integrate weather forecasts with risk assessment, communication, and reduction activities, are increasingly widespread, particularly in middle- and high-income countries. HEWS are frequently touted as an adaptation to climate change, but little attention has been paid to the question of how best to ensure effectiveness of HEWS in a changing climate.

Results:HEWS satisfy the tenets of an adaptation measure, but climate change poses challenges infrequently addressed in heat action plans, particularly changes in the onset, duration, and intensity of dangerously warm temperatures, and of evolving population-level associations between heat and adverse health impacts. HEWS could be improved by, for example, by using increasing understanding of high-risk areas for resource planning by health care providers to enhance preparedness for demand on services during an extreme heat event. Further, the timing of warnings could be changed to more nuanced warnings that take particularly susceptible groups into consideration. With increasing forecasting skill and greater understanding of who is most at risk, HEWS could set a series of thresholds based on vulnerability.

Discussion: Iterative management should be central to a HEWS, acknowledging that today’s systems will need regular evaluation to ensure continued effectiveness, taking into consideration recent and projected changes in climate and scientific understanding of susceptible population groups. Climate change adaptation and implementation science research frameworks can be used to identify modifications to improve the effectiveness of HEWS as temperatures continue to rise, incorporating scientific insights and new understanding of vulnerability and of interventions. At a minimum, iterative management activities should involve planned reassessment (approximately every five years) of hazard distribution and population-level health effects of heat exposure.

**6B.3**

*Challenges for verifying global heatwave and coldwave forecasts: Can emerging technology help?*

**Joanne Robbins1, John Nairn2, Grant Williamson3, Amanda Wheeler3, Sharon Campbell3, David Bowman3, Fay Johnston3 (1Met Office, UK, 2Bureau of Meteorology, Australia, 3University of Tasmania, Australia)**

The Met Office is currently trialling global heatwave and coldwave forecasts on a real-time basis, using the Excess Heat Factor (EHF) and Excess Cold Factor (ECF) indices developed by Nairn and Fawcett (2013; 2015) and used by the Australian Bureau of Meteorology. Outputs have been visualised through the Global Hazard Map (GHM), a Geographical Information System (GIS) web map service used by the Met Office Global Guidance Unit to inform its global weather assessment and provide early warning of high impact weather to key stakeholders. In March 2016, an evaluation of the GHM tool and EHF/ECF forecasts was completed. Almost 90% of heatwave events, which led to impacts, were successfully forecast and the hit rate was consistently above 65%, for all events and forecast lead times.

During this evaluation, it became increasingly evident that verifying the occurrence of such events at the global scale was challenging, as much of the impact information is held by individual government departments with availability of temperature data varying widely globally. Identifying heatwave or coldwave effects on human populations through global data available on the web is difficult because of inconsistent terminology, fragmentary recording and the complex interactive nature of correlated environmental conditions, such as wildfires. The University of Tasmania has produced ‘AirRater’ – a smartphone app which disseminates information about current atmospheric conditions (temperature, smoke, pollution and pollen) and forecasts of heat and cold waves. The app also collects clinical symptom reports from registered users enabling subsequent epidemiological analyses of the effects of atmospheric conditions. Adapting this app offers a potential avenue for verification of global heatwave and coldwave forecasts as well as improving understanding of how these atmospheric extremes interact with air pollution and air borne allergens to affect human health.

**6B.4**

*Heat Wave Temporal Structure, and its Implications for Heat Stress Vulnerability with Global Warming*

**Jane Baldwin, Jay Dessy, Gabriel Vecchi, Michael Oppenheimer (Princeton University, USA)**

Many heat wave definitions employed by meteorologists require a certain number of threshold-exceeding hot days in a row to constitute a heat wave. In reality, the temporal structure of heat waves having substantial human impact varies significantly, with many featuring hot days interspersed with cooler breaks. In this study, we develop more flexible heat wave definitions that count hot days that follow short breaks, quantifying the hazard of these temporally compounded hot days. We apply these definitions to analyse daily temperature data from observations, NOAA Geophysical Fluid Dynamics Laboratory global climate model simulations of the past and projected future, and synthetically generated time series. Using results from this analysis, we demonstrate that hot days that closely follow prior hot days or heat waves will constitute a greater proportion of heat wave hazard as the climate warms, and suggest an explanation for this phenomenon. This result implies that in order to limit heat-related mortality and morbidity as the climate warms, there is a need to consider added vulnerability caused by prior heat waves.

**6B.5**

*An update to the German Heat health warning system – A focus on the elderly population and urban areas*

**Stefan Muthers, Gudrun Laschewski, Andreas Matzarakis (Deutscher Wetterdienst, Germany)**

The German Heat Health Warning System (HHWS) is based on a heat balance model of the human body and the extracted Perceived Temperature (PT) in combination with a building simulation model, which allows estimating both, the daily outdoor conditions relevance for thermal stress and the nocturnal conditions relevance for regeneration. For days with an indoor night-time temperature above specific regional thresholds and an outdoor PT reaching the level of strong or extreme heat stress, a warning is released. The weather forecast information used, however, resembles the conditions of a rural or suburban climate station. Moreover, the heat balance model is based on the thermo-physiological conditions of a 35-yr old male walking with 4 km/h for standardisation. Therefore, the population group most sensitive to heat waves, i.e., elderly people living in dense urban areas is not adequately considered in the HHWS.

With the year 2017 an update has been released, which allows for a better consideration of elderly people and urban areas in the HHWS. Modifications of the heat balance model of Gagge et al. (1986) show that elderly people with reduced activity tend to suffer earlier from extreme heat stress than the used standard person. A specific threshold for extreme heat stress for elderly people is therefore considered in the HHWS. Additionally, the urban heat island is taken into account by implementing a statistical approach of Wienert et al. (2013). The air temperature is modified based on the size of the city and the meteorological conditions of the previous 24 hours. The modified air temperature is then used as forcing for the building simulation model. This approach allows considering the elevated night-time conditions in cities and their effect on the indoor temperatures in the HHWS.

**6B.6**

*Impacts of the 2015 heat wave on mortality in the Czech Republic – A comparison with previous major heat waves*

**Aleš Urban1, Hana Hanzlíková1, Jan Kyselý1,2, Eva Plavcová1 (1Czech Academy of Sciences, Czech Republic, 2Czech University of Life Sciences, Czech Republic)**

The study compares impacts of heat waves in summer 2015 on mortality in the Czech Republic with major heat waves back to 1994. We analysed daily natural-cause mortality in the entire population of the Czech Republic. A mortality baseline was determined using generalized additive model adjusted for long-term trends, seasonal and weekly cycles, and identified heat waves. Mortality deviations from the baseline were calculated in order to quantify excess mortality during heat waves, defined as periods of at least three consecutive days with air temperature higher than or equal to 30.0°C. We used additional heat wave characteristics in order to better describe the intensity of heat waves.

During the 1994**–**2015 period, 14 major heat waves were identified in the Czech Republic. 10 heat waves were associated with significant excess natural-cause mortality. The characteristics of summer 2015 were comparable with 1994 in both the intensity of heat waves and the magnitude of heat-related mortality. 25 heat-wave days within 4 heat waves were identified in 2015, in comparison with 20 heat-wave days clustered to 2 heat waves in 1994. Despite the smaller excess mortality due to the major heat wave in 2015 than in 1994 (880 vs. 1165 excess deaths per 10 million inhabitants), the relative increase from the baseline was larger in 2015 (274%) than 1994 (234%). The intensity of a heat wave, considering its absolute temperature, length and temperature increase relative to the previous conditions, was the most important driver of the heat wave impact on mortality. Our findings suggest that the impact of major heat waves on excess mortality remained approximately constant during the examined period and further research needs to be done to understand the effectiveness of mitigation measures to prevent heat-related mortality in the Czech Republic.

**6B.7**

*Managing increasing heatwave severity, Australia's national heatwave service*

**John Nairn1, Bertram Ostendorf2, Peng Bi2 (1Bureau of Meteorology, Adelaide, Australia, 2University of Adelaide, Australia)**

Analysis of heatwave severity trends for Australian capital cities in the period 1910 to 2015 demonstrates why the Australian Bureau of Meteorology has experienced an increasing demand for heatwave services. This is consistent with studies warning of increasing frequency and intensity of heatwaves. However, the regional variability in heatwave severity across southern Australia and into the tropics illustrates a variable heatwave severity impost over this period. The resulting insight provides a guide for planning and mitigation strategies for the evolving heatwave threat across the Australian continent. This is most evident in southeast Australia where the strongest trend in increasing heatwave severity is demonstrated.

Heatwave intensity using the Excess Heat Factor developed by Nairn and Fawcett is expressed as a function of long-term and short-term daily temperature anomalies and has been shown to correlate well to human health impact in cities. A recent set of studies have also demonstrated the efficacy of EHF for human health impact in regional areas of Western Australia, South Australia and New South Wales.

Heatwave intensity range under this methodology is governed by local climatology, largely dependent upon latitude and geographical location. Normalised maps of heatwave intensity are created using common severity characteristics of the cumulative distribution function at every location.

Thresholds for heatwave severity have been mapped in a public product since the austral summer of 2014. A Heatwave Stakeholder Reference Group formed from emergency, health and media agencies has guided service enhancements and improved heatwave impact knowledge. Further work with this group has resolved the need for a national heatwave warning framework.

**6B.8**

*Building climate services for extreme heat in Bangladesh*

**Hannah Nissan1, Katrin Burkart1, Simon Mason1, Erin Coughlan de Perez2, Maarten Van Aalst2 (1Columbia University, USA, 2Red Cross, Red Crescent Climate Centre, Netherlands)**

Extreme heat is a major public health concern, and was responsible for four of the ten deadliest natural disasters worldwide in 2015. However, heat-related mortality is largely avoidable, and can be reduced through heat health adaptation plans and early warning systems. Near the tropics, where hot weather is considered the norm, the perceived heat risk is often low, and in many developing countries heat waves are only now gaining recognition as a serious health risk.

There is compelling evidence of a substantial heat-related mortality burden in Bangladesh. Reliable heat forecasts, which are not currently available in Bangladesh, are an essential building block of a heat early warning system. Too often, however, forecasts are developed without considering their relevance for public health and decision makers. The threshold for taking action within a heat early warning system must be both related to human health outcomes and forecastable using available weather and climate information. This presentation proposes a threshold for heat wave forecasts in Bangladesh that could be used to trigger preparedness measures in a heat early warning system. Encouragingly, opportunities exist for extreme heat forecasts from days to months ahead, offering the potential to provide more advance warning and increasing the capacity to prepare. In Bangladesh, as in many places, efforts to implement heat health policies are often thwarted by lack of data and resources, and inadequate knowledge about the causes and impacts of heat waves. Obstacles and possible pathways to implementing effective heat adaptation plans will also be discussed.

**S2.1**

*Pursuing Coherence from Multiple Spring and Autumn Phenological Measures*

**Mark D. Schwartz (University of Wisconsin-Milwaukee, USA)**

Integrating multiple phenological measures offers important opportunities to overcome impediments that hinder advancing understanding of ecosystem processes. Merging the essence of satellite-derived remote sensing data (which facilitate needed spatial integration and large area coverage), with detailed conventional (visual) ground observations (which provide necessary information on species timing differences), is an important avenue for progress. A relatively new resource to address this challenge is near-surface remote sensing data collected from fixed-position cameras. This paper presents on-going findings from a multi-year comparison of the spring and autumn seasonal transitions in Downer Woods (a small urban woodlot on the University of Wisconsin-Milwaukee campus dominated by *Fraxinus americana* and *Tilia americana*) and at several research sites near the WLEF tall flux tower site in the northern mixed forest region of Wisconsin (with *Acer rubrum*, *Acer saccharum*, and *Populus tremuloides* as major deciduous species). The study areas include continuous imagery from fixed-position visible/near-infrared cameras (part of the Phenocam network), air/soil temperatures, and flux tower measurements (in northern WI), as well as detailed ground-based species-specific visual phenological observations and light sensor data measured under the canopy, collected in both spring and autumn. In general, the results show that Phenocam visible information can be successfully compared to all these other phenology-related data series, however the specifics and level of success varies among the study sites and seasons. These changes can be in turn simulated by process models based on seasonal temperatures. Thus, concurrent collection of these data suggests a coherent process whereby production of more robust ground-based species-aggregated “pixel” data (scalable to large areas) may be achievable and applicable to complex environments and ecosystems. Such an approach could potentially improve phenology-based spatial estimates of carbon and energy flux.

**S2.2**

*Temporal coherence of phenological and climatic rhythmicity in Beijing*

**Xiaoqiu Chen, Weiqi Zhang (Peking University, China)**

Using plant phenological data in the Beijing Botanical Garden from 1979 to 2013, we revealed three levels of phenology rhythms and examined their coherence with temperature rhythms. The sequential and correlative rhythm shows that occurrence dates of various phenological events obey a certain time sequence within a year, and synchronously advance or postpone among years. The positive correlation between spring phenophase dates is much stronger than that between autumn phenophase dates, and attenuates as the time interval between two spring phenophases increases. This phenological rhythm can be explained by positive correlation between above 0°C mean temperatures corresponding to different phenophase dates. The circannual rhythm indicates that recurrence interval of the same phenophase in two adjacent years is about 365 days, which can be explained by the 365-day recurrence interval in the first and last dates of threshold temperatures. In addition, an earlier phenophase date in the current year may lead to a later phenophase date in the next year through extending recurrence interval and vice versa. Thus, the sequential and correlative rhythm and circannual rhythm of plant phenology are interacted, which mirrors the interaction between seasonal variation and annual periodicity of temperature. The multi-year rhythm implies that plant phenophase dates display quasi-periodicity more than one year. The same 12-year periodicity in both plant phenophase and threshold temperature dates confirmed temperature controls of the phenology multi-year rhythm. Our findings provide a new perspective for examining plant phenological response to climate change, and developing comprehensive phenology models considering temporal coherence of phenological and climatic rhythmicity.

**S2.3**

*Spatial simulation of autumn land surface phenology in the temperate deciduous broadleaf forest of China*

**Weiguang Lang, Xiaoqiu Chen (Peking University, China)**

Autumn vegetation phenology plays critical roles in detecting the end of the growing season and its response to climate change. Using five vegetation indices (namely NDVI, EVI, WDRVI, GRVI and PSRI) calculated from MODIS data, we extracted dormancy onset dates in the temperate deciduous broadleaf forest (TDBF). Then, we validated the satellite-derived dormancy onset dates based on ground-observed leaf fall end dates (LF) of dominant tree species at 27 stations/pixels and selected the best vegetation index. Moreover, we analysed spatial pattern of the best vegetation index-retrieved dormancy onset dates and its relationship with spatial pattern of seasonal mean temperatures over the entire area. Results show that dormancy onset derived from PSRI has the best performance in reflecting ground-observed LF at station/pixel scales. The spatial pattern of multiyear average dormancy onset dates shows a latitudinal gradient at a rate of -3.12 days per degree and a longitudinal gradient at rate of -1.33 days per degree, respectively. The spatial pattern of dormancy onset dates in each year correlate significant positively with the spatial pattern of mean temperatures over the research region. Namely, the higher the mean temperature at a pixel, the later the dormancy onset at the pixel. The explained variances of yearly spatial regression models to the dormancy onset are between 59% and 75%. Thus, spatial differentiation of temperatures controls spatial differentiation of dormancy onset dates in TDBF. On average, a spatial shift in mean temperature by 1℃ may cause a spatial shift in dormancy onset date between 2.7 days and 3.7 days. Further analysis indicates that the higher the regional autumn mean temperature in a year, the larger the spatial sensitivity of the dormancy onset date in response to mean temperature in the year. Thus, the regional climate warming may increase spatial variability of autumn phenology.

**S2.4**

*The phenology of seabirds in a changing climate: are birds adjusting their breeding season?*

**Katharine Keogan1, Sarah Wanless2, Richard A. Phillips3, Francis Daunt2, Ally Phillimore1, Sue Lewis2 (1University of Edinburgh, UK, 2Centre for Ecology & Hydrology, UK, 3British Antarctic Survey, UK)**

Environmental conditions in marine ecosystems are highly dynamic, causing fluctuations in resource availability across space and time. These fluctuations are exacerbated by long term local, regional and large scale climatic trends, and are expected to increase as climate change escalates. To ensure successful reproduction, individuals should adjust timing of breeding in correspondence with suitable conditions to avoid becoming mismatched with resources. Numerous studies have demonstrated trends in breeding phenology and identified some of the environmental drivers that effect this timing, yet we lack a clear understanding of specific regional and global factors contributing to overall timing variation. A holistic understanding is therefore needed to assess the potential demographic consequences of phenological change across populations. Within marine ecosystems, seabirds are a widely used indicator species group, and are not responding to environmental change in parallel with terrestrial systems. We combined 140+ long-term data sets of breeding phenology, representing a wide-ranging and diverse subset of seabird species. Using a phylogenetic meta-analysis, we (i) identified trends in breeding phenology across regions, taxa and life-histories, and (ii) quantified the effects of underlying environmental factors. We present results which demonstrate the effects of phylogeny on plasticity of breeding phenology, and analyses of local and large scale climate cues driving breeding phenology on a global scale. These results provide a much needed synthesis of the effects of a dynamic climate on breeding phenology in a top-predator species group in the face of increasingly extreme climatic events.

**S2.5**

*Modelling Variability of White Ash Populations in Spring and Autumn Phenology*

**Liang Liang (University of Kentucky, USA)**

To better account for intraspecific variability in phenological models can improve the phenological forecast capability across heterogeneous genotypic gradients. This study explores the varied phenoclimatic relationships of white ash (*Fraxinus americana*) provenances in a common garden in Kentucky, US. The objective of the study is to develop algorithms for modelling deciduous tree phenology across populations and geographic locations at large spatial scales. Since the project was initially presented in ICB 2014, two additionally years (2015 and 2016) of data have been collected (all together 2013~2016, for both spring and autumn seasons). Preliminary results evidenced that northern provenances leafed out earlier than the southern provenances (i.e. being countergradient) under colder autumn-winter weather, and vice versa (i.e. being cogradient) under relatively milder autumn-winter weather. This variation of the spatial gradient is potentially linked to varied chilling and forcing requirements by different provenances. In addition, a supporting analysis using spatially extensive data from the USA-National Phenology Network (NPN) suggested that the bud break of white ash trees at higher latitudes required less forcing than those at lower latitudes. Moreover, spatial patterns of autumn phenology across provenances consistently displayed a cogradient pattern (northern provenances changed leaf colour and shed leaves earlier than southern provenances) across years. The dominant influence of photoperiod along with the coordinating impact of temperature on the fall phenology is evident. Except that in 2016, the gradient of fall phenology appeared to be confused by unusually early leaf senescence of certain trees under stress from an invasive insect (i.e. emerald ash borer or EAB) infestation. Work is underway to utilize both the common garden and USA-NPN data, along with alternative scenarios of interannual weather change, to better quantify these environmental drivers, and to develop phenotype-based dynamic models for both spring and autumn phenology.

**S2.6**

*Variations in autumn phenological seasons in Northern China over the past 50 years and its relationship with climate*

**Junhu Dai, Zexing Tao, Huanjiong Wang, Quansheng Ge (Chinese Academy of Sciences, China)**

Autumn plant phenology has dramatic effects on carbon balance, nutrient cycles as well as biodiversity of ecosystems. However, shifts of autumn plant phenology in China have not been systematically studied, except for very few studies on limited species. Meanwhile, the influences of rising temperature on autumn phenology present large discrepancies in the temporal extent, magnitude and direction of the shifts for different regions. Based on the phenological observations from China Phenological Observation Network since 1963, we determined a leaf colouring season (LCS) when the leaves of more than 50% of the species are under coloration and analysed the temporal patterns, regional difference, and the forms of variations in start, peak, end and length of LCS at five typical stations in Northern China. We also examined four potential factors and different time periods which might influence the length of LCS for each station through linear regression method. The result indicated that: (1) all the stations except for Mudanjiang showed a delaying trend (0.04-0.26 days/year) in peak of LCS, but only the trend in Beijing is significant (*p*<0.01). The durations of LCS in Beijing and Mudanjiang exhibited evident trend of shortening (-0.07 to -0.14 days/year, *p*<0.01), but those in the other three stations exhibited extending trends. (2) the extending LCSs are mostly induced by an earlier start and a later end in Xi’an and Mudanjiang. While, the shortening LCSs in Beijing and Mudanjiang were caused by a much later start date and by a much earlier end date of LCS, respectively. (3) the LCSs were mainly affected by accumulated cold temperatures during the LCS in Beijing and Mudanjiang (*r*2=0.24, 0.70, *p*<0.01, *p*<0.05), and by the same factor during the preseason 2 months of the LGS in Xi’an and Harbin (*r*2=0.69, 0.50, both *p*<0.01). Regarding Minqin, the dominant factor was the mean preseason temperature, which explained 38% of the variance (*p*<0.01). In addition, we also found that precipitation in all the tested periods has little influence on LCS in all the stations. The results indicate a complex response of autumn phenology to climate change across space, and further studies are imperatively required to make better understandings.

**S2.7**

*Asymmetric effects of daytime and night time warming on spring leaf phenology*

**Yongshuo H. Fu (Beijing Normal University, China; University of Antwerp, Belgium)**

Plant phenology determines the structure and functioning of ecosystems, whereas the process of spring leaf unfolding is still unclear. Specifically, the classical concept of growing degree days for leaf unfolding was developed hundreds of years ago, but this model does not include the recently reported greater importance of daytime than night time temperature. Based the remote-sensing phenological dates, we found that the spring leaf phenology related more to daytime, rather than night time temperatures. Furthermore, we conducted a manipulative experiment on daytime vs. night time warming with saplings of three species of temperate deciduous trees, and found similar results. In detail, we found that both daytime and night time warming significantly advanced leaf unfolding, but trees were most sensitive to daytime warming (7.4 ± 0.9, 4.8 ± 0.3 and 4.8 ± 0.2 days advancement per degree Celsius warming (days °C-1) for birch, oak and beech, respectively) and least sensitive to night time warming (5.5 ± 0.9, 3.3 ± 0.3 and 2.1 ± 0.9 days °C-1). Interestingly, a Bayesian analysis found that the impact of daytime temperature on leaf unfolding was approximately three times higher than night time temperatures. Night-time global temperature is increasing faster than daytime temperature, so model projections of future spring phenology should incorporate the effects of these different temperatures.

**S2.8**

*A European phenological database, PEP725, www.pep725.eu*

**H. Scheifinger, T. Hübner, E. Koch, A. Paul, M. Ungersböck (Zentralanstalt für Meteorologie und Geodynamik, Austria)**

“Phenology – the timing of seasonal activities of animals and plants – is perhaps the simplest process in which to track changes in the ecology of species in response to climate change” (IPCC 2007).

PEP725, the Pan-European Phenological Database, is a European research infrastructure to promote and facilitate phenological research. Its main objective is to build up and maintain a European-wide phenological database with an open, unrestricted data access for science, research and education. So far, 27 European meteorological services and 7 partners from different phenological network operators have joined PEP725.

In most European countries, phenological observations have been carried out routinely for more than 50 years by different governmental and non-governmental organisations following different observation guidelines. Therefore, data is stored at different places in different formats. This has been hampering large-scale studies as one has to address many network operators to get access to the data before one could start to bring them in a uniform style.

[www.pep725.eu](http://www.PEP725.eu) has been developed to solve these problems by offering a single entry point to more than 11 800 000 phenological records, all of them classified according to the so called BBCH scale. The first datasets in PEP725 date back to 1868; however, there are only a few observations available until 1950. Having accepted the PEP725 data policy and finished the registration, the data download is quick and easy and can be done according to various criteria, e.g., by a specific plant or all data from one country.

[www.pep725.eu](http://www.pep725.eu) also displays a map of near-real time phenological observations from a few countries with real-time monitoring.

PEP725 is funded by EUMETNET, the network of European meteorological services, ZAMG, who is the acting host for PEP, and the Austrian ministry of science, research and economy.

**7A.1**

*UTCI assessment of cold stress suffered from the local wind “Hijikawa-Arashi” in Ehime, Japan*

**Ohashi Yukitaka, Katsuta Takumi, Tani Haruka, Okabayashi Taiki (Okayama University of Science, Japan)**

At a coastal area in Ozu City, Ehime Prefecture, Japan, a strong cold wind called “Hijikawa-Arashi” (hereafter, HA) often occurs during the winter season. Since this local wind reaches 10 m/s in speed with a fog, residents always suffer from cold stress. Our study quantitatively revealed this cold stress by using the UTCI (Universal Thermal Climate Index).

To calculate UTCI, we measured the meteorological elements (air temperature, relative humidity, wind speed, and globe temperature) by in-situ walking. Research participants were up to eleven people aged from 20 to 49 years. This observation was conducted for ten days of November to December in 2016. The HA blows strongly at the hours (6-9 Local Time) of early morning which just overlaps with residents outdoors walking to work and school. The measured UTCI was compared with the actual (real-time) cold sensations and body (surface and core) temperatures of participants.

The results obtained from the above observations are as follows.

(1) We encountered HA on six days of the ten observation days. The strongest wind reached 14 to 15m/s instantaneously at the height of a person.

(2) Spatial variations of UTCI corresponded well to body surface temperatures of participants; both UTCI and body temperature were lower in areas suffering from the strong cold HA wind than those not suffered. The UTCI recorded -30oC and 5oC for the HA area and non-HA area, respectively.

(3) UTCI values in the strong HA day (greater than ~10m/s) were underestimated for cold sensation votes (converted to a temperature scale) of participants, while those on a weak HA day were in good agreement with participant votes.

(4) Based on the result of (3) above, we can obtain a corrected UTCI: UTCI\* = 1.14 UTCI - 3.8 (R2 = 0.82), by regression analysis**.**

**7A.2**

*The thermal comfort range of UTCI and its application on the long-term climate in hot and humid regions*

**Tzu-Ping Lin, Shing-Ru Yang (National Cheng Kung University, Taiwan)**

The Universal Thermal Climate Index (UTCI) aims to evaluate the heat stress on human body, and a globally universal thermal stress classification is recommended for worldwide use. However, in the view of thermal adaptation, there should be different thermal stress classification of UTCI for the residents in different climatic regions. Therefore, this study uses the database of 2,135 questionnaires from Keelung in the north and Tainan in the south of Taiwan, located in hot and humid regions to establish a nine-level (cold to hot) thermal stress classification, and apply this classification in the past 10-year climate to observe the thermal distribution characteristic. The result shows the comfort range of UTCI in Taiwan is 23.1-27oC, cold is >12oC, and hot is <38.2oC. The UTCI range of thermal comfort is smaller than the aforesaid universal heat stress range. The results of this comfort range for long-term climate show that the comfort frequencies of Keelung and Tainan is about 21% and 23% respectively, the hot frequency is 2% and 5% respectively, showing the different climatic characteristics. In addition, in response to the wind speed measurement from weather station, UTCI uses the wind speed at the height of 10m. Considering the thermal comfort characteristic, this study presents a comfort range calculated from the wind speed at the height of 2m, which is 1.4oC higher than the original neutral temperature. This study establishes the standard comfort range of UTCI for hot and humid regions, and reveals the pedestrian level comfort range of UTCI, which can be used for different data requirements and evaluated subjects in hot and humid regions.

**7A.3**

*Neutral temperature ranges of Korean human thermal sensation in urban and beach areas*

**Sookuk Park1, Stanton E. Tuller2 (1Jeju National University, Rep. Korea, 2University of Victoria, Canada)**

Neutral temperature range is an equivalent temperature range in which a given climate yields human thermal sensation votes (TSVs) in the neutral range. The range is a target for urban planners and landscape architects to create comfortable outdoor environments. This study investigated Koreans’ neutral temperature ranges in urban and beach areas. Microclimatic data measurements and 9-point human thermal sensation surveys from ISO 10551 were conducted together. Surveys occurred in two different years at each area and included a total of 1807 subjects at the beach and 1644 in the city. Neutral temperature range was taken as physiological equivalent temperature (PET) and universal thermal climate index (UTCI) values for neutral TSV responses.

Urban areas had very similar results: 16-24oC PET and 18-24oC UTCI in 2012-13; and 17-22oC PET and 18-23oC UTCI in 2016. However, beach areas had different results: 23-29oC PET and 26-30oC UTCI in 2015; and 19-25oC PET and 22-27oC UTCI in 2016. PET and UTCI of beach areas in 2015 were 6.4oC PET and 4.1oC UTCI higher than those in 2016, and those of urban areas in 2012-13 were 4.1oC PET and 2.0oC UTCI higher than those in 2016. Therefore, neutral temperature ranges in urban areas were not affected by increased thermal environments. Urban survey subjects would be more consistent with the same residents from year to year. In beach areas people seem to have more psychological effects as tourists. They are looking for a warm beach environment during their limited stay and the temporal inconsistency of people would contribute to more variation in survey responses between years. The neutral temperature ranges in urban areas were similar to those reported in western/middle Europe. Those in beach areas were similar to Tel Aviv and Nigeria.

**7A.4**

*A comparative analysis of outdoor thermal comfort in Hong Kong and Melbourne during summer*

**Cho Kwong Charlie Lam1,2, Kevin Ka-Lun Lau3 (1Sun Yat-sen University, China, 2Monash University, Australia, 3The Chinese University of Hong Kong, Hong Kong)**

Extreme heat presents a health risk for urban population due to likely future increase in heatwave intensity. In the past decade, there is a growing interest to study how extreme heat affects outdoor thermal comfort worldwide. As a thermal comfort index, the Universal Thermal Climate Index (UTCI) claims that its thermal stress classification can be applied globally. However, this scale of thermal stress could be interpreted differently depending on the context. This study aims to examine the differences in thermal perception between local residents from two climate zones within the same UTCI range in summer.

We compared summer thermal comfort survey data from Melbourne (*n* = 2170, January – February 2014) and Hong Kong (*n* = 414, July - August 2007). We calculated UTCI from weather station data in outdoor space (e.g. parks) in both cities. T-tests were conducted to compare the statistical significance of the differences in thermal perception and clothing choices of the residents in both cities.

Hong Kong residents appear to be more heat-tolerant compared with Melbourne residents in summer. During summer, Hong Kong had a higher neutral UTCI (31.6°C) than Melbourne (29.8°C). When the respondents felt slightly warm or warm, the mean UTCI in Hong Kong was about 2.6°C higher than Melbourne. Melbourne residents wore significantly more clothing than Hong Kong residents when UTCI exceeded 30°C. Once UTCI exceeded 39°C, more than 50% of respondents from both cities felt uncomfortable.

To assess the exposure and vulnerability of residents to heat extremes, it is necessary to recognize how different populations respond to heat stress and their thermal tolerance. This information will inform heat stress mitigation strategies for climate risk management. It is also important for urban planners and designers to provide a more thermally comfortable environment through more climate-sensitive design.

**7A.5**

*Effect of Radiation Environment on Outdoor Thermal Sensation*

**Atsumasa Yoshida, Dalki Hayashi, Shinichi Kinoshita (Osaka Prefecture University, Japan)**

The simultaneous measurements of the thermal environment and the thermal sensation of subjects were performed to examine the effects of radiation environment with various factors comprehensively. This study employs human thermal load as a thermal comfort index. Human thermal load refers to the thermal load on the human body and is calculated from the energy balance of the whole body in heat flux. Of all components of the human energy balance, radiation transfer is supposed to be dominant outdoors. Dual subject experiments were carried out in adjacent outdoor spaces where roadside trees affect and do not affect the thermal environment. The effects of several types of greenery, namely tree canopy, wall greenery, hedge and ground greenery, on thermal sensation were discussed by using the human thermal load. The subject experiments were also carried out in a sunny outdoor area and in the environmental chamber illuminated by a lighting unit under the conditions with different ground solar reflectance. The changes of solar irradiation, reflected solar radiation and infrared irradiation from the wall and the road were examined in view of the thermal sensation. A correlation of the thermal sensation and the human thermal road was found for all types of greenery and ground cover where the radiation transfer was different. The thermal sensation was suggested to be estimated by the human thermal load from the information of greenery state and ground cover. The quantitative evaluation of the thermal sensation is possible with the human thermal load under the steady state.

**7A.6**

*Study of the Fabrication Process of EVA/Starch Foams Using Subcritical CO­2 and Ultrasound*

**Rebeca Delatore1, Daniel Velasco2, Miguel Angel Rodríguez-Pérez2 (1São Paulo State University, Brazil, 2Universidad de Valladolid, Spain)**

Foams poly (ethylene-co-vinyl acetate) (EVA) are industrially applied in a broad range of products, including sports gear, insulation materials and new building materials. In contrast to glassy polymers, few studies in literature concern the foaming of semi crystalline polymers using subcritical carbon dioxide. In this study, foams produced from blends of EVA with high VA (vinyl acetate) content (28%) and corn starch has been successfully fabricated using subcritical CO2. The carbon dioxide (CO2) was used as a foaming agent to create porosity in these blends. A detailed description of the fabrication and characterization of the structure has been carried out. The results showed that the corn starch acts as filler for EVA, showing a good nucleate effect during the foaming. Different types of cellular structure (closed, partially interconnected and fully interconnected) and cell sizes were obtained depending on the relative density and the amount of starch included in the composition. Besides, the presence of the ultrasound during foaming process seems to provide or increase of open cell for the foams and improve the cellular structure. The fabricated EVA/starch materials have high potential for various applications in thermal comfort for civil construction

**8A.1**

*Determining malaria hotspot using climatic variables and geospatial technique in central urban area of Ibadan, Southwest, Nigeria*

**A Akinbobola1, J. Bayo Omotosho1, E.C. Okogbue1, John Oludare1,2 (1Federal University of Technology, Akure, Nigeria, 2Nigerian Meteorological Agency, Abuja, Nigeria)**

Malaria is one of the leading cause of morbidity and mortality in the developing countries, most especially in the sub-Saharan Africa where the transmission rates are very high and where the predominance of this disease is believed to be one of the major impediments to economic development and growth. Despite some intervention by government, many people are still infected by the disease. Therefore, this study seeks to evaluate the environmental risk factors affecting malaria prevalence and the spatial-temporal distribution of malaria incidence, in order to delineate the most severely affected area in Ibadan, Southwest, Nigeria. The data and materials used include Monthly reported cases of malaria for ten years, 2006-2015, meteorological data (Rainfall, relative humidity and Temperature) and remotely sensed data such as Landsat 8 Operational Land Imager (OLI), Shuttle Radar Topography Mission (SRTM) and soil map of the study area. The relationship between malaria incidence and climate variables were evaluated. The result obtained from climate-malaria correlation was used in ranking the selected climatic factors in developing malaria risk map. Mapping of different spatial clustering patterns like hot spots, high risk and cold spots over the entire study area was done by Hotspot analysis. The results showed that there is a strong relationship between climatic factors and malaria incidence especially maximum temperature and relative humidity. It was also observed that the intensity of clustering of high values (hot spot) and low value (cold spot) was low and varied throughout the study period, but relatively high in the year 2010, 2011 and 2014. The statistically significant hotspots of malaria were consistently detected in southern and eastern part of Ibadan central urban area (Ibadan South-West, Ibadan South-East and Ibadan North-East LGAs) and except Ibadan North-East LGA once in 2011. However, Ibadan North and Ibadan North-West LGAs remained malaria coldspot throughout the study period. The results could help government agencies, health practitioners and policy makers to plan in the prevention and control of malaria prevalence in the area.

Keywords: Climatic variables, Malaria, Hotspot, Temperature, rainfall

**8A.2**

*Present Day and Future Population Dynamics of the Dengue Vector Mosquito Aedes aegypti Using a Water Container Energy Balance Model*

**Daniel F. Steinhoff, Andrew J. Monaghan (National Center for Atmospheric Research, USA)**

Dengue infections are estimated to total nearly 400 million per year worldwide, with both the geographic range and the magnitude of infections having increased in the past 50 years. The primary dengue vector mosquito *Aedes aegypti* is closely associated with humans. It lives exclusively in urban and semi-urban areas, preferentially bites humans, and spends its developmental stages in artificial water containers. Climate regulates the development of *Ae. aegypti* immature mosquitoes in artificial containers. Potential containers for *Ae. aegypti* immature development include, but are not limited to, small sundry items (*e.g.,* bottles, cans, plastic containers), buckets, tires, barrels, tanks, and cisterns. Successful development of immature mosquitoes from eggs to larvae, pupae, and adults is largely dependent on the availability of water and the thermal properties of the water in the containers.

An energy balance container model termed the Water Height And Temperature in Container Habitats Energy Model (WHATCH'EM) solves for water temperature and height for user-specified containers with readily available meteorological data. Output from WHATCH’EM is used to estimate development parameters for the immature life stages of the *Ae. aegypti* mosquito, allowing for assessment of habitat suitability across varying natural environments. Variability amongst different artificial containers (*e.g.,* size, colour, material, shape), shading scenarios, and water availability scenarios is also addressed. WHATCH’EM is also coupled with an *Ae. aegypti* life cycle model to include the effects of the aforementioned factors on survival. Projections of future climate scenarios that take into account changes not only in temperature but also precipitation, humidity, and radiative effects are used in WHATCH’EM to estimate how *Ae. aegypti* population dynamics may change.

**8A.3**

*Spatial-temporal Distributions of Several Infectious Diseases in Different Climate Zones in Western China*

**Yuxia Ma, Yuxin Zhao, Sixu Yang, Jianding Zhou, Xiaodong Zheng (Lanzhou University, China)**

Climate warming has both direct and indirect impacts on public health, including affecting the distribution of infectious diseases and speeding up the diffusion of epidemics. In this study, spatial-temporal distribution of four infectious diseases in Gansu province located in western China was studied. Results showed that Hepatitis A occurs in all areas of Gansu province, while epidemic encephalitis and epidemic haemorrhagic fever are parochial. The incidences of infections have great differences in different climate areas. The high incidences of Hepatitis A are mainly found in Gannan Tibetan plateau. Epidemic encephalitis mainly occurs in south Gansu, where the climate is warm and humid. Epidemic haemorrhagic fever mainly occurs in Gannan Tibetan plateau. The infections also have a seasonal climax. Epidemic encephalitis mainly occurs from July to September, hepatitis A mainly in August, September and October, and epidemic haemorrhagic fever mainly from October to December and in February. Pearson correlative analysis shows that there are good correlations between the monthly cases of infections and monthly average values of meteorological elements. The above results indicate that climate factors play very important roles in the occurrence of infections.

**8B.1**

*Climate variability and change as elements modulating air pollution and behaviour of Acute Infection disease*

**Daysaríh Tápanes Robau1, Paulo Ortíz Bultó2, Pablo Fernández de Arróyabe1 (1Cantabria University, Spain, 2Institute of Meteorology of Cuba, Cuba)**

Climatic variability, as a primary expression of climate change, is one of the most relevant determinants of current environmental problems that affect human health, in particular the behaviour of acute infectious diseases. The objective of this paper is to know the influence that climate has on the dispersion of gaseous compounds, particulate material and virus circulation how these modulate the epidemic pattern of diseases. Identified potential predictors for a prediction model using climatic information are considered here. In the work, the behaviour of acute respiratory infections (ARI) associated with air pollution, circulation of Respiratory Syncytial Virus and the influence of climate on the seasonal pattern of the disease are determined, identifying the potential predictors for the formation of a bioclimatic forecast model from the use of the climatic predicted described by Bultó complex indices and the air pollution in the study area.

**8B.2**

*Air Pollution Episodes Associated with Prescribed Burns in Sydney Australia*

**Melissa Hart1, Giovanni Di Virgilio1, Ningbo Jiang2 (1University of New South Wales, Australia, 2NSW Office of Environment and Heritage, Australia)**

Air pollution events associated with wildfires have been associated with extreme health impacts, including increased hospital admissions and death. Prescribed burns are vital to reduce the severity of wildfires. However, if undertaken during unfavourable meteorological conditions, they too have the capacity to trigger extreme air pollution events. The Australian state of New South Wales has increased the annual average area treated by hazard reduction activities by 45%, in order to limit wildfire activity.

During prescribed burns, under certain meteorological conditions and fire characteristics, the Sydney air shed can experience elevated particulate matter concentrations, especially fine particulates (PM2.5) that occasionally exceed national air quality standards. This presentation will discuss the meteorological conditions associated with historic planned burns that have adversely affected air quality in Greater Sydney and introduce a tool we have developed that allows for better planning of prescribe burn times in order to minimize impact on air quality within populated areas. The insights gained from this study will help improve prescribed burn scheduling in order to reduce the pollution risk to the community, while allowing fire agencies to conduct this important work.

**8B.3**

*An analysis of the impact of climate change on the air pollution in Beijing–Tianjin–Hebei region, China*

**Xiakun Zhang, Shuyu Zhang (National Meteorological Center of China Meteorological Administration, China)**

The air pollution in the Beijing–Tianjin–Hebei region in China has been intensifying. In addition to the increase in the amount of pollutants, climate change is suspected to have an impact on air pollution. Ground meteorological observation data, high altitude observation data and reanalysis data from the National Centers for Environmental Prediction of the Beijing–Tianjin–Hebei region from 1971 to 2015 were used in this study. The effects of the changes in the meteorological factors, such as temperature, precipitation, wind speed, number of gale days; atmospheric stability and winter Siberian high-pressure system were analysed. Atmospheric boundary layer thickness was calculated and analysed. In addition, the correlations of PM2.5 concentration with atmospheric boundary layer thickness and relative humidity were studied. Analysis results showed the following: first, the temperature increased by 1.5°C, the precipitation reduced by 66.4 mm, the wind speed decreased by 0.98 m/s and by more than 5 m/s during gale days annually on average in the 44-year study period. In the 1970s, the number of gale days averaged 52 days. After 10 years, it decreased to less than 10 days. Decreased temperature, wind speed and precipitation hindered the diffusion of air pollutants. Second, the thickness of the atmospheric boundary layer in the study region decreased annually, with 1985 being the pivotal year. After 1985, the boundary layer thickness obviously began to decline. In 1990, the boundary layer thickness decreased by approximately 500 m. After 1990, the boundary layer thickness exhibited minimal changes, and it was maintained within the 1200–1300 m range. However, boundary layer thickness fluctuated across seasons, with the maximum thickness observed in spring, followed by summer. The minimum thickness was observed in winter. A diurnal variation in the average atmospheric boundary layer thickness was also notable. The average atmospheric boundary layer thickness was low at night. During the day, at sunrise and sunset, the boundary layer thickness shifted from low to high and from high to low respectively; however, the change was minimal. Boundary layer thickness and PM2.5 concentration exhibited a negative correlation, with a correlation coefficient of 0.92 at 0.01 significance level. Therefore, the air pollution decreased as the boundary layer thickness increased annually, the highest level of air pollution was recorded in winter, and air pollution was higher at night than during the day. Third, the interannual change in atmospheric stability was insignificant compared with the monthly and diurnal changes. The monthly variation of neutral atmospheric stratification was unremarkable, whereas stable and unstable atmospheric stratification showed significant seasonality. Unstable stratification showed an increasing trend from summer to spring. For a long period, the frequency of unstable stratification gradually increased from 32% in April to 49.7% in August, whilst the stable class decreased. From autumn to winter, the frequency of stable stratification showed an increasing trend from 36% in September to 60.1% in January, whilst the unstable class decreased (i.e. 16.8% in December). The vertical diffusion of air pollutants was stronger in spring and summer than in autumn and winter; thus, air pollution easily intensified during fall and winter. Atmospheric stability occurred at night, whereas the atmosphere changed and became unstable during the day; thus, the level of air pollution increased at night. Fourth, relative humidity and PM2.5 concentration were positively correlated, with a correlation coefficient of 0.64 at 0.05 significance level. Fifth, the winter Siberian high pressure significantly decreased annually, with 1985 being the pivotal year. From 1984 to 1996, the winter Siberian high pressure continually declined by approximately 4 hPa. The boundary layer thickness changed, but the wind speed remained the same. The weak Siberian high pressure, particularly the weak cold air activity, reduced air pollutant diffusion and easily induced air pollution. During winter monsoons, the cold air significantly reduced the temperature, precipitation and wind speed in the study region, particularly during gale days. These decreases significantly reduced the diffusion and precipitation of air pollutants. The boundary layer thickness decreased annually; as a result, stable atmospheric stratification prevailed in fall and winter, the vertical air pollutant dispersion weakened, and the air pollutant capacity decreased. Atmospheric relative humidity increase is favourable to air pollution. Therefore, even if pollutant discharge is controlled, climate change by itself can deteriorate air quality.

**8C.1**

*Developing the second generation of biometeorological forecasts: the methods and fundaments*

**Luis B. Lecha Estela1, Luis Monteagudo Lima2 (1University of Havana, Cuba, 2Cardiology Centre of Villa Clara, Cuba)**

The ambulatory monitoring of arterial pressure (AMAP) is a useful technology to study the continuous and individual behaviour of cardiovascular parameters. Based on their results, individual characteristics of circadian rhythm may be established and doctors can indicate more precise therapies and preventive treatments. Additionally, these cardiovascular parameters may be associated with the synchronous behaviour of meteorological elements in order to study the influence of meteor-tropic effects on vulnerable persons. A field study with 1420 hypertensive patients under monitoring at the Cardiology Centre of Villa Clara were developed since February 2013 until December 2015, comparing their results with the daily and inter-daily behaviour of meteorological elements measured at the weather station of Santa Clara city and the content of issued biometeorological forecast during the same period. The patients were classified according with characteristics of their circadian rhythm. During AMAP test seven anomalies of cardiovascular parameters were counted like signals of external influences on individual physiology, including the occurrence of forecasted meteor-tropic effects. The patients with Riser type of circadian rhythm are most vulnerable to meteor-tropic effects because of 84% of them presented more than three anomalies during the AMAP test. The other more vulnerable group of hypertensive patients was Non-Dipper type patients with 68% of cases affected by more than three anomalies. The identification of specific influences from meteor-tropic effects on hypertensive patients allows the design and implementation of individual therapeutic and preventive procedures guided to prevent and to mitigate influence of weather changes on this vulnerable group of people. The next step will be to elaborate and send automatically through cellular phones individual medical advices according with the issued biometeorological forecasts. The patients will receive this way medical indications and preventive recommendations not meteorological information. This will be the second generation of biometeorological forecasts.

**8C.2**

*An Evaluation of Intraseasonal to Interannual Climate Forecasts and Forecasting Tools for Use in Agriculture; Decision Making in the South East United States.*

**Fergus J. D. Keatinge, Peter R. Waylen, Jane Southworth, Ray G. Huffaker, Gerrit Hoogenboom (The University of Florida, USA)**

The implementation of accurate climate forecasting data into crop modelling systems, for the interests of agricultural decision making and economic prosperity, is of vital global importance. Production in agriculture and related industries such as: seed developers, fertilizer producers, extension specialists, insurance and risk management support have a strong interest in weather and climate forecasts. This research provides a comprehensive evaluation of current intraseasonal to interannual (ISI) forecasting models, tools and projects to facilitate the implementation of accurate climate forecast data for improved decision making in agriculture. Examples include both single-model and ensemble based forecasting tools, such as the NCEP Climate Forecast System Version 2 and the North American Multi-model Ensemble (NNME). Evaluation criteria are spilt into two categories, climatological based forecasting and the use of ISI forecasting in agriculture. Evaluation criteria examples include (but are not limited to); forecast skill, forecast effectiveness, patterns of variability, inertia, external forcing, forecast scale, forecast variables, access, organization and result communication. The south-eastern United States (including various upper south states and south-central states) is the focal region of the evaluation study due to the regions extensive climatic variability, extended wet and dry periods and temperature volatility, vital aspects in temporal dependent agricultural decision making. Results show progress in ISI forecasting but still a clear need for improved forecast development to provide more effective agricultural decision making. Currently an array of limiting factors are leading to stagnation in model development and communication for agro-based decision makers, decreasing the use of ISI forecasting the plant management based decisions to maximize yield. Future research thus required includes the implementation of appropriate climate forecasts into a gridded crop model system (G-CMS), namely the Decision Support System for Agrotechnology Transfer (DSSAT) and the analysis of economic ramifications, including the application of this research in agricultural risk management.

**8C.3**

*Enhancing Resilience to Heat Extremes: Multi-model Forecasting of Excessive Heat Events at Subseasonal Lead Times*

**Augustin Vintzileos (University of Maryland, USA)**

Heatwaves are among the most dangerous, yet invisible, of natural hazards. According to NOAA, the distribution of 30-year based annual mean fatalities from natural hazards in the U.S. ranks as follows; those from heat (130), floods (81), tornadoes (70), lightning (48) and hurricanes (46). Early warning to excessive heat events can be improved by using multi-scale prognostic systems. We designed and developed such a system for forecasting excessive heat events at lead times beyond Week-1. This Subseasonal Excessive Heat Outlook System (SEHOS) consists of (a) a monitoring/verification component and (b) a forecasting component which in its baseline version uses NOAA’s Global Ensemble Forecast System (GEFS) predictions of temperature and humidity from Day-8 to Day-14. In this presentation, we discuss the definition of heat events, sources of predictability and present the forecast skill of SEHOS for the GEFS reforecast period (1985-2014) and real-time forecasts during summer 2016. We then use subseasonal reforecasts from several models from the S2S database and discuss the forecast value added by multi-model approaches in predicting excessive heat events.

**9A.1**

*A panting score index for sheep*

**A. M. Lees, M. L. Sullivan, A. J. Cawdell-Smith, J. B. Gaughan (The University of Queensland, Australia)**

Assessment of thermal comfort during periods of heat load is essential during heat load events. Panting score (PS) is routinely used as an indicator of thermal status in cattle. The objective of this study was to define a PS system for live export sheep. One hundred and forty-four Merino weathers (44.02±0.32kg) were used in a replicated climate control chamber study. Each replicate (n=2) was conducted over 29 d and consisted of 2 treatments: hot (**HOT**) and thermoneutral (**TN**). There were 6 sheep/pen and 3 pens/room. Individual PS were determined for each animal at 3 h intervals between 0800 h and 1700 h daily for the duration of the study. Panting scores were visually determined based on the open and closed mouth panting using a scale of 0 (no panting) to 4.5 (opened mouth). Data were converted to means for each pen. Data were then expressed as a phase and observation time within the study: Phase 1 (day 1 to 7); Phase 2 (day 8 to 15); Phase 3 (day 16 to 23); Phase 4 (day 24 to 29); observation time: Time 1 (0800 h); Time 2 (1100 h); Time 3 (1400 h); and Time 4 (1700 h). Data were analysed using a repeated measures model assuming a compound symmetry covariance structure (PROC MIXED, SAS Institute, Cary, NC). The model included replicate, treatment group (HOT; TN), time unit (phase or observation time) and time×treatment interaction. The subject factor corresponded to the eight replicate-treatment group-room combinations.

Panting scores were greater (*P*=0.0085) for the HOT (1.49±0.02) compared with the TN (1.17±0.02). Panting score provides a visual assessment of respiratory dynamics and can be used to assess heat load. These results suggest that a PS index for sheep may be a valuable management tool during hot periods on live export voyages.

**9A.2**

*Global climate change is going to affect beef cattle performance in Turkey: Performance of beef cattle determined by comprehensive climate index for different climate models.*

**H. Koknaroglu, J.A. Harrington Jr2, T.L. Mader(1Suleyman Demirel University, Turkey, 2Kansas State University, USA, 3University of Nebraska, USA)**

Purpose of this study was to determine the effect of future global climate change on beef cattle performance in Turkey. Performance was determined using the comprehensive climate index (CCI) for three different climate scenarios. Four General Circulation Models (GCMs) were used to obtain climate change monthly scenario output data for input into the CCI model for 15 Turkish cities. The four GCMs were from the Hadley Center in the UK (HADLEY), the Centre National in France (CNRM), Atmosphere and Ocean Research Institute in Japan (MIROC), and the Meteorological Research Institute in Japan (MRI). Scenarios for three different levels of greenhouse gas trajectories (mild, moderate, and high) were used. Model output data for a period in mid-century (2040-2059) and late-century (2080-2099) were used to examine potential shifts in environmental stresses for animal production. CCI model enables one to quantify beef cattle performance based on environmental conditions (temperature, relative humidity, wind speed, solar radiation) at any time in the year and the CCI was used to predict dry matter intake (DMI), average daily gain and feed efficiency of feedlot cattle. Of the three levels of greenhouse gas trajectories, mild had little impact whereas high had considerable effects on performance. Late-century had more negative effect than mid-century regardless of the GCM models. Results showed that climate change is going to affect cattle performance in the future and cities known as hotter places are going to be affected adversely whereas cattle production in colder places is going to benefit from climate change. Cattle having higher average daily gain did not mean that they would have better feed efficiency. Altitude is shown to be a factor affecting beef cattle performance.Since there is variation among cities in terms of cattle performance, policy makers should consider these differences and promote cattle raising in the favourable places.

**9A.3**

*Circadian variations in rectal temperature responses of packed donkeys deprived of feed and water administered with ascorbic acid during the cold-dry (harmattan) season*

**Victor O. Sinkalu, Joseph O. Ayo, Salka N. Minka, Jecintha N. Umekesiobi (Ahmadu Bello University, Nigeria)**

The study investigated the influence of cold-dry (harmattan) season and ascorbic acid (AA) administration on daily rhythmicity of rectal temperature (RT) in packed donkeys deprived of feed and water for 24 hours. Six experimental donkeys administered with AA and six control donkeys given distilled water were used for the study. The RT of each donkey and the DBT, RH and THI in the animal pen were recorded bi-hourly for 24 hours. The DBT and RH values fluctuated between 17oC and 33oC, and from 13% to 35%, respectively, predominately outside the thermoneutral zone for the donkey. The application of the periodic model showed a clear daily rhythmicity of RT in the donkeys. Rhythm characteristics of the mesor of RT in the donkeys did not differ between control (36.3 ± 0.3oC) and experimental (36.1 ± 0.3oC) groups. The amplitude of daily rhythm of RT in the experimental donkeys (1.80 ± 0.05oC) was greater (P < 0.05) than that of the control donkeys (1.35 ± 0.03oC), which showed that the lower the mesor the greater the amplitude. The acrophases of daily rhythm of RT in both experimental and control donkeys were restricted to the light phase of the light-dark cycle at 18:00 h, but, the RT of the experimental donkeys at this hour of the day was higher than that of the control donkeys by 0.6oC. In general, the RT showed a descent phase during the night and early morning hours, with RT lower than normal values; and an ascent phase during the hot afternoon hours of the day. In conclusion, the result, for the first time, demonstrated the circadian rhythm of RT values in donkeys during the harmattan season, and that AA, by lowering the mesor, modulated the rhythm of RT in donkeys, deprived of feed and water for 24 hours.

**9A.4**

*Impact assessment of climate change on intensive pig and poultry production by the simulation of the indoor climate of livestock buildings*

**G. Schauberger, R. Vitt (University of Veterinary Medicine, Austria)**

In the near future, intensive of pig and poultry production may be severely affected in the middle latitudes by heat stress, which will increase due to the expected climate change. In temperate climate regions like Central Europe these animals are predominantly kept in confined housing systems which are characterised by ventilation systems. Therefore, the impact of climate change scenarios on these systems cannot be assessed only by ambient meteorological parameters, as they are modified by the confined livestock building and the livestock itself. This means that the indoor climate, which is the environment relevant for farm animals, has to be considered by simulation models, describing the interaction between animals which release sensible and latent (water vapour) heat, the insulation of the building to capture the sensible heat, and the ventilation system. The ventilation system is the most effective link to the outside, but inevitably differences will occur between climatic conditions outside and inside livestock buildings. The indoor climate will in turn impact on animal health and welfare, productive, reproductive and economic performance. The features as well as the limitations of such simulation models will be presented and discussed. On the basis of such model calculations the husbandry conditions can be simulated to reveal the effectiveness of adaptation measures (i.e. adaptive capacity), which sums up to livestock and farm vulnerability. The thermal environment is a major parameter as it directly impacts animal welfare and health. The productivity of farm animals can be investigated by parameters which are sensible to the thermal environment: For fattening pigs and broilers this can be described by daily weight gain and feed conversion, egg production for laying hens and the reproductive performance of sows (litter size, number and body weight of weaned piglets etc.).

**9A.5**

*Estimating the Climatic Energy Demands (Feed and Water) of Dromedary Camels Fed at the Maintenance Level: A Theoretical and Practical Aspect*

**Emad M. Samara, Khalid A. Abdoun, Ahmed A. Al-Haidary (King Saud University, Saudi Arabia)**

Background:Energetics constitutes a highly important aspect of animal biometeorology. Due to the necessity for dromedary camels to adapt their energy budget to the thermal environment in order to optimize comfort, determining their energetics at every spatio-temporal scale is undoubtedly of vital importance. Nevertheless, data on climatic energy demands (feed and water) for these animals appears to be lacked.

Design:The present experiment was carried out inside a climatic-controlled chamber on 10 dromedary camels individually fed at the maintenance level. Using a two-dimensional steady heat transfer model, the rate of sensible (*q*sensible), latent (*q*latent), total heat dissipation, and thus total heat production were all estimated and expressed in terms of an effective ambient temperature (*T*e). Accordingly, the lower (LCT) and upper (UCT) limits of the thermo-neutral zone were defined. More importantly, the climatic feed demand was estimated from the slope of the increasing rate of *q*sensible below the LCT, while the climatic water demand was estimated from the slope of the increasing rate of *q*latent above the UCT.

Results:The obtained findings clearly substantiate that the heat exchange profile has manifested particular differences. The LCT for lies within the *T*e range of 17–25°C while their UCT lies in 35–43°C. Moreover, results demonstrated that the extra feed demand under sub-neutral conditions can be met by adding at least 100 g of grass hay (Gross energy estimated as 4.09 Kcal/g) per °C below the LCT, while the extra water demand under supra-neutral conditions can be met by adding at least 500 mL of water per °C above the UCT.

Concluding remarks:Information about the energetic demands estimated herein for dromedary camels exposed to short-term laboratory conditions and fed at the maintenance level can, therefore, be considered as the starting seed for a long-term research program. Such information is crucial to both economical animal production and responsible animal stewardship. Identifying the energetic bottleneck for camels is of further interest.

**9A.6**

*Enteric methane emission of Jersey dairy cows: an investigation on circadian pattern*

**Alex Sandro Campos Maia1, Sheila Tavares Nascimento2, Marcos Davi de Carvalho1, Vinícius de França Carvalho Fonsêca1 (1Sao Paulo State University, Brazil, 2University of Brasilia, Brazil)**

The Brazilian government has funded several surveys aiming at estimating the contribution of different livestock production systems to greenhouse gas (GHG) dynamics, especially enteric methane emissions. The purposes of these efforts have been to obtain reliable baseline emissions data to find potential mitigation options. In this study, we quantified the circadian pattern of the energetic metabolism associated with enteric methane emission of Jersey dairy cows managed in a tropical environment. Twelve Jersey dairy cows with 326.28 ± 30 kg body weight, 17.66 ± 1.8 milk yield, and 165.5 ± days in milking were assigned in two Latin square (LS) designs. Subjects were fed a total mixed ration of corn silage (70%) and grain (30%; corn and soybean) twice daily. Evaluations were performed from 08:00 to 20:00 (LS1) and from 20:00 to 08:00 h (LS2), protected from solar radiation and rain overnight. Meteorological variables were recorded. Ventilation rate (VE), breathing rate (F), percentage of oxygen (O2), carbon dioxide (CO2), and methane (CH4) from the exhaled air were measured by an indirect calorimetry system, using a facial mask. From these data, metabolic heat production (q"met ; W m-2) and methane emission (ECH4; g h-1) were calculated. Data were analysed by the least squares method. Ambient air temperature and relative humidity ranged from 22 to 31°C and 27 to 88%. Minimum and maximum metabolism were 133.91 ± 3.2 (05:00 h) and 243.21 ± 3.83 W m-2 (17:00 h), increasing slightly from 06:00 h and remaining constant through the day until 20:00 h. On the other hand, methane emission had two apparent peaks, occurring after feeding times (09:00 and 18:00 h); the maximum value observed was 12.47 g h-1. From the data obtained in the present investigation, enteric methane emission of confined Jersey dairy cows bred in a tropical environment is approximately 184 g day-1/cow.

**9A.7**

*Thermoregulation in different coat coloured locally adapted Brazilian sheep*

**Jacinara Hody Gurgel Morais Leite1, Wallace Sostene Tavares da Silva1, Wilma Emanuela da Silva1, Renato Diógenes Macedo Paiva1, Josiel Borges Ferreira1, José Ernandes Rufino Sousa1, Luis Alberto Bermejo Asensio2, Débora Andrea Evangelista Façanha1 (1UFERSA, Brazil, 2Universidad de La Laguna, Spain)**

The present paper aimed to show thermoregulatory responses of locally adapted sheep with different coat colours, exposed to direct solar radiation in an equatorial semiarid region. There were used four groups according to the coat colour: (1) dark red animals, (2) intermediate red, (3) light red and (4) white coated animals. Forty Morada Nova ewes were observed in each of three herds for 7 consecutive months. Animals were measured for rectal temperature (RT), skin surface temperature (ST), respiratory rate (RR) and skin surface evaporation (CE), from 11:00 AM to 02:00 PM. The RR was higher in the animals of groups 1 to 3, which also showed higher values for ST when compared to the white coated animals. Groups 1, 2 and 3 used RR in a more intense way compared to group 4; however, CE was higher for the white animals. The logistic regression analysis showed that animals with dark red coat triggered more the RR, where 79.74% of the animals presented RR above 60 breaths.min-1, while the animals with white coat triggered less this mechanism and only 52.6% had RR above this value considered as stressed. For RT, all the animals, regardless of tonality, maintained the values within the normal range for sheep, only 17% of the animals of group 1 presented the RT above 39.9 ° C and 10% of the white animals showed RT above 39.9°C. All group of animals, regardless of tonality, were able to maintain homeothermy. These results discard the assumption that the animals with dark red or light red coat are less adapted to a hot environment. White coat animals were also able to maintain thermal balance when exposed to the same levels of solar radiation as the red animals. These results confirm the adaptive ability of Morada Nova, regardless of its colour and variety.

**9A.8**

*Acid-Base Equilibrium in Locally Adapted Brazilian Sheep Under Natural Heat Stress*

**Débora Andréa Evangelista Façanha, Fabrício Xavier Morais, José Moreira de Oliveira Filho, Chromacio Calafange Medeiros, Josiel Borges Ferreira, Wilma Emanuela Silva, José Ernandes Rufino de Sousa (UFERSA, Brazil)**

The research was conducted at Small Ruminant Research Centre, UFERSA, Brazil, aiming to evaluate thermoregulatory aspects and their influence on acid-base equilibrium in red, black and white varieties of Morada Nova, a locally adapted Brazilian sheep, under natural heat stress in an open field. Data were collected once a week during the dry period, from 5 to 6 AM, from 12 to 1 PM and from 5 to 6 PM. The thermoregulatory traits evaluated were: respiratory rate (RR), rectal temperature (RT), skin surface temperature (ST) and cutaneous evaporative rate (CE), on the neck and flank area. Hemogasometric tests determined the blood pH (pH), carbon dioxide venous pressure (PCO2), the base excess (BE) and the presence of bicarbonate ions (HCO3-). Meteorological data were registered, and Black Globe Humidity Index (BGHI) and the Radiant Heat Load (RHL) were estimated. The environment data showed that at 12 PM the animals were exposed to a severe heat stress, confirmed by an increase of RT overcoming the homeothermy zone. This fact increased thermoregulatory mechanisms, specially RR, once it was normal at 5 PM and then increased significantly during heat stress, especially in black coated animals. On the other hand, cutaneous evaporation was not different among the varieties nor at any time of the day, confirming that, although the Morada Nova is a non-wooled breed, the most important way that they use to dissipate heat is respiratory thermolysis. However, the increase of RR caused hyperventilation and, as a consequence, an increase of blood pH compatible with respiratory alkalosis in all varieties, but more intensely in black animals. The decrease of PCO2 and decrease of HCO3 confirmed this disequilibrium. An important finding was that after the exposure to heat stress, the animals were able to recover homeothermy, regardless of the coat colour.

**9A.9**

*Relationship between body weight and respiratory traits of livestock bred in tropical environment*

**Carolina Cardoso Nagib Nascimento, Vinícius de França Carvalho Fonsêca, Cintia Carol de Melo Costa, Leandro Zucheratto Camerro, Marcos Chiquitelli Neto, Alex Sandro Campos Maia (Universidade Estadual Paulista, Brazil)**

Body weight and metabolism relationship help to understand better evolutionary aspects of animals. In the same way, overall characteristics in the respiratory physiology has a direct relationship with body mass. In order to study this subject, we performed four trials using an indirect calorimetry system to assess energetic metabolism and respiratory traits of cattle breeds (Nellore, Guzerat and Jersey cows) and Anglo-Nubian goats bred in the tropics. These studies were carried out at the Laboratory of Animal Biometeorology (21° S, 48° W, 605m altitude). The indirect calorimetry system was based in a portable open circuit by the use of facial mask. The metabolic heat production (q"met; W m-2), ventilation (VE; L s-1), respiratory rate (RR; breath min-1), tidal volume (VT; L breath-1), production of carbon dioxide (VCO2; L s-1), and intake of oxygen (VO2; L s-1) were determined. Prior to the trials, animals were habituated to contention and use facial device. Non-linear functions were fitted to estimate the relationship between respiratory traits and body weight. Results showed that lighter animals had a higher q"met, TV, VE, VO2, RR per unit body weight than largest. When we compared VE and RR of dairy and beef cattle with similar weight, Jersey cows had higher values per unit of body mass than Guzerat. These findings are important to comprise differences in the energy requirements of animals. We developed a portable calorimetry system to assess energetic metabolism and physiological traits of the respiratory tract in livestock.

**9B.1**

*Hot under the collar – the relationship between temperature and crime in Australia*

**Heather R. Stevens, Paul J. Beggs, Petra L. Graham (Macquarie University, Australia)**

Heat waves are anecdotally linked to a range of anti-social behaviours such as domestic violence, alcohol abuse, and road rage. The association between heat and violence is so entrenched that it has become part of the English language – a hothead, simmering anger, or to be hot under the collar. However, does extreme heat cause such behaviours? Although some international studies have made connections between temperature and crime and/or aggression, very little research has been done within the unique Australian climate. The aim of this study is to investigate the relationships between temperature and crime in New South Wales (NSW), Australia, as well as how age and gender influence the relationship. The study uses statistical modelling to examine seasonal, monthly, and daily relationships between temperature and recorded crime rates, controlling for confounding factors. The study looks at both crimes against the person (e.g., homicide, assault) as well as crimes against property (e.g., theft, vandalism). Data is drawn from the Australian Bureau of Meteorology and the NSW Bureau of Crime Statistics and Research over a 30-year period for the whole of NSW as well as metropolitan and regional areas. Preliminary results show that there is both a seasonal and daily correlation between temperature and most categories of crime. For example, incidents of assault in NSW consistently peak in summer (often with a double peak, in December and March) and are at a minimum in winter. The study also considers the various theories that may explain these relationships. The findings of this novel study give insights into how to better understand and manage crime. The results also become more pressing when considering a future warming world.

**9B.2**

*Multi-dimensional social vulnerability and flood disadvantage assessment to support socially just flood risk management*

**Gina Cavan1, Aleksandra Kazmierczak2, Sarah Lindley3, Angela Connelly3 (1Manchester Metropolitan University, UK, 2European Environment Agency, Denmark, 3University of Manchester, UK)**

Flooding is already a severe risk in Scotland, demonstrated recently by the winter 2015/16 floods costing the economy up to £700 million. Climate change is likely to exacerbate the frequency and severity of flooding, causing an increased risk of riverine, coastal, and surface water flooding. This heightened risk of flooding will mean greater risk to human health, including, injuries, deaths, and mental health conditions. However, not all individuals and communities will be affected by flooding equally because their ability to copy with flooding is different. Flood disadvantage occurs where socially vulnerable neighbourhoods coincide with areas which may be exposed to flooding, thus, have high flood hazard-exposure.

This paper presents an improved method for the assessment of exposure and vulnerability to climate extremes. More specifically, it focuses upon the development of a multi-dimensional assessment of social vulnerability, and applies this within a spatially explicit framework to provide the latest flood disadvantage assessment for Scotland. This assessment is then compared to the Scottish Index of Multiple Deprivation, to evaluate the value of a more comprehensive and focussed assessment specifically for flood risk management.

The research was carried out at the neighbourhood level for Scotland. In total, 34 indicators relating to 14 thematic domains were combined into the index of social vulnerability to flooding. The index of social vulnerability to flooding was combined with the flood hazard-exposure index, which took different sources of flooding (coastal, river, surface water) and different flood return periods into account, including the impacts of climate change. This was then developed into the index of flood disadvantage.

This paper outlines the methodology, results, and recommendations for flood risk management, and provides transferable lessons for future assessments.

**9B.3**

*Assessing the effect of weather on human outdoor perception using Twitter*

**Laura Giuffrida, Hanna Leona Lokys, Otto Klemm (University of Muenster, Germany)**

Human Comfort in Outdoor Spaces (HCOS) is linked to physical, physiological and psychological responses of people to environmental variables. Previous studies have established comfort ranges for these variables through questionnaires, reaching only small populations. However, larger amounts of data could not only generate more robust results in local studies, but also allow the possibility of creating an approach that could be applied into a wider range of weather conditions and different climates. This thesis describes a new methodology to assess people’s perception of weather based on human responses to weather conditions extracted from tweets, with the purpose of establishing comfort ranges for environmental variables. Tweets containing weather-associated keywords were collected using the Twitter API and then linked to real-time meteorological data acquired from the Open Weather Map API, which provides weather variables measured nearby the locations in which the tweets were posted. Afterwards, people’s perception of weather was extracted from the tweets using a classifier trained specifically on weather data that identified irrelevant, neutral, positive and negative tweets. The obtained tweets and their related meteorological data were analysed to establish comfort ranges. Comparing the resulting ranges to others obtained in previous studies, a generally good agreement was found with the indices Effective Temperature (ET) and Termohygrometric index (THI) derived from questionnaires, but the peak of comfort is shifted towards lower and higher temperatures, respectively. Regarding the single weather variables, the obtained comfort ranges are alike the ones found in previous research, in particular, the temperature comfort range matches perfectly at 20°C – 22°C. Therefore, it was concluded that tweets can be used for the assessment of HCOS; not only the results of this methodology are comparable to the ones obtained in previous studies, but also the procedure itself shows new features and opportunities for future applications.

**9B.4**

*Communication of Heat Stress Information for Risk Management*

**Matthias Otto1, Bruno Lemke1, Tord Kjellstrom2,3 (1Nelson Marlborough Institute of Technology, New Zealand, 2Centre for Technology Research and Innovation, Cyprus, 3Australian National University, Australia)**

We compile climate and population data from internationally refereed and acceptable sources and combine these with exposure-response relationships for heat stress indices to evaluate global and country-wide work capacity loss due to heat. From our grid-cell based data (67,000 cells, 0.5 x 0.5 degrees) we calculated, for example, the global number of people subjected to very high heat stress will rise to over 400 million in 2085 from the current value of less than 1 million.

Our data and methodologies are made available to researchers and other interested parties, with user feedback incorporated into ongoing development. We will present our data sources, quality assurance methods, different applications and examples of their use. An insight will be given into the data-mining capabilities of the comprehensive database that drives these applications. The database contains data from diverse disciplines like meteorology, geography, demography, climate science and modelling, and is open-ended in terms of future additions.

An application to analyse, view and produce trends from daily climate data since 1980 at more than 18,000 weather stations will be demonstrated. Our interactive website with access to gridded historic and modelled global climate data allows the user to locate, for example, the Spanish city of Seville, and find that the afternoon WBGT level during August has increased from 26C to 27.5C during the recent 35 years. Depending on the chosen climate model, our web application shows WBGT potentially rising to above 29C in the 2050s. We believe our data and applications are valuable decision support tools for local risk management. The outputs will be tested as a contribution to risk management tools of the EU project HEATHSHIELD.

**9B.5**

*Heatwave risk perception and its management in the field: a study among the local stakeholders of the French National Heatwave Plan*

**Karine Laaidi, Christophe Perrey, Mathilde Pascal, Aymeric Ung, Sébastien Denys, Pascal Beaudeau (French National Public Health Agency, France)**

Background / objectives: In France, the National Heatwave Plan was implemented in 2004 following the major 2003 heatwave, which recorded 15,000 excess deaths, to limit the adverse impacts of heatwaves on health. The objective of this study is, among local stakeholders, to: (i) assess their knowledge of heatwave-related risk on public health, (ii) assess their knowledge of the plan implementation in the field; (iii) list their difficulties and propositions to improve the heatwave plan and more generally the prevention on heat.

Methods: We conducted interviews in face-to-face with local stakeholders from institution area (mayors, prefects, regional health agencies…) and operation area (emergency physicians, associations, home health care and domestic help…), and among mini groups of persons working at vulnerable elderly people’s home (nurses, domestic help, care givers…). These interviews took place in 6 French cities with different characteristics (more or less populated or accustomed to heat, having experienced or not heatwave alerts or excess deaths). A focus was made on vulnerable people registries which allow cities to call them during heatwaves and assist them if needed.

Results: In total, we conducted 95 individual and 6 mini group interviews. The stakeholders have a variable knowledge of the plan and risks details. Stakeholders reported expectations in having: (i) recommendations and communication tools better targeted for each population at risk (isolated people, outdoor workers, single-parent children…); (ii) a more collaborative approach, mainly aimed at sharing good practices among professionals, to fight isolation and enhance solidarity towards vulnerable people; (iii) improvement of provisions concerning worse-case events with reference to the 2003 heatwave.

Conclusions: Interviewed stakeholders suggested several recommendations to improve the French National Heatwave Plan to respond to all specific emergency situations with adequate resources. These recommendations will be further discussed to improve the plan regarding communication and prevention on heat impact on health.

**9B.6**

*Nocturnal tornadoes in Tennessee, USA: An interdisciplinary approach to understanding public safety challenges*

**Kelsey N. Ellis, Lisa Reyes Mason, Kelsey N. Gassert, Mary E. Winchester (University of Tennessee, USA)**

In the state of Tennessee, the incidence of killer tornadoes, particularly those occurring at night, is among the highest in the world. Reducing tornado fatalities in Tennessee and across the Southeast region is a current objective of the United States government, researchers, and weather forecasters. The first step to decreasing fatalities from tornado events, including those happening at night, is to attain a better understanding of the meteorological, climatological, socioeconomic, and communication challenges leading to these fatalities, followed by a cooperative effort to apply these findings to improve public safety. Nocturnal tornadoes are unique because they cannot easily be seen, occur when the public may be asleep, and happen in a different ambient environment, and therefore require a special focus to isolate factors leading to fatalities. We employ a climatological analysis; phone surveys (n=1800) and in-depth interviews (n=45) with residents of Tennessee; and in-depth interviews with forecasters (n=9) at the three National Weather Service (NWS) forecasting offices in Tennessee to better understand the public safety challenges that exist surrounding nocturnal tornadoes across the state. We present information regarding the public’s understanding of their nocturnal tornado risk, access to nocturnal tornado warnings, and response to nocturnal tornado warnings, as well as challenges to NWS forecasters associated with these night time severe weather events.

**9B.7**

*Biometeorological Data Infrastructures and Human Vulnerability definition based on a Citizens Science Approach*

**Pablo Fdez-Arroyabe, Dominic Royé (University of Cantabria, Spain)**

The design and implementation of any climate-related health service implies avoiding the digital divide as it means having access and being able to use complex technological devices, massive meteorological data, user´s geographic location and biophysical information. This research presents the basic components needed to co-create a Biometeorological Data Infrastructure, which is a complex platform formed by: a mainframe, a biometeorological model, a database management system, data procedures, communication protocols, different software packages, users, datasets, websites, mobile applications and accounts in the different social networks. A specific system is presented through the research. The elaborated system produces four daily world maps of the partial density of the atmospheric oxygen, in order to collect real-time user´s feedback based on their health condition. The biometeorological data infrastructures are shown to be a useful tool to delineate individual vulnerability to meteorological factors and changes as one key factor in the definition of any biometeorological risk. This technological approach to study weather-related health impacts is the initial seed for the definition of biometeorological profiles of persons, and for the future development of customized climate services for users in the near future.

**S3.1**

*Overview of “climatological aspects of forecasting heat waves over Europe”*

**Christina Koppe (Deutscher Wetterdienst, Germany)**

Epidemiological analyses of historic heat events in Europe emphasize the importance of predicting heat waves and Heat Health Warning Systems (HHWS) have been implemented in several European countries to provide warnings/advices to minimize the detrimental health effects and mortal outcomes. Most HHWS rely only on weather forecasts to trigger the health warning, but the impact of heat stress on human health depends not only on climate factors, but also on individual factors such as physiology and behaviour as well as factors that modify the thermal environment on the micro scale (e.g. city structures, buildings). For this reason, it is challenging to quantify and forecast the local and individual impact of a heat wave. Existing HHWSs use different thresholds for triggering health warnings and they also vary the weighting of the meteorological parameters of relevance for heat-exchange with the environment i.e. air-temperature, humidity, radiation and wind-speed.

The challenge of an effective HHWS is to bridge the gap between the meso-scale meteorological forecasts and the highly variable impacts on the individual human being. In addition, with increasing lead-time of a weather-forecast its spatial and temporal accuracy is decreasing. As it is impossible to bridge this gap on the population level and to develop an all-purpose heat-wave forecast, the following questions should be answered before a HHWS is implemented:

What is the aim?

Who is the target?

How high are the acceptable level of uncertainty and the required level of accuracy?

What kind of intervention is triggered?

In this presentation, an overview will be given on the different methods for forecasting and downscaling heat events on different spatial and temporal scales. In addition, the advantages and disadvantages of the different approaches will be discussed.

**S3.2**

*Challenges in linking climate services and European-scale heat warnings*

**Christoph Spirig, Ana Casanueva, Sven Kotlarski, Jonas Bhend, Pascal Noti, Mark A. Liniger (Federal Office of Meteorology and Climatology MeteoSwiss, Switzerland)**

Robust meteorological heat predictions on different temporal scales are an important component of strategies to adapt to the increasing risk of heat stress caused by environmental heating. The development of specific long-term predictions and climate scenarios for health applications can profit from the currently emerging field of climate services.

Based on work carried out within the European HEAT-SHIELD project we here present two examples for linking climate services with European-scale heat stress and outline their specific challenges. First, a prototype system of a European early-warning system for heat stress episodes several weeks ahead based on operational forecast products of the European Centre for Medium-Range Weather Forecasts (ECMWF) is presented. Second, long-term heat stress changes over Europe are assessed based on state-of-the-art regional climate projections provided by the CORDEX initiative. Both examples consider the wet bulb globe temperature (WBGT) as primary heat stress indicator. It is shown that for both the early-warning system and for long-term projections, the availability of robust and accurate observational data on climatological time scales and different spatial scales is crucial. Weather forecast and climate model output, furthermore, is typically subject to systematic biases that partly arise from the scale gap between the atmospheric model grid and individual measurement sites and that need to be treated adequately before deriving specific heat stress indices. Solutions to tackle this challenge will be presented. Last but not least, modelling and prediction uncertainty can be large but can be quantified and be accounted for by ensemble analysis techniques. In the case of climate change projections uncertainties relating to future greenhouse gas emissions can furthermore strongly impact the results but can, again, be assessed by exploiting comprehensive model ensembles.

**S3.3**

*Physiological responses and human health aspects of heat stress*

**Glen P. Kenny (University of Ottawa, Canada)**

Heat stress can induce a substantial stress on the human thermoregulatory system and although healthy humans can tolerate extreme heat conditions for short periods, older adults and those with chronic disease may lack the physiological capacity to defend against potentially dangerous increases in core temperature. This presentation will provide an overview of the integrated physiological responses required to maintain core temperature during heat stress and discuss how aging and chronic medical conditions alters the body’s normal response to heat. Healthy humans are capable of surviving in extreme heat conditions for limited periods. To do this, the thermoregulatory system adjusts physiological mechanisms to adjust the rate of heat loss to the environment through increases in skin blood flow and sweating. However, physical inactivity, aging and chronic medical conditions can severely hamper this process by restricting the body’s ability to transfer heat from its core to the environment. Recent studies show that even relatively healthy physically active adults as young as 40 years have an impaired ability to increase heat loss. This thermoregulatory impairment is worsened in older adults (>60 years) especially in those individuals with low cardiorespiratory fitness. Decrements in skin blood flow and sweating are further compounded by chronic health conditions such as type 2 diabetes, obesity and chronic hypertension and are paralleled by substantial heat stress impacts on health and well-being. The medications required in the treatment of medical health conditions may cause dehydration, lower skin blood flow and reduced sweating which could consequently impair thermoregulation increasing the risk of a heat-related illness or death in the most vulnerable. Naturally (as occurs over the summer time) or artificially (experimentally activated) induced heat adaptation can provide an important thermoregulatory advantage during heat stress and may help protect health in heat vulnerable populations limiting heat-related morbidity and mortality.

**S3.4**

*Epidemiological analyses of environmental heat factors related to mortality*

**Andreas D. Flouris (University of Thessaly, Greece)**

The clinical importance of the physiology of thermoregulation is immense. The prime example for this is that an exodus of body temperature from its optimal range is so suggestive of a pathological condition that this variable is continuously monitored in all hospitalized patients and reported in every medical history, while the clinical thermometer is one of the most essential scientific instruments for the practice of medicine This presentation will provide an overview of environmental factors that have been related to mortality based on epidemiological data, with a particular focus on the impact of heat exposure. Epidemiological studies published to date suggest that extreme and even moderate heat are directly linked with rise of cardiovascular, cerebrovascular and respiratory mortality. Most heat-induced deaths are of cardiovascular origin, yet there is no increase of cardiovascular admissions during heatwaves. This has led to the conclusion that deaths from cardiovascular disease during heatwaves occur rapidly before the patient is admitted to a hospital and that the first hours of heat exposure have a major impact on cardiovascular mortality. Overall, heat-induced mortality is exacerbated with age as older individuals have a susceptibility to heat stress due to inadequate increases in skin blood flow and eccrine sweating in response to hyperthermia. Therefore, it is logical to anticipate that the combined effects of population aging and climate change will increase future heat-induced mortality. To address this vital public health issue, it is vital to develop criteria to identify and, ultimately, protect individuals who are more susceptible to heat stress, particularly those who are still part of the workforce and, thus, are physically active during periods of increased heat.

**S3.5**

*Impact of individual and integrated environmental heat stress factors on physical exercise performance*

**Lars Nybo1, George Havenith2 (1University of Copenhagen, Denmark, 2University of Loughborough, UK)**

Human heat balance is markedly challenged when elevated endogenous/metabolic heat production is combined with environmental heat stress. For a given individual at an identified acclimatization and metabolic state the impact of environmental heat stress relies on a combination of the absolute (dry) temperature, humidity, radiation and wind speed. This presentation will consider how the combination of environmental factors affects working performance and the thermoregulatory capacity. Each of the mentioned environmental factors may hamper human exercise capacity; however, meta-analyses of performance studies indicate that ambient temperature per se is a poor predictor of the integrated environmental heat stress and that two of the prevailing heat stress indices (WBGT and UTCI) fail to predict the environmental influence on performance. Thus, across a wide range of relevant heat stress conditions, the weighing of wind speed appears erroneous for predicting the impact of a given temperature, radiation and humidity level on acclimatized subjects. When the environmental air temperature surpasses that of the human skin (usually above ~35°C), it is true that increasing wind speed will increase heat gain by dry mechanisms. However, the negative effect on Newtonian heat-exchange seems to be fully outweighed by the facilitating effects on evaporative heat loss as long as the air humidity and hence environmental vapor pressure remain adequately lower than that of the wetted skin areas available for evaporative heat loss. The present analyses appear of importance both for appropriate heat warnings to working people and for advices on applying wind speed to benefit thermoregulation in a given occupational setting.

**S3.6**

*Clothing modulated heat stress in the context of climate change*

**Chuansi Gao (Lund University, Sweden)**

The increase in average global temperature and higher frequency of heat waves predicted by the majority of meteorological models will increase the effect of heat stress on human beings. For specifically addressing the impact of this environmental health risk on individuals, improved methods including individual factors such as clothing and metabolic rate are needed. This presentation gives an overview of the importance of protective clothing in relation to heat stress indices (WBGT, PHS, UTCI).

Human body heat production and heat dissipation must be balanced. The latter becomes difficult if environmental heat stress level is high. Clothing can protect against extreme heat and other hazards, but it resists also heat dissipation from the body to the environment. The efficacy of the above heat stress indices is limited due to insufficient integration of protective clothing and its interaction with climates. The magnitude of evaporative heat loss hampered by clothing is not constant in hot dry and hot humid environments. Thus, the heat stress modulated by clothing and its interaction with climate should be integrated into any comprehensive heat stress assessment in the context of climate change.

Current WBGT index assumes ordinary one-layer work clothing. Clothing adjustment factor is being introduced to WBGT index. However, a constant clothing adjustment factor may not work for both hot dry and hot humid climates. PHS index does not apply to clothing insulation higher than 1.0 clo. UTCI is limited in its assessment to a fixed moderate metabolic rate and typical clothing for urban populations. On the warm side at air temperature about 32 to 40°C, the basic leisure clothing insulation is only modelled to be constant at about 0.3 clo. Therefore, the UTCI suffers similar limitations as WBGT and PHS indices for the assessment of heat stress when wearing protective clothing.

**S3.7**

*Heat-health warning systems: integrating physiological knowledge and climate information into operational advices for occupational purposes*

**Marco Morabito1, Alfonso Crisci1, Alessandro Messeri2, Simone Orlandini2 (1Institute of Biometeorology, Italy, 2University of Florence, Italy)**

All European countries have climate services providing forecasts on upcoming weather scenarios and cross-national collaboration improves the ability to predict forthcoming heat events with high spatial resolution. Many European countries have developed their own heat-health warning systems referring to the general population or specifically targeting heat-vulnerable citizens such as elderly. However, systematic translation of effective information to the individual level is lacking and we should consider the personalized physiological characteristics e.g. endogenous heat production and individual heat dissipation capacity. Heat stress in workers is of special interest and importance because they are frequently engaged in intense physical activities combined with exposure to sunlight or industrial heat and sometimes required to wear specific clothing that limits perspiration. To target this issue, the “Heat-Shield” project will develop a heat warning system to anticipate threats to worker’s health and disseminate adaptation measures. An effective occupational heat warning system should consider the complex set of meteorological conditions that affect heat-discomfort in shaded and sunny outdoor conditions and their relationships with health events and the physiology of workers engaged in various occupational activities. The Wet Bulb Globe Temperature (WBGT) represents a thermal indicator originally developed for military activities and subsequently widely applied for occupational purposes with modified WBGT thresholds. In particular, WBGT thresholds have been adapted depending on physiological and behavioural occupational conditions, such as the workload, clothing and acclimatization status of the workers will be considered in the evaluation. Based on these conditions, specific preventive measures, such as work/rest schedule timing and hydration recommendations will be provided. In addition, it is increasingly necessary to acquire more and more detailed physiological information obtained by monitoring conducted directly in the workplace in order to implement the Heat-Shield heat warning system to improve the further translation/down-scaling to the individual occupational level.

**S3.8**

*Climate Change and Working Life: Linking Stakeholders for Risk Assessment and Management*

**Tord Kjellstrom1,2, Lucka Kajfez-Bogatat (1Centre for Technology Research and Innovation CETRI, Cyprus, 2Australian National University, Australia, 3University of Ljubljana, Slovenia)**

All models of ongoing and future climate change indicate an increasing global temperature and hotter environments in most of the world. This will have profound effects on working life for many million people as their work becomes affected by heat stress. The physiological science concerning heat stress impacts has been well understood for many decades, and protection of workers health and labour productivity is already a key issue in many countries.

An emerging priority is to apply scientific methods in physiology, epidemiology, occupational health, and climatology to assess the future trends of the health and productivity risks. Scientists in these disciplines and biometeorology are major stakeholders in developing risk assessments - the basis for effective risk management. The stakeholders in risk management include enterprises and workers likely to be affected by heat stress now and/or in the future, as well as the communities and their leaders involved in decision-making concerning prevention, including climate change mitigation. The HEAT-SHIELD project will develop advisory materials and heat warning systems for local use and regional and national assessments of value for government policies. Interactive web-based map systems will serve as communication tools and will encourage and facilitate inter-sectoral links.

In Europe, several programs in the European Commission can link to our work. This includes these offices: Agriculture and Rural Development (AGRI), Climate Action (CLIMA), Employment, Social Affairs and Inclusion (EMPL), Energy (ENER), and Environment (ENV). The other group include Eurostat (ESTAT), Health and Food Safety (SANTE), Mobility and Transport (MOVE), Regional and urban Policy (REGIO), JRC, EEA, EU-OSHA, European Employment Services (EURES) and European Committee for Standardization (CEN). This report at ICB2017 will present examples of the progress to date of the HEAT-SHIELD project stakeholder interactions, and will seek new cooperation opportunities with occupational epidemiologists.

**21st International Congress of Biometeorology**

**Abstracts – Poster Presentations**

**P1**

*The effect of vitamin E, L-carnitine and ginger in reversing heat stressed induced damage to antioxidant status and immune response in two broiler strains*

**Zia ur Rehman, Naila Chand, Rifat Ullah Khan (The University of Agriculture, Pakistan)**

The present study was designed to find the effect of natural and synthetic antioxidants on the performance of two broiler strains under high ambient temperature. A total of three hundred and twenty day-old chicks of Hubbard and Cobb were reared for a period for 21 days under the same nutritional and management system. On day 21 onward, one subgroup was kept as control while other sub groups were provided with vitamin E (250 mg/kg), ginger (2%) and L- carnitine (500 mg/kg) in basal diets. On day 28, 35 and 42 significantly (P<0.05) high antibody titre was recorded only in vitamin E supplemented group. Significantly (P<0.05) higher T3 and T4 values were recorded in vitamin E supplemented group on day 21, 28, 35 and 42 compared to control and other treatments. No significant (P>0.05) difference was found in the hormone concentration during on day 35 and 42. On day 21 and 35, serum MDA level of ginger fed group was similar to vitamin E supplemented group. The supplementation of vitamin E at the rate of 250 mg/kg improved the antioxidant status and immune response in the two broiler strains.

**P2**

*Physiological responses and adaptive characters in**Bonsmara-Hereford crosses vs. Hereford purebred on environment stress.*

**Paula Batista, Ana Espasandin, Celmira Saravia (University of Republic, Uruguay)**

In a grazing system, in Northwest Uruguay, in contemporary heifer yearling crosses Bonsmara-Hereford (BH, n=15) and Hereford pure (HH, n=18), adaptive traits were measured: respiratory rate (RR) and rectal temperature (RT), in summer at 08 (AM) and 16 hours (PM); morphological features (coat in summer and winter, and histology of the skin in spring), production (body weight (BW) and absolute weight gain (AWG)) and body condition score (BCS). The environment was characterized with Temperature and Humidity Index (THI) adjusted by wind speed and radiation (THIadjust), heat waves (HW) (mild-MHW and without heat waves-WHW) and Comprehensive Climate Index (CCI) levels.

In summer BW was 307±35 kg in BH and 301±23 kg in HH. In winter BW was 329±47 kg in BH and 309±26 kg in HH. In AWG, genotypes were not different, but was in BCS, BH was higher than HH (p=0.02).

In AM, HH was higher than BH in RR during moderate (p=0.05) and severe stress (p=0,029) and RT in mild stress (p=0.02) and severe (p=0.03) as CCI.

In PM, HH was higher in RR during MHW (p=0.0007) and at all levels of CCI (p<0.0001), and RT in MHW (p=0.0003), moderate stress (p=0,001) and severe (p<0.0001).

BH presented shorter summer coat than HH (p=0,004) and also in winter coat (p=0,014), with no difference in the weight of the hair.

No differences in density of sweat glands (SG) (p=0.5) and hair follicles (p=0.5), SG epithelial height (p=0.6), apical depth (p=0.5) and baseline (p=0.3) of adenomere SG, was a trend (p=0.07) in greater area of SG in HH.

BH has increased tolerance to hot weather with less RR and RT than HH, shorter coat and better performance in LW and BC. Not differences in histology skin explained for genotype and moment of extraction of the sample.

**P3**

*Assessment of thermal comfort around sotetsubate “field with cycas hedge” in Amami-Ohshima, Japan*

**Jin Ishii1, Tsuyoshi Hashimoto2, Shinichi Watanabe3, Kosuke Kurihara2, Ayu Tachikawa2 (1Meijo University, Japan, 2University of Tsukuba, Japan, 3Daido University, Japan)**

In Amami-Ohshima Island Japan, the fields along the beach are surrounded by cycas (*Cycas revoluta*) hedge, in order to protect crops from sea breeze and seawater. This field is called *sotetsubate*, which means “field with cycas hedge.” *Sotetsubate* has created as a locality-specific cultural landscape. Bioclimatic conditions around the field with cycas hedge may change drastically. Although the changes of thermal comfort will occur as a consequence of the changes of the bioclimatic conditions, there are few biometeorological researches working cycas hedge and thermal comfort. For instance, there will be the strong sun and the sea breeze at the beach along the field, where thermal discomfort may be increased by the radiation or be mitigated by the wind. In the field with cycas hedge next to the beach, the sea breeze will weaken, which may increase thermal discomfort. In the meanwhile, the cycas will afford sun shade, which may reduce thermal discomfort. There will be harsh bioclimatic conditions at the roadside near the field, because the sun is strong and the wind is moderate. The purpose of this study is to assess the thermal comfort relevant to the bioclimatic condition around the field with cycas hedge or the so called *sotetsubate*. Measurements were carried out on September 7 in 2016 at 5 points, where there is a beach next to a field with cycas a hedge, shaded and sunlit spots in the field and a roadside near the field. As bioclimatic conditions, air temperature, humidity, wind velocity and solar and long wave radiation were measured and the UTCI was calculated for these bioclimatic conditions. The lowest UTCI was recorded at the shaded spot in the field with cycas hedge. When the sea breeze blew, UTCI at the beach was lower than that at the sunlit location in the field and thermal discomfort at the roadside was mitigated.

**P4**

*The Impact of Environmental Risk Factors on Cardiovascular and Respiratory Mortality over Multiple Decades – Orange County, California (1975-2005)*

**F. L. T. Gonçalves1, S. L. Pinheiro2, J. R. Gonzales1, S. C. Sheridan3 (1University of São Paulo, Brazil, 2FIOCRUZ, Brazil, 3Kent State University, USA)**

This study aims to evaluate the influence of environmental variables on cardiovascular (CVD) and respiratory (RES) diseases in Orange County, California during the period 1980-2004. As well as establishing a thermal comfort index, this study uses statistical modelling through principal component analysis (PCA). Daily data from the County’s meteorological stations (temperature, pressure, humidity and wind speed), as well as air pollution (NO2, CO, SO2 and O3) data and mortality from respiratory and cardiovascular diseases were used. The first analyses have shown a tendency to increase RES and decrease CVD mortality rates, as well as a significant seasonal variation, with a clear increase in the number of deaths during winter and decrease during the summer. Considering the different types of thermal sensations, based on the Effective Temperature index, most RES and CVD diseases occur when the sensation is Cold, followed by Moderate Cold and Lightly cold. However, based on the Effective Temperature index as a function of the wind, most of the RES and CVD diseases occur when the thermal sensation is Very Cold. The PCA for RES diseases showed high positive weights in factor 1 for meteorological variables (air temperature, dew point temperature and specific humidity). Although the value of RES diseases is not statistically significant, it is believed that a decrease in temperature and humidity and an increase in pressure (continental polar conditions, which are characterized by being cold and dry) favour RES. However, for CVD, it was observed that factor 2 presented high positive weights for the pollutants, based on this factor (except O3), it is believed that an increase in the concentration of pollutants may lead to an increase in mortality by CVD. This is a first analysis performed and heat waves during summertime will be the next goal in order to compare with other regions.

**P5**

*Carbon dioxide fertilization offsets negative impacts of climate change on Arabica coffee yield in Brazil*

**Fabian Y. F. Verhage1, Paulo C. Sentelhas2, Niels P.R. Anten1 (1Wageningen University, Netherlands, 2University of São Paulo, Brazil)**

Arabica coffee production provides a livelihood to millions of people worldwide. Climate change impact studies consistently project a drastic decrease of Arabica yields in current production regions by 2050. However, none of these studies incorporated the beneficial effects that elevated CO2 concentrations are found to have on Arabica coffee yields, the so-called CO2 fertilization effect. To assess the impacts of climate change and elevated CO2 concentrations on the cultivation of Arabica coffee in Brazil, a coffee yield simulation model was extended with a CO2 fertilization and irrigation factor. The model was calibrated and validated with yield data from 1989 to 2013 of 42 municipalities in Brazil, and found to perform satisfactorily in both the calibration (R2 = 0.91, d = 0.96, MAPE = 8.58%) and validation phase (R2 = 0.96, d = 0.95, MAPE = 11.16%). The model was run for the 42 municipalities from 1980 to 2010 with interpolated climate data, and from 2040 to 2070 with climate data projected by five global circulation models according to the RCP 4.5 scenario. The model projects that yield losses due to high air temperatures and water deficit will increase, while losses due to frost will decrease. Nevertheless, extra losses are offset by the CO2 fertilization effect, resulting in a net increase of the average Brazilian Arabica coffee yield of 0.8% to 1.48 t ha-1 in 2040-2070, assuming growing locations and irrigation use remain the same. Simulations further indicate that future yields can reach up to 1.81 t ha-1 if irrigation use is expended.

**P6**

*Comparison of the suitability of thermal comfort for different types of farrowing house*

**Priscilla Ayleen Bustos Mac Lean, Douglas D’Alessandro Salgado, Isabela Garcia Mendes de Araújo, Vinicius Bonomo Valderramas, Fernanda Andrucioli, Tainara Ribeiro Parreira, Cristina Oliveira (São Paulo State University, Brazil)**

The environment for piglets in the first days of life is a challenge, especially as to the practices to keep the microclimate inside the farrowing house. The experiment evaluated the thermal compliance of the microenvironment of farrowing of different materials compared to the records of thermal comfort recommended by the literature. The experiment was carried out in Tupa, Brazil, for 21 days between January and February 2017, in a commercial farm. Dataloggers HOBO (Onset®, model U12-012) were installed, recording the temperature every 30 in four farrowing houses of 1.0x0.5x0.6 m, with resistors of 170W, two of polyethylene (POL1; POL2) and two of masonry (MAS1; MAS2). Temperature records were classified according to the recommended limits for thermal comfort zone (TCZ), lower critical temperature (LCT) and higher critical temperature (HCT), for the initial three weeks of breeding. A Qui-Square test for homogeneity of nonconformity was performed using the Minitab®17. None of the farrowing house had minimally met the recommended temperatures within the TCZ, with 78.87% of temperature records remaining outside this area. Most of the nonconforming records were in the temperature range between the upper limit of the TCZ and the HCI (66.49%). MAS1 and MAS2 presented a more uniform pattern of temperature, in contrast POL1 and POL2 presented extremely different results from one another (P<0,001) by the classification of suitability of thermal comfort. POL2 presented a more aggravating nonconformity among all, with 1.19% of the registries above the HCI and a total of 80.56% of nonconformity. Only 21.13% of the temperature records are within the TCZ for the two farrowing house. All the evaluated farrowing houses presented disagreement as to the classification of the temperature. The cement farrowing is more homogeneous among them, whereas the ones of polyethylene have strong variability, being more subject the variations of the temperature of the maternity.

**P7**

*Cutaneous evaporation of hostein cows exposed to solar radiation*

**Patric André Castro1, Alex Sandro Campos Maia1, Vinícius de França Carvalho Fonsêca1, Gustavo André Bernado Moura1, Sérgio Faustini Campos1, Marcelo Simão da Rosa2, Charles Henrique Ribeiro2 (1Sao Paulo State University, Brazil, 1Federal Institute of South of Minas, Brazil)**

At high temperatures, surface evaporative cooling is the dominant mode of heat loss in dairy cattle; this mechanism is affected by wind velocity, air temperature, humidity and solar radiation. This work aimed to study cutaneous evaporation (q”es) of Holstein cows exposed to solar radiation in a tropical condition. The work was carried out at the Federal Institute of South of Minas Gerais (Lat. 21º S; Long. 46º W; 1048 m altitude). Twelve Holstein cows were assigned in a four 6 x 6 Latin Square design. Animals were assessed exposed to solar radiation from 07:00 to 19:00h during twelve consecutive days. The q”es was determined with a ventilated capsule from body surface saturation pressure (Pcap {TEP}) and vapour pressure of ambient (Patm {Tair}). A pump was connected to the tube leaving the capsule; this equipment pulled the air through the influx tube, into the capsule, over the animal’s body surface and out into the vapour analyser. Skin temperature was recorded using a thermistor (range = 0 - 45°C; accuracy = ± 0.3°C). Air temperature (TA, °C), and the solar radiation (RS, W m-2; λ = 200 – 3600 nm), corresponding to the direct and diffuse short-wave were measured in one-minute intervals by a portable weather station (Model – 110 Nova Lynx). Levels of solar radiation were defined as a fixed effect in the statistical analyses. Preliminary results showed that skin temperature ranged from 32 to 42°C and cutaneous evaporation from 49 to 348 W m-2 respectively. These traits were positively correlated (r = 0.32; P = 0.0001). When solar radiation was lower than 300 W m-2, q”es was 199 ± 0.37; on the other hand, reached 305 ± 0.30 W m-2 when levels of RS was higher than 600 W m-2.

**P8**

*UTCI as a prediction tool for heatwave-induced health hazards in Europe*

**Claudia Di Napoli1, Anna Mueller-Quintino2, Florian Pappenberger2, Hannah L. Cloke1 (1University of Reading, UK, 2European Centre for Medium-Range Weather Forecasts, UK)**

In recent years the increased frequency and intensity of severe and prolonged episodes of summer heat (e.g., the 2003 European heatwave and the 2010 Russian heatwave) proved that hot temperatures are responsible for excessed mortality in affected areas and Heat Health Warning Systems (HHWSs) need to be put in place in order to mitigate negative health outcomes associated with hot weather extremes.

A heatwave-associated HHSW is being developed as part of the multi-hazard early warning system constructed at the pan-European scale within the HORIZON2020 project ANYWHERE (EnhANcing emergencY management and response to extreme WeatHER and climate Events). The ANYWHERE HHSW is based on the operational computation of the UTCI-Fiala model to predict the Universal Thermal Climate Index (UTCI), an equivalent temperature representing the thermal stress induced by the atmospheric environment on the human body.

A feasibility study has recently demonstrated the utility of forecasting UTCI to assess health hazards on a global scale up to 10 days in advance using the ECMWF ensemble forecast system as input to the UTCI-Fiala model [1]. With the ANYWHERE HHSW we have implemented a similar approach to explore UTCI forecasts as a medium-range health warning tool for extreme hot temperatures over Europe. Here we present the thermal stress levels predicted by UTCI-Fiala model for representative heatwave case studies. We also discuss about the results as a potential source of advice for decision makers in the heat-health field.

[1] Pappenberger F. et al., *Int. J. Biometeorol.* **59**(3): 311-323, 2015

**P9**

*Numerical modelling of weather conditions during the wildfires*

**Visnja Vucetic1, Branimir Omazic2 (1Meteorological and Hydrological Service, Croatia, 2N1 Television, Croatia)**

In Croatia, forests cover 44% of the area, and the mean annual burned area is about 10,000 ha mainly on the Adriatic coast and islands. For early warning of fire brigades, it is important to know the weather situation that precedes the wildfires. Two large wildfires were intentionally caused on the peninsula of Peljesac on the southern Croatian coast on 20/21 July 2015 at night and were completely extinguished in mid-August. The aim of this study is to research weather conditions and vertical structure of atmosphere that led to the start of the wildfires using meteorological data and the ALADIN/HR numerical simulation model. Very dry and hot weather (25 days without rain and seven consecutive days with maximum daily air temperature above 34°C) preceded the fires. The absolute maximum temperature of 38.8°C on the peninsula of Peljesac was measured in the first day of the fire, and the next night minimum daily temperature was 30°C. During the wildfires, slightly lower air pressure prevailed on the southern Adriatic, the warm air was up to 850 hPa and relative humidity was around 40% during the day. A few hours before the fires wind gusts reached 12 m/s. Canadian forest fire weather index (FWI) showed high risk of wildfire until 2 August 2015 and initial spread index (ISI) indicated the worst possible forest fires - fire crown. The ALADIN/HR model predicted weak wind up to 5 m/s, decreasing air temperatures with height and almost neutral air stratification in the lower troposphere during the fire. The rapid spread of the fire, which affected in a short time a large part of the peninsula, favoured very dry dead fuel material of the Mediterranean vegetation and quick lifting of hot air accelerated on very steep terrain.

**P10**

*Comparison of the 2003 and 2015 heat waves in South-West Germany – Meteorological situation, boundary conditions, and health impacts*

**Stefan Muthers, Andreas Matzarakis (Deutscher Wetterdienst, Germany)**

In early July 2015, a severe heat wave hit Central Europe. Extraordinary high daytime temperatures were observed at several stations from London to Berlin. With a summer mean surface air temperature anomaly of 3.65°C the summer was comparable to the hot summers of 2003 and 2010 (3.63°C and 3.68°C standard deviation, respectively, according to Dong et al., 2016 BAMS). When focusing on the health impact of the 2015 heat wave, a prominent increase of the daily mortality rates is found for South-West Germany (Baden-Württemberg, population ~10.9 Mio). Although the increases in the daily mortality rates are not as pronounced as for the August 2003 heat wave, 2015 can be characterized as the second most severe heat wave of the period 1968 to 2015.

In this work, we compare the two heat waves according to their meteorological pre-conditions, their timing, duration, and extend as well as their health impacts.

**P11**

*Study of relations between the Emergency Medical Service data and selected weather and bioweather factors in Ústí nad Labem area*

**Martin Novák (Czech Hydrometeorological Institute, Czech Republic)**

A time-series of the acute cases of the Emergency Medical Service (EMS) is the subject of this study. Medical data were constituted by daily records of the EMS of the Ústecký Region, in the concrete from EMS base in Ústí nad Labem (it is the city in northern Bohemia, Czech Republic). The area with circa 130 thousand citizens is covered by this EMS base.

Time series analysis was applied to this medical time series then these data were compared with the time-series of selected meteorological and biometeorological factors from the same period (2009-2016). The medical data were also compared with daily mean concentrations of suspend particles PM10 (for cold season) and with daily maximal concentrations of the tropospheric ozone (for warm season). Finally, complete time-series of medical data was compared with a time-series of the bioweather forecasts (BWF) issued for the same area. The analyses were executed for two different medical datasets – overall daily data of all patients and reduced daily data series of the elderly (65+).

The aim of this study is to help with an improvement of current version of the BWF model. These forecasts have been issued by the Czech Hydrometeorological Institute (CHMI) since 1993. The current model is based on the list of selected meteorological factors with assigned weights. A sum of weights determines a final forecasted stress level (the CHMI BWF has a scale with three levels: 1 – mild stress, 2 – intermediate stress, 3 – high stress).

Some other elements (except inputs of current BWF model) were used for this poster – the inter-diurnal change of the daily mean air temperatures, the apparent temperature, concentrations of selected measured air pollutants. The presented results are parts of more extensive study which is currently processed at the Regional Branch of CHMI in Ústí nad Labem.

**P12**

*Heat stroke risk for aging society in Japan – a case study of Saitama City from 2006 to 2016*

**Fujino Takeshi, Sunuwar Dipendra (Saitama University, Japan)**

In Japan, the incidents of hundreds of victims from indoor heat stress is being reported. The risk of heat stress happening indoor being based upon data of Saitama city and data from 2006 to 2016, for May to August, was evaluated using air temperature and humidity effect as a measurement index. By calculating the Apparent Temperature (AT), defined by Steadman (1984), the heat stroke risk is calculated using the data collected from the Japan Meteorological Agency and Fire and Disaster Bureau. We neglected factors like wind effect and other social conditions like clothing, family status etc. The accumulated figure of AT for 12, 24, 36, 48, 60 and 72 hours were calculated and the events of indoor heat stroke victims was evaluated. Results showed that the heat stroke evaluation from accumulated AT would be more precise and definite than considering the daily maximum temperature as the odds of heat stroke at 72 hours accumulated AT was above 2,100°C, was greater than odds of heat stroke occurring at daily temperature above 32°C. And in terms of demographics, age and gender, the odds of male victims are greater by 2 times compared to females, and the proportion of victims aged more than 65 years old was higher than 50% in the 11-year study period. A specific model based on this data analysis is yet to be created and still cannot be considered as perfectly precise for analysis and forecasting. Along with increasing global warming and an aging society in Japan, problems related to heat stress have also been increasing.

**P13**

*Extreme heat events associated to respiratory diseases in children up to 10 years old in São Paulo city*

**Sara Lopes de Moraes, Emerson Galvani (University of São Paulo, Brazil)**

Climate change in urban areas has intensified the extreme heat events over the years, therefore it is essential to understand who is vulnerable to these events and how they act. Bearing that in mind, this study investigated the association between hospital admissions for respiratory diseases in children up to 10 years old and meteorological variables (air temperature, relative humidity and rainfall), Effective Temperature Index – ET, air pollution - PM10 (particulate matter with aerodynamic diameters less than 10 μm). To identify this association, we used the statistical method GLM - log-linear with negative binomial distribution. The respiratory daily admissions data (ICD-10: J00-J06, J09-J18, J20-J22, J30- J32 and J40-J47) were provided by the Brazilian Health Informatics Department (DATASUS) for 14 districts of São Paulo city, Brazil, from 2003 until 2013. We identified the year of 2005 as one of extreme heat (especially in fall and winter) based on the mean and standard deviation during the analysis period. The results showed that in 2005 the increase of 1ºC of the daily mean air temperature reduced the admissions of children up to 10 years old with 27.2% (IC 95% = 0.529; 0.997). The increasing hospitalizations were related to rainfall (IC 95%: 0.963;0.997), relative humidity (IC 95%: 0.963;0.997) and to the ET (IC 95%: 1.093;2.219). There is the need to approach more extreme events and associate them with the vulnerability of the society and of respiratory diseases deflagration.

**P14**

Estimation of fatigue by air temperature increase and reduction by air conditioners in Jakarta, Indonesia

**Tomohiko Ihara, Ren Kusama (The University of Tokyo, Japan)**

Background: Global warming has increased air temperature in the world. At the same time, urbanization has proceeded and the urban population rate exceeded 50% in 2011. Such urbanization is posing another air temperature increase called the urban heat island. Present and future global warming and the urban heat island are expected to pose human health problems, particularly, in mega cities in low-latitude developing countries. However, mild heat-related disorders by air temperature increase, which are not described in statistics but are considered to have large impacts on society, have not been estimated there. Adaptation measures for increasing air temperature to avoid the impacts of heat have also not been studied.

Objective: We quantify fatigue by air temperature increase, which is one of mild heat-related disorders, in Jakarta, Indonesia, which has the second largest urban area population in the world. Furthermore, we evaluate the fatigue reduction effect by air conditioners as an adaptation strategy.

Method: We conducted an epidemiological survey for three consecutive weeks for adults living in Jakarta. A questionnaire used in our survey is composed of respondent’s sex and age, Chalder fatigue scale for the past one week and previous day, and the use of air conditioners. We analyse the survey result with daily maximum air temperature using smoothing spline regression to obtain fatigue damage functions without and with air conditioning.

Results and Discussion: The number of respondents were 263 and 264 in February and October 2016, respectively. Analysis of the survey results indicated that a fatigue damage function without air conditioning is V-shaped and its optimum temperature is about 31 degrees Celsius while a function with air conditioning is monotonic and decreasing. Based on these functions, rise in the rate of air conditioner use from the current 50% to 90% was calculated to reduce fatigue by 7.6%. This fatigue reduction was evaluated to result in a reduction in 2,870 DALYs per year.

**P15**

*Calculating disability-adjusted life years (DALYs) for heat related illnesses due to urban heat island in Japan*

**Yuki Hashimoto, Tomohiko Ihara (The University of Tokyo, Japan)**

Background: Urban air temperature is higher than rural air temperature due to urbanization. High air temperature makes increasing heat related illnesses (HRIs) (e.g. circulatory disease, respiratory disease, and heat stroke). Many studies have evaluated HRIs due to global warming (GW). Few studies, however, have assessed HRIs due to urban heat island (UHI). The disability-adjusted life year (DALY) is one of the most appropriate methods for assessment of HRIs because of comparability among various diseases.

Objective: The aim of this study is to calculate and evaluate DALYs for HRIs due to UHI in Japan based on Japanese public statistics of deaths from 2000 to 2014.

Method: We calculate optimum temperature (OT) which is air temperature at which mortality is the minimum using smoothing spline regression, and regard deaths when air temperature is OT and more as HRIs. HRI of GW is distinguished from that of UHI from difference between urban mortality and rural mortality, because urban area is affected by GW and UHI whereas rural area is affected by GW only. We define twelve major cities whose populations are over one million as urban areas and fifteen less urbanized cities and towns as rural areas. DALY is equal to the sum of the years of life lost (YLL) because the years lost due to disability (YLD) is negligibly smaller than YLL. We calculate YLL for HRIs using estimation of mortality.

Results & Discussion:We calculated OT for HRIs whose fifty years and more was 29.0 ºC though that of almost young age was not detected. The obtained OT was used for calculating HRIs of urban and rural areas and evaluating HRIs by UHI. Furthermore, HRI’s DALYs were estimated based on life expectancy for each illness. We discussed our calculated DALYs compared with previous studies.

**P16**

*The Climate Perception of Men and Women and Thermal Comfort in Santa Maria – RS*

**João Paulo Assis Gobo, Emerson Galvani, Fabio Luiz Teixeira Goncalves (Universidade de São Paulo, Brazil)**

This study is based on climate perception of men and women in Santa Maria-RS, through climate data analysis and field experiments. Therefore, primary meteorological data, obtained from mobile weather station in downtown, were used, as well as meteorological data from the meteorological station of Santa Maria (INMET). Field Experiments through interviews were also carried out with the local population, in order to get the perception responses of pedestrians circulating in the urban environment. There significant differences between the responses obtained of climate perception of men and women, where women have shown a greater discomfort than men (7,2%). There was also a pattern of direct relationship between the votes of climate/weather perception, both men and women, regarding the result of human thermal comfort indices for the period studied.

**P17**

*Changing Rainfall Regime and its Implications for Human Comfort in Sokoto State, Nigeria (1926 – 2015)*

**Umar Aliyu Tambuwal, Aliyu Ismaila (Usmanu Danfodiyo University, Nigeria)**

The literature on bioclimatology in the West African Sahel is replete with discussions on the impact of extreme weather events on human comfort with emphasis on extreme temperature anomalies resulting from the catastrophic droughts of the late 1970s and 1980s which ravaged the region, with the almost exclusion of the effects of the changing rainfall regime on human welfare. This paper attempts to bridge this gap by examining the changing rainfall regime and its implications for human comfort in Sokoto State, Nigeria, using monthly rainfall data spanning ninety years (1926-2015). The period was divided into three slices viz: 1926-1955, 1956-1985 and 1986-2015 for comparative purposes. Monthly rainfall data obtained from Nigerian Meteorological Agency (NiMet) were subjected to Kendall *tau* Statistic, Rainfall Seasonality Index (RSI) and Rainfall Anomaly Index (RAI) for analyses. The result showed an upward trend in monthly maximum rainfall totals during all the slices, though not statistically significant. The rainfall regime has changed from being ‘most rains in 3 months or less’ to being ‘markedly seasonal with a long dry season’.The monthly rainfall anomaly pattern revealed a marked increase in rainfall during the period of relative rainfall maximum (August) for all slices except 1956-1985 and pronounced decrease during the period of relative rainfall minimum (May-June) for all slices except 1986-2015. The changing rainfall regime as well as pronounced decrease in rainfall during the period of relative rainfall minimum could have serious implications for human welfare in the region. It is recommended that seasonal rainfall prediction model be developed to accurately predict rainfall anomalies for health planning in the region.

**P18**

*Definition of climatic classification method based in thermal human comfort*

**Carlos Javier Esparza López, Jorge Armando Ojeda Sánchez, Carlos Escobar del Pozo, Adolfo Gómez Amador (University of Colima, México)**

The global climatic classifications that are commonly accepted were based ON agronomics purposes. The climatic conditions pointed in this classifications as Köppen, not necessary reflects what human feels through days, weeks or months. In this study, a method for classifying the climate based in human comfort is presented. The variables used to identify human comfort are dry bulb temperature and relative humidity. These are the main variables to determine the inside buildings conditions for the human being. The time lapse is a major factor to consider for the weather chart due the variations of temperature and RH. The proposal method was tried for the southwest states of Mexico using dry bulb temperatures given by the National Meteorological System. Hourly temperature for each representative day of each moth was calculated from maximum and minimum temperatures. An effect was found named “the blanket effect” that modifies the status of every city to be in the cold. A correction step was rehearsed with good agreement with reality. Nine basic states for weather conditions were settled up: comfort, hot, cold, humid, dry, hot dry, hot humid, cold humid and cold dry. Also, a correlation coefficient of r=-0.925 was found between thermal swing and mean RH for 96 cities over all the country. Finally, a validation step with 6 cities in three climatic classifications commonly accepted was tried applying the blanket effect correction showing good agreement with social perception of the environment.

**P19**

*Climate change impact on ecosystems at the East edge of European Russia*

**Oleg Askeyev, Arthur Askeyev, Igor Askeyev (Tatarstan Academy of Sciences, Russia)**

Since the 1960s, the climate in eastern edge of Europe has undergone rapid change. Annual, summer, winter temperature trends remain strongly positive. In this region of Russia, climate change was more rapid than in other parts of Europe even in close zones to Gulf Stream. For example, summer (May-August) temperature in East England significant increase equating to 1.6°C over 55 years, whereas in Kazan region of Tatarstan republic increase equating to 2.4°C. These climates change, seriously impact to phenological events, animal and plant population dynamic. For example, practically all early arrival birds and early flowering plant has significant trend on early arrival and flowering. Sedentary bird species has significant positive trend on numbers dynamic. And these trends in east edge of Europe are more pronounced than in West Europe, particularly in last 20 years. Prolongation of changes in the dates of the appearance of permanent snow cover at a later date, warm winters, early spring, very hot summer periods determine major changes in ecosystems in the extreme East of Europe. These changes have a serious impact on agriculture, forestry and water and fisheries management. On the whole, the impact of the changing climate in the study area remains more positive. But careful monitoring of the processes is necessary, so as not to miss the moment when the impact of climate change will become irreversibly negative.

**P20**

*Variability of Climatic Elements in Nigeria over Recent 100 Years*

**T. Salami1, O.S. Idowu1, N.J. Bello2 (1Nigerian Meteorological Agency, Nigeria, 2University of Agriculture, Nigeria)**

Climatic variability is essential issue when dealing with the issue of climate change. Variability of some climate parameter helps to determine how variable the climatic condition of a region will behave. The most important of these climatic variables which help to determine climatic condition in an area are both the Temperature and Precipitation.

This research deals with Long term climatic variability in Nigeria. Variables examined in this analysis include near-surface temperature, near surface minimum temperature, maximum temperature, relative humidity, vapour pressure, precipitation, wet-day frequency and cloud cover using data ranging between 1901-2010. Analyses were carried out and the following methods were used: - Regression and EOF analysis.

Results show that the annual average, minimum and maximum near-surface temperature all gradually increases from 1901 to 2010. And they are in the same case in wet season and dry season. Minimum near-surface temperature, with its linear trends are significant for annual, wet season and dry season means. However, the diurnal temperature range decreases in the recent 100 years, implies that the minimum near-surface temperature has increased more than the maximum. Both precipitation and wet day frequency decline from the analysis, demonstrating that Nigeria has become dryer than before by the way of rainfall. Temperature and precipitation variability has become very high during these periods especially in the Northern areas. Areas which had excessive rainfall were confronted with flooding and other related issues while area that had less precipitation were all confronted with drought. More practical issues will be presented.

**P21**

*Impacts of recent climate change on meteorological wildfire danger in the Czech Republic*

**Martin Mozny, Lenka Hajkova, Tomas Vrablik (Czech Hydrometeorological Institute, Czech Republic)**

Climate strongly influences the danger and probability of wildfires. We analysed the monthly and seasonal fire weather index, drought and number days with high and very high fire risk calculated on the daily meteorological data from 110 stations in the Czech Republic in the 1961–2015 period. Within this period a statistically significant relationship was found between the mean number days with high and very high fire risk and the number of wildfires. Our results showed the different impacts of climate change to wildfire risk in the Czech regions. In the summer, half-year (April to September) 54% stations had a statistically significant positive trend of the standardised precipitation evapotranspiration index and 43% of stations for the fire weather index. Increased risk of drought and wildfire danger was recorded at most of the stations, with an altitude below 350 m. In these areas; it was detected the largest increase of wildfires, especially in the wildland-urban interface. For example, in the extremely hot and dry summer of 2015, there were recorded more than 100 fires every day. The highest increase of fire danger index was recorded in April, May, July and August. The rising number of homes in the wildland-urban interface, associated impacts on lives and property from wildfire, and escalating costs of wildfire management have led to an urgent need to prepare adaptation strategy. The meteorological support for fire protection and planning is also important. Czech Hydrometeorological Institute operates the fire danger warning system aims at alerting the public to conditions in which fires may start and spread easily. As per the climate projections for the 21st century, it is likely to expect more wildfire dangers in the future.

**P22**

*Vine and hops as indicators of climate change in the Czech Republic*

**Martin Mozny1, Lenka Hajkova1, Lenka Bartosova2,3, Miroslav Trnka2,3 (1Czech Hydrometeorological Institute, Czech Republic, 2Global Change Research Institute AS CR, Czech Republic, 3Mendel University in Brno, Czech Republic)**

Climate change is a major challenge for growing grapes and hops. Statistical data suggest that the production of the hops and grapes is particularly vulnerable to a change climate. Even with the modest warming so far experienced yields of grapes and alpha acid production fluctuated considerably. Recorded observations show an increase in air temperature and more frequent water deficits, which is associated with an earlier onset of plant phenological phases and with a faster ripening than in the past. The same trend is observed in wild plants. Climate change has a positive effect on the viticulture, through improving the quality of wine, but the risk of fluctuation´s yields due to late spring frost damage persists. On the contrary, climate change has a negative impact of traditional aromatic hops, by reducing alpha acid production. For example, extremely hot and dry summer in 2015 caused a great vintage, but the content of alpha decreased by 46%. Hop and wine growing in tiny areas are more vulnerable than in larger areas with different climatic conditions. Thus, climate change may gradually lead to changes in the regionalization of hop and wine production. Policy assistance may be necessary for the adaptation of the Czech hop growing industry to changed climatic conditions.

**P23**

*Pan evaporation trends from 1971 to 2015 in the Czech Republic*

**Martin Mozny1, Radim Tolasz1, Miroslav Trnka2,3 (1Czech Hydrometeorological Institute, Czech Republic, 2Global Change Research Institute AS CR, Czech Republic, 3Mendel University in Brno, Czech Republic)**

Evaporation measurement can improve our understanding of the climatic water balance. We analysed the monthly and seasonal measurement of water surface evaporation from 22 stations in the Czech Republic in the 1971–2015 period. Evaporation data were obtained using GGI-3000 pans, at one station simultaneously using Class A pan. The tanks were 0.3m square and 0.6m deep, and were sunk into the ground with a 5cm projection above the surface. Since 2000, GGI-3000 has been gradually automated via precise water level sensors (EWM). Special software was used to homogenate the series and, therefore, correct the depth of water in each pan. The main difference with other published results is the positive trend of pan data for most of the stations, when many sites, but not all, showed a decline. Temperature, solar radiation and wind speed had a positive effect on pan evaporation. Wind speed was not a dominant factor affecting pan evaporation trend unlike the Class A pan. The distribution of pan evaporation totals within the Czech territory is influenced by orographic conditions**.**

**P24**

*Forest drought monitored by the SPI*

**Jaroslav Vido, Paulína Nalevanková, Katarína Střelcová (Technical University in Zvolen, Slovakia)**

Hydrometeorological institutes around the globe use the Standardized Precipitation index (SPI) as a standard method to monitor drought. The reasons are simplicity and reliability of the SPI for quick information about drought spells. Although the SPI has a possibility to be adjusted for specific ecosystem or natural conditions by changing of the time scale, this possibility is not used in many cases. It is because lack of information about drought related resistivity of specific ecosystem. In our contribution, we would like to present method how to adjust the SPI for drought monitoring in temperate forest of central Europe. To do so, we investigate relationship between physiological characteristics of European beech (Fagus sylvatica), soil water potential and the SPI with various time scales. The results showed that the best relationship is between the soil water potential with the SPI for five weeks. This also indicates that the beech forest has a five-week resistance to drought stress.

**P25**

*Variability of Malaria prevalence in Kano In Relation to Climate Variability*

**A Akinbobola, E.C Okogbue, J. Bayo Omotosho (Federal University of Technology, Nigeria)**

Climate variability has been observed to have the potential of enhancing diseases occurrence and transmission. Malaria is identified as one of the climate sensitive diseases in Kano, North western, Nigeria. Therefore, this study explored the variability of malaria prevalence in Kano in relation to climate variability from 1992-2015. Confirmed malaria cases in Kano were collected from hospital registers and the Patient Information System in a standard government hospital in Kano. Monthly data of minimum and maximum temperatures, rainfall and relative humidity were collected from the Nigerian Meteorological Agency (NIMET). The association between malaria incidence and climate variables were explored. Questionnaires, key informant interviews and observational surveys were conducted in the study area to assess possible impacts of non-climatic variables on malaria prevalence. There were 5, 500 confirmed malaria cases for the period 1992-2015 in Kano. The results showed that the relationship between malaria incidence, temperature and rainfall is statistically significant. However, analysis of the questionnaire, observation and key informants’ interview showed that the correlation between the incidence of dengue as surveyed and the non-climatic variables are not statistically significant. It therefore reveals that the risk of malaria transmission increases with climate variability if the non-climatic factors of mosquito control and surveillance are poor. Climate projections for Nigeria have shown that the country’s climate will continue to vary. The temperature in Nigeria will continue to rise by at least an estimated range of 0.3-1.0°C by 2030. There will be more very hot days and warm nights and a decline in cooler weather. It is predicted that extreme rainfall days are likely to occur more often in Kano. Therefore, it is essential that the public health infrastructure is strengthened to combat the threat of climate variability and change and its impact on malaria prevalence.

Keywords: Malaria, Prevalence, temperature, correlation, questionnaire

**P26**

*Spatial Analysis of Malaria Risks in Akure, Ondo State, Nigeria*

**Sikiru Bayo Abdulkareem, Balogun Ifeoluwa Adebowale, Suleiman Abdulazeez Adegboyega (Federal University of Technology, Nigeria)**

This study aims at generating malaria risk map for Akure by using integrated approach of Remote Sensing and GIS in epidemiology, with a view of determining the degree of vulnerability in the study area and also providing information that could assist in reducing the malaria incidence through appropriate medical intervention. Records of rainfall data for the study area obtained from the 3B43 Monthly (0.25 × 0.25-degree resolution) of the Tropical Rainfall Measuring Mission (TRMM), in addition to in-situ data of temperature and relative humidity measured across different locations in the city during an experiment carried out between 2008 and 2012 were utilised. The mean monthly malaria data across the 23 electoral wards were interpolated using the Inverse Distance Weighted (IDW) techniques. Malaria hazard map was generated using fuzzy logic techniques and subsequently the risk map was produced. The malaria risk map indicates varying categories of risk to malaria diseases exists in the city. The low risk areas have the probability range of 1.6% - 10.9%, the medium risk areas have the probability range of 10.9% - 27.14%, the high risk areas have the probability range of 27.14% - 50.33% of the population, and the very high risk areas have the probability ranges from 50.33% - about 81.99%. The study recommends the establishment of health centres at the high and very high risk areas at accessible locations and reasonable distances away from the existing inadequate health facilities.

**P27**

*Silo opening dates: Another source of phenological data?*

**Marie R. Keatley1, Irene L. Hudson2 (1University of Melbourne, Australia, 2Swinburne University, Australia)**

Australian phenological data are sparse. Silo construction in New South Wales began in 1917 after large grain losses through wet weather and rodents. Most were in rural towns whose economy was dominated by wheat growing. Hence silo opening dates for wheat receival were newsworthy items for local papers. This paper is the initial examination of whether silo opening dates can be used as an unconventional phenological source, expanding the Australian phenological base.

The opening dates of 202 silos (1924 to 1955: records per year ranged from 19 to 164, mean = 80, records per silo range from 1 to 29, mean = 12) were sourced from the National Library of Australia’s digitized newspapers collection. The mean opening date of all silos was year day 330 (November 26th) with a range of 29 days (318 in 1935 and 1955 to 347 in 1934).

Opening dates (1934-1955) of 8 northern and 13 southern silos were examined to determine whether there is any climate influence. The silo groups are separated by 450 kilometres with southern silos being in a wetter and cooler environment compared to the northern silos.

The southern silos opened on average year day 331 (November 27th) 15 days later than their northern counterparts (year day 316; November 12th). Separated by 125 kilometres, the southern silos have a west to east gradient of opening days; the most westerly opening 13 days earlier (324 versus 337). Although separated by 120 kilometres in a north to south direction there is no gradient in opening dates for the northern silos.

Rainfall is positively correlated with northern silo opening dates and overall negatively with southern silo ones (n=3 stations situated at the middle and each end of group). This suggests there is some climate influence. Further work is required before the records can be considered an alternative phenological source: examination of the other silo locations and the relationship with temperature.

**P28**

*Developing applicable climate science for agriculture and hydrological sectors in Argentina*

**Olga C. Penalba1,2, María Laura Bettolli1,2, Vanesa C. Pántano1,2, Mercedes Poggy1,2, Juan A. Rivera3 (1Universidad de Buenos Aires, Argentina, 2CONICET, Argentina, 3CCT-Mendoza/CONICET, Argentina)**

Argentina, located in Southern South America, is a country with a large latitudinal range spanning different climates. The complexity of precipitation regimes is of undeniable climatological interest, and an understanding of their characteristic features also has economic relevance. In a changing climate, it is highly valuable to understand possible future changes in both extreme events. However, in order to put potential future changes in context, the present day must be first well understood.

Rainfall extremes -excess and deficit- were analysed. These extreme events are complex phenomena and different in their genesis. Furthermore, their impact on affected sectors - agriculture and hydrology- is different.

In this context, this research analyses climatic indices –Standardized Precipitation Index, Standardized Streamflow Index, Soil Hydric Conditions, Daily Extreme Rainfall Intensity, Long Dry Sequences – in order to know the frequency and magnitude of these phenomena and the temporal and spatial variability. The atmospheric circulation during specific extreme events is also explored to determine regional and global atmospheric-oceanic forcings. Finally, projected changes were evaluated for drought (frequency, duration and severity); and the main meteorological variables involved in soil-atmosphere interaction, to evaluate the potential impact on the soil hydric condition.

One of the results, related to the impact of climate change on main drought characteristics, is that the multi-model ensemble tends to produce less droughts, with higher duration and lower severity. Therefore, the region can experience more frequent water shortages with significant economic losses if proper adaptation measures are not proposed.

These studies attempt to contribute to the knowledge and information about climate extreme events, variability, predictions and projections for managing weather and climate risk in Argentina.

**P29**

*Grapevine phenology in Croatia under climate change*

**Marko Vucetic1, Visnjica Vucetic1, Petra Cicek Pomper2 (1Meteorological and Hydrological Service, Croatia, 2Techical Scool, Croatia)**

The cultivation of grapes and wine production in Croatia has a long tradition, thus it is important to establish how climate change effects the phenological cycle of grapevines. The aim was to determine whether the part of the country that is suitable for cultivation of grape continues to be favourable in the future. For this purpose, the Huglin agroclimatological index (HI) along with data of seven phenological stages of seven grapevine varieties from eight phenological stations across Croatia have been analysed in the period 1961-2016. Linear trend analysis showed that dates of leaf unfolding, beginning of first flowers and end of the flowering occurred earlier by 1-3 days/decade in the Adriatic area and 3-5 days/decade in the continental area. However, dormancy during winter is a very important factor for the beginning of the flowering. The buds of grape remain dormant, while they have accumulated sufficient chilling units (CU). In the continental part, the CU this is 450-550°C and in the mid-Adriatic 30-75°C for the temperature threshold below 7°C. The onset of full ripening and fruit picking comes significantly earlier in Croatia. In the period 1961-1990 HI was up to 2400°C for the mid-Adriatic, up to 2000°C for the continental area and below 1600°C for mountainous areas. In the last 30 years the increase of HI is evident in the whole of Croatia (up to 200°C). In the extremely hot years at the beginning of the 21st century, earlier and later continental varieties ripened practically at the same time. The grapes had a very high sugar content, which resulted in wines with high alcohol content. Thus, in the near future in the continental part it could become possible to grow thermally more demanding red grape varieties, while earlier varieties could be cultivated in mountainous areas.

**P30**

*Advances in* *biometeorological studies in China learned from publications in Journal of Geographical Sciences*

**Xin Zhao, Yunjia Xu, Junhu Dai, Zexing Tao (Chinese Academy of Sciences, China)**

Biometeorology, an interdisciplinary field of science that studies the interactions between the processes of atmosphere and living organisms, has attracted wide attention in China over the past few decades. In this study, we made a statistical analysis on biometeorological papers published in Journal of Geographical Sciences (in English) and Acta Geographica Sinica (in Chinese) from 2001-2016. Both of the journals are co-sponsored by the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences and Geographical Society of China (GSC), which can reflect the highest academic level of scientific papers on geography in China. The analysis revealed that: (1) a total of 3,701 papers had been published on both the journals during 2001-2016. Among these papers, 262 were related to biometeorology, and 56% of them were published in the past six years (2011-2016). (2) more than 177 papers had been published on agricultural and forest meteorology, comprising topics of productivity of ecosystem, land use and land cover change, and impacts of weather conditions on the growth of crops and plants. In addition, meteorological disaster (29 papers), urban climatology and meteorology (23 papers), phenology (20 papers), air pollution (7 papers), human health (4 papers), animal biometeorology (1 paper) and review of biometeorology (1 paper) were also intensely discussed. (3) Since 2011, the number of biometeorological papers has increased by 30%. More studies were focused on phenology and air pollution, indicating increasing importance of phenology in the field of climate change, and impacts of the progress of industrialization and global warming on human living conditions. However, less papers were concerned about urban climatology and meteorology and animal biometeorology. Papers on agricultural and forest meteorology, meteorological disaster and human health still accounted for the same rates. These studies showed a chance and challenge for researchers to broaden its multidisciplinary topics, with further emphasis on ecology and epidemiology, the problems arising in the development of human society, as well as forecast and prevention of natural disasters.

**P31**

*Online questionnaire on sunlight as an interior design element*

**Naoko Matsuda1, Kazuo Nagano2 (1Osaka Sangyo University, Japan, 2Kyoto Prefectural University, Japan)**

Light through the window is one of the important elements of interior design. Its intensity and direction vary inevitably due to the latitude, time, and weather although it can be partly controlled by window treatments such as curtains, blinds and more. That means the natural light is more difficult to manage for many people who arrange their interior with or without expertise. This study conducted an online questionnaire for the public to clarify their awareness of sunlight as an interior design element, which can determine how they cope with it.

The 4,814 respondents, who ranged in age from 20 to 39, completed the questionnaire. They were asked to choose the most favourite element in their own room from 30 alternatives, which were comprised of the various furnishings like a sofa, electric appliances like a TV, the fabrics like wallpaper, and other elements like the light from the window.

The result showed that the alternative “The light from the window” was in 13th by 2.6% of all respondents, while the n/a option was ranked first by 25.2% and a sofa was second by 6.8%. This sunlight option was chosen by 5.1% of females with child(ren) in their thirties and 1.2% of males remaining single in their twenties. It could be due to the existence of others at home for each stage of life. For areas where the percentage of possible sunshine in winter was lower, the percentages of the males’ and females’ choice of the sunlight were lower and higher, respectively. It is suggested that the females tend to prefer the soft daylight which can create the mood in their room, whereas the males tend to prefer the bright sunshine.

**P32**

*An agro-climatic approach to determine citrus postbloom fruit drop risk in Southern Brazil*

**Ana Raquel Soares-Colletti1, Paulo Cesar Sentelhas1, C. A. Alvares2 (1University of São Paulo, Brazil, 2Suzano Paper Company, Brazil)**

Postbloom fruit drop (PFD) causes lesions on the petals of citrus flowers and induces fruit abscission causing severe damage to production when the flowering period coincides with intense rainfall. The aims of this study were to develop a phenological-climatological model for PFD occurrence and, together with weather data from several locations, to determine and map the agro-climatic favourability of PFD occurrence in the state of São Paulo, Brazil. A phenological flowering model was developed to identify when citrus flowering occurs. The flowering starts after when a temperature below 10°C in the months of June or July is reached followed by cumulative rainfall within five days of at least 20 mm, and then 96°C days. Between the beginning of flowering and its peak 147°C days are required and between the peak and its end, approximately, 229°C days, being 206°C days from the peak to the moment when flowers remaining are about 50% of total. The relationship between PFD incidence and accumulated rainfall during the critical period (between flowering peak and 50% of flowers remaining) was adjusted by the Gompertz model (R2 = 0.99, p < 0.05). After its validation, this model was used to estimate PFD incidence for 29 locations in the state, from 1993 to 2013, which allowed to map the PFD climatic favourability through a Geographical Information System using linear models based on latitude, longitude and altitude. The obtained map showed a trend of PFD incidence increasing from the northwest of the state towards the south and the coastal region, with medium to very high favourability in the centre region. The results of this study can be used by growers as a guide for disease control planning as well as for defining the regions where the climatic conditions are likely to escape this disease.

**P33**

*Vertical temperature distribution measured with a drone at locations adjacent to the edge of the forest and the lake in summer*

**Naoshi Kakitsuba (Meijo University, Japan)**

In order to estimate the cooling effect of a large lake or a forest, vertical temperature distribution was measured with a drone at locations nearby a forest and a lake. Both the lake and the forest are located in a suburban area in Aichi prefecture, Japan. Since it was reported that the prevailingly wind blew from the north in summer, measurements were taken at the southern edge of the lake and the forest (Location 1), the location at 5 m south from the edge (Location 2), and the location 10 m south from the edge (Location 3). Air temperature, relative humidity, and atmospheric pressure were measured with a device attached to the drone in the morning (9:00AM-10:00AM) and the afternoon (1:00PM-2:00PM). Altitude of the flying drone was controlled at 5 m, 10 m, 15 m and 20 m above each ground surface. In addition, wind velocity and wind direction were continuously measured on the ground surface at Location 1. The results showed that 1) a profile of vertical temperature distribution was different due to types of ground surface under no or small cooling effects, 2) cool air from the lake appeared to move to the location 2 in the morning but ceased in the afternoon because temperatures at Locations 1 were 2oC higher than those at other locations in the afternoon, 3) cool air from the forest was observed not in the morning but in the afternoon, and 4) the way of cool air movement from the lake and the forest may be dependent on frequency of vertical wind direction since air temperature in the range of 10-20 m height became lower when wind frequently blew upward. These results may be of help for designing urban climate, particularly in the case of the large green areas in a city.

**P34**

*Simulation of long-term solar UV effects on surface plant litter decomposition*

**Wei Gao, Maosi Chen (Colorado State University, USA)**

Solar Ultraviolet (UV) radiation has been found to be potentially linked with abnormal mass loss and nitrogen dynamics of plant litter in some dry ecosystems. Although there were many field studies exploring the nature of photodecomposition, the effort of incorporating the underlying mechanisms into an ecological model was rare. In this study, three commonly studied UV related mechanisms for litter decomposition were added to the DayCent-UV model: (1) direct photolysis, (2) facilitation of microbial decomposition via converting photo decay products to labile materials, and (3) microbial inhibition effects. The DayCent-UV model was first calibrated with the observed ecosystem variables (e.g. soil water, aboveground biomass, actual evapotranspiration, and net ecosystem exchange). Then, the photo decay submodel of DayCent-UV was trained and validated against the LIDET (Long-Term Intersite Decomposition Experiment) observations of remaining carbon and nitrogen at three semi-arid sites in Western U.S. The results showed that optimized DayCent-UV better simulated the observed linear carbon loss pattern and the persistent nitrogen mineralization in the 10-year LIDET experiment at the three sites than the model without UV decomposition. With the optimized DayCent-UV, the equilibrium model runs covering the prior 100 years suggest that the most important ecological impact of UV photo decay of surface litter in dry grasslands is to increase N mineralization from the surface litter (by 25%), and decay rates of the surface litter (by 15%), and decrease the organic soil carbon and nitrogen (by 5%).

**P35**

*Circadian variation of methane emission and metabolic heat production of Nellore Cattle*

**Cíntia Carol de Melo Costa, Alex Sandro Campos Maia, Vinicius de Franca Carvalho Fonsêca, Rodrigo Simão, Patric André Castro, Eric de Andrade Culhari (São Paulo State University, Brazil)**

The aim of this study was to evaluate enteric methane emission (ECH4, g h-1) and the metabolic heat production (qmet, W m-2) of Nellore cattle in natural meteorological conditions, and see the correlation between these variables during 24 hours. This experiment was conducted at the Animal Biometeorology Laboratory of the São Paulo State University, Jaboticabal, Brazil (21.25° S, 601 m altitude) in December of 2016. Six Nellore cattle with similar weight, age and body condition were assigned in four Latin Square experimental design (24 classes of hours (1-2h; 3-4h; …; 23 - 24h; 24 -1h) during six days). Enteric methane emission and metabolic heat production were determined with animal protected from solar radiation, using an indirect calorimetric system with a facial mask, developed by Innovation group of Biometeorology (INOBIO). Air temperature (TA, °C), humidity (RH, %) and solar radiation (GS, W m-2) were recorded in one-minute intervals by a portable weather station (Model 110 - Nova Lynx). Maximum and minimum values of TA were 30.92 ± 0.20 and 21.69 ± 0.20°C, respectively. ECH4 was higher between 8 to 12h and 19 to 22h; these peaks occurred after feeding times. Similar pattern was observed with qmet, which increasing from 8 h, reaching maximum value at 11h (191.39 ± 5.92 W m-2) during the morning, and at 22 h (167.21 ± 5.81 W m-2) overnight. The qmet and ECH4 showed a positive and higher correlation (r = 0.78; p = 0.0001) and both presented a positive but lower correlation (r = 0.29 and 0.04 respectively; p > 0.05) with TA. So, it can be concluded that ECH4 and qmet are directly correlated. Furthermore, enteric methane emission of housed Nellore cattle bred in tropical condition is approximately 42.71 g day-1 per animal.

**P36**

*Tourism climate potential in Hungary in the light of climate change*

**Attila Kovács, János Unger, Noémi Kántor (University of Szeged, Hungary)**

Climate is one of the most significant components that affect the tourist attractiveness of a certain region. Climate change influences each and every tourism destination and activity on a different level as well as affects other environmental resources in an indirect way. It is essential to provide tourism industry, one of the most dynamically improving industrial sectors, with the necessary tools for coping with the inevitable effects of climate change. Development of adaptation strategies can be facilitated by analysing the expected changes in the tourism climate potential.

In Hungary only a few initial steps have been made in regarding the impact assessment of climate change on tourism. Therefore, this study aims at assessing the exposure of Hungarian tourism sector to cli­mate change using a modified form of the Tourism Climatic Index (mTCI). This measure is adapted to the Hungarian people taking into consideration their seasonally variable subjective thermal sensation. Current tourism climate evaluations are based on the 30-year measurement database of the Hungarian Meteorological Service, while future climate estimations are based on the regional climate model ALADIN-Climate 4.5, run on a 10-km horizontal resolution grid.

**T**he yearly evolution of mTCI shows a “bimodal” structure. Spring brings a significant improvement after winter followed by a slight decline between June and September. After this another improvement and then a decline can be observed until the end of autumn. Concerning the possible future climate potential an unfavourable change can be expected from May to September while improving conditions can be anticipated for the rest months.

**P37**

*Sigmoid relationship between surveyed clothing insulation and thermal index in outdoor spaces*

**Kazuo Nagano, Kumika Sumisato (Kyoto Prefectural University, Japan)**

The adjustment of clothing insulation in outdoor spaces is a behaviour according to human thermal comfort, which is affected by the six basic factors. This study derives the regression equation of the clothing insulation on a thermal index, which represents the integrated effect of these factors, since the existing equations are a function of the temperature only.

The web-based questionnaire in which respondents were asked to select one illustration of how many clothes they wore when going out each day, was repeated every Sunday for a year and was open until the111 males and 111 females in Kyoto completed it. The mean daily values of clothing insulation were calculated according to the clo values assigned to each illustration and the frequencies. The outdoor temperature, humidity, wind velocity, and shortwave and longwave radiation were observed in Kyoto during the questionnaire period. The thermal index ETVO was calculated based on these meteorological data.

The results showed the daily clo value was little changed when the ETVO fluctuated drastically within 3-4 days, while the values on the whole were negatively correlated with the ETVO of 10 to 30°C, and stayed stable beyond the range. Therefore, the sigmoid regression was used to measure the association between the ETVO and the clo value. The estimation by this equation can reflect the realistic situations that most people have no more clothes to bundle up against the chill and cannot take off their clothes in public against the hot weather, whereas the required clothing insulation (IREQ) is based merely on the heat balance. Thus, this equation can be useful for assessing outdoor thermal comfort realistically by using universal thermal indices, and for informing people who adjust insufficiently the amount of their clothing to the rapid change in their thermal environment of the appropriate insulation.

**P38**

*Tree growth dynamics as indicator of tree reaction to environmental stress*

**Adriana Leštianska, Peter Fleischer, Katarína Střelcová (Technical university in Zvolen, Slovakia)**

Climate change projections indicate an increase in the frequency and duration of extreme climate events in the coming decades in Central Europe. The increasing frequency and intensity of climate extremes in Slovakia has obvious negative impacts on forest tree production and causes increasing damage on forest ecosystems from lowlands to mountain regions. However, it is not clear which tree species will be able to cope with drier climatic conditions and higher year-to-year climatic variability.

This study aims at increasing the understanding on species-specific effects of climate factors on growth, which is necessary to assess the responses of tree growth to anticipated climate changes. We compared the growth response to climate fluctuation of four mature coniferous species, Scotch pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* Karst), European larch (*Larix decidua* Mill.) and Silver fir (*Abies alba* Mill.) during growing season 2015. The species originate from different regions of Slovakia (larch, fir), Ukraine (pine) and Russia (spruce, pine) characterised by different environmental conditions (climate, soil, bedrock). The individual tree species are located in Borová hora Arboretum (Zvolen valley, Slovakia) which has a character of uplands with altitudes from 290 m a.s.l. to 377 m a.s.l. Climate and soil conditions were therefore the same for all the trees studied.

Using band dendrometers we evaluated intra-annual dynamics of stem radial growth (RG), stem radius variation (RV) and offsets and durations of daily cycles of stem radius of individual species, which are compared in relation to weather and soil conditions with emphasis on the extremes.

**P39**

*Phenological Networks in the Pacific: Development and Community Engagement*

**Lynda E. Chambers1, Roan D. Plotz1, Siosinamele Lui2 (1Australian Bureau of Meteorology, Australia, 2SPREP, Samoa)**

Many Pacific Islanders forecast seasonal climate conditions through observation and monitoring of meteorological, astronomical and biological indicators (e.g. phenology). Built over many generations, these knowledge systems are adapted to local conditions to cope with a highly variable and vulnerable environment. Traditional climate knowledge systems continue to influence all aspects of modern Pacific livelihoods from agricultural productivity to disaster response and recovery.

Adaptation to changing climatic conditions in the Pacific would benefit from an improved understanding of how traditional forecasting methods compare to, and might be combined with, those based on climate models. A critical component of this is the design and implementation of national monitoring networks (e.g. rainfall monitoring networks), based on the traditional indicators identified, the majority of which are phenological. Highlights and challenges are illustrated using case studies from Samoa, the Solomon Islands and Vanuatu. The information gained from these networks has the potential to improve the accuracy, utility, and uptake of local seasonal forecasts by ensuring the communication of climate information is in a locally relevant context.

**P40**

*Sustainability of Croatian tourism in changing climate*

**Ksenija Zaninovic1, Lidija Srnec1, Grigory Nikulin2, Ivan Güttler1, Renata Sokol Jurkovic1 (1Meteorological and Hydrological Service of Croatia, Croatia, 2Swedish Meteorological and Hydrological Institute, Sweden)**

The aim of the paper is the investigation of suitability of climate conditions for future tourism in Croatia by means of the data provided by two different downscaling data sets. In this way, the uncertainty of simulations of future climate is reduced. The analysis has been performed for different climate region of Croatia for 06 and 12 UTC. The suitability of climate for different types of tourist activities is estimated by means of climate index for tourism (CIT) which integrates thermal, aesthetic and physical facets of atmospheric environment, and the changes in climate potential of tourism are estimated by changes of climate index for tourism in the two future 30-year periods 2011-2040 and 2041-2070. In the first experiment for future climate, two randomly chosen simulations from the global atmosphere-ocean circulation model ECHAM5-MPIOM under the IPCC emission scenario A2 were downscaled using regional climate model RegCM3 and compared with referent period 1961-1990. For the second experiment, the referent period was 1971-2000, and the ensemble of five climate realisations with regional climate model (RCM) SMHI-RCA4 forced by five CMIP5 global atmosphere-ocean circulation models (GCM) HadGEM2-ES, CNRM-CM5, EC-EARTH, IPSL-CM5A-MR and MPI-ESM-LR under two IPCC emission scenarios RCP4.5 and RCP8.5 is used. The analysis of future conditions for different parts of the day enables a comprehensive overview of climate potential for tourism in future. The results indicate more pronounced bimodal distribution of CIT during year in the warmest part of the day, resulting with the seasonality shift of ideal conditions for most activities to spring and autumn, and the prolongation of see activities (beach tourism, motor boating and sailing). In the morning, the improvement of favourable climate conditions for all types of tourism in future can be expected during the whole year mostly pronounced from May until September.

**P41**

*The effect of winter tropical urban climate upon the human body*

**Yoshihito Kurazumi1, Jin Ishii2, Kenta Fukagawa3, Emi Kondo4, Ariya Aruninta5 (1Sugiyama Jogakuen University, Japan, 2Meijo University, Japan, 3Kyushu Sangyo University, Japan, 4Ariake National College of Technology, Japan, 5Chulalongkorn University, Thailand)**

Considering that the average temperature of the earth is forecast to rise, studying effects on the human body from outdoor thermal environments in tropical regions may be important for considering how to spend time outdoors in the future. In this study, we measured effects on thermal sensations of the human body in an outdoor thermal environment in winter in Bangkok, Thailand, a tropical region. The influence of the outdoor tropical urban thermal environment in winter season on the human body was studied by using the outdoor thermal environment evaluation index ETFe. In addition, the effect of sunlight shielding was studied. Furthermore, the effects on the human body during winter vs. dry season were compared, and the seasonal difference in thermal sensation was clarified. The effects of blocking direct sunlight and reflected sunlight are presented here. In spaces with nothing to block the direct sunlight and reflected sunlight, feelings of discomfort are considered to be more apparent. Even in winter tropical urban climate, the most effective ways to lower the thermal sensation are by using “sunlight shielding” and “ground surface cover” to lower the ETFe and larger sky factor rate. It is shown that the long-wave thermal radiation by the surface temperature of the building and the ground surface is increased. Even in the winter tropical zone, sunlight shielding by leaves and material with low heat capacity is necessary. Under an environment with a remarkable strong thermal environment stimulus, the human psychological reaction is focused on the thermal environment stimulus. It is clear that in winter, people prefer a lower temperature than in the dry season, and in the dry season they tolerate higher temperatures than in winter.

**P42**

*Heat and cold wave in Russia as the uncomfortable factor of the environment*

**Vera Vinogradova, Alexandr Zolotokrylin, Alexey Vinogradov (Russian Academy of Sciences, Russia)**

Heat and cold waves are significant and dangerous climate anomalies. Hence, assessing changes in heat and cold waves is crucial both for Russia and the world. Worldwide research shows that climate extremes are becoming stronger nowadays and this implies a growth of frequency of heat and cold waves. Defining a criteria of extreme events depends on the choice of thresholds. In this paper, we consider the thresholds for determining the heat wave as the value of 95th percentile of maximum temperature distribution, and the cold wave as the value of 5th percentile of minimum temperature distribution. Changes in the number, intensity and duration of heat and cold waves in Russia for various periods from 1951 to 2010 were evaluated according to this rule. The purpose of work is to estimate changes in the number, duration and intensity of heat and cold waves in Russia as factors of the natural discomfort. Heat waves were classified by the level of discomfort. Analysis of the results shows an increase in the number of days with abnormally high temperatures, since the 1990s of the XX century. The most significant increase is seen in the European part of Russia and the Far East. Heat load growth was detected up to absolutely and extremely adverse values during the period of contemporary climate warming. It was mainly caused by the increase in the number of days with high temperatures. These changes are particularly evident for regions in the northeastern part of Russia and the European Territory. A decrease in cold waves as well as a growth of minimal temperatures was observed in winter in much of Russia since lately 1990s. However, these tendencies are weakening in the beginning of the XXI century: a significant area in Southern Siberia is seen where cold waves are becoming stronger and minimal temperatures are decreasing.

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**P43**

*Change of plant phenophases explained by survival modelling*

**Barbara Templ1, Stefan Fleck2, Matthias Templ3 (1Zentralanstalt für Meteorologie und Geodynamik, Austria, 2Statistik Austria, Austria, 3Zurich University of Applied Sciences, Switzerland)**

It is known from many studies that plant species show a delay in the timing of flowering events with an increase in latitude and altitude, and an advance with an increase in temperature. Furthermore, in many locations and for many species, flowering dates have advanced over the long-term. New insights using survival modelling are given based on data collected (1970–2010) along a 3000-km long transect from northern to eastern central Europe. We could clearly observe that in the case of dandelion (Taraxacum officinale) the risk of flowering time, in other words the probability that flowering occurs, is higher for an earlier day of year in later decades. Our approach assume that temperature has greater influence than precipitation on the timing of flowering. Evaluation of the predictive power of tested models suggests that Cox models may be used in plant phenological research. The applied Cox model provides improved predictions of flowering dates compared to traditional regression methods and gives further insights into drivers of phenological events.

**P44**

*Effects of Environment on the Behaviour of Holstein Cows*

**Sheila Tavares Nascimento1, Caroline Silva Gonzaga Bueno2, Alessandra Aparecida Silva2, Claudete Regina Alcalde2 (1Universidade de Brasília, Brazil, 2Universidade Estadual de Maringá, Brazil)**

The aim of this work was to evaluate how meteorological parameters affect the behaviour of Holstein cows in pasture during the summer. Eight Holstein cows were used, four with predominance of black coat and four with predominance of white coat. The study was conducted in the city of Maringá, PR, Brazil (23º25’S; 51º56’W; 515m). Environmental parameters were measured every 20 minutes (air temperature, relative humidity, mean radiant temperature) and behavioural at 10-minute intervals (activity, posture and location, observing whether the animals were in the sun or in the shade) for 13 days between 8am and 5pm in February and March of 2015. The shortwave irradiance and the amount of radiation absorbed by the cows were also estimated. The animals in general, regardless of the predominance of the coats (black or white), sought more frequently the shade at the times with the highest incidence of radiation and lower radiant thermal load (CTR) observed under the tree, although they remained most of the time standing which may be an indication of discomfort. When comparing the behavioural differences related to the predominance of black or white coats, it was observed that predominantly black animals remained in the shade most of the time during observation times. Animals with predominance of black coats absorb more radiation, but are less sensitive to the exposure to high levels of radiation, as they have the protection of the epidermis by melanin. The behaviour of Holstein cows was influenced by environmental parameters, due to a higher use of shading during the periods with higher solar radiation and stayed the most of the time standing and in leisure, independently of the predominant coat colour.

**P45**

*Livestock Thermal Balance Simulator RGS 2000*

**Eric de Andrade Culhari, Alex Sandro Campos Maia, Vinícius de França Carvalho Fonsêca, Bruno Rodrigo Simão, Patric André Castro (São Paulo State University, Brazil)**

Mathematical modelling has proved to be an important tool in the animal production. However most of them are characterized by extensive equations. The use of computational software is a valuable tool, being this the aim of this work the development of the software "*Thermal Balance Simulator RGS 2000*" to predict the thermal balance of Livestock. Visual Basic For Applications language (VBA) and Excel Microsoft were used; functions were fitted and intuitive buttons were created in the software layout, which we can choose the way of simulation inputting simple traits as relative humidity (HR,%), air temperature (TA,°C), black globe temperature (TG,°C), wind speed (U, m s-1), hair coat surface temperature (TS,°C), core temperature (TB, °C), sweating rate (S, g s-1), respiratory rate (*F*, breath/min), and animals dimensions as body length and diameter(m). Simulation of the sensible heat flow by a Holstein cow (length 2.0m; diameter 0.9m) placed in the shade was performed. Considering TA = 32°C, TG =35°C, U = 1.5 m s-1, TS = 36°C, the output showed the convection and long wave radiation flux from the order of 25.8 W m­-2 and 7.15 W m-2 respectively. In other way, simulating the same animal exposed to direct solar radiation, and considering TA = 29°C, TG = 50°C, U = 1.5 m s-1, TS = 44°C, the output showed an increasing on the convection flux going to 97.57 W m-2, and a loss change for a heat gain by long wave radiation and present a value as -44.25 W m-2. The negative sign shows the change to heat gain.

**P46**

*Multivariate approach of adaptive characteristics in locally adapted sheep*

**Débora Andréa Evangelista Façanha, Wilma Emanuela da Silva, Jacinara Hody Gurgel Morais Leite, Josiel Borges Ferreira, Wallace Sostenes Tavares da Silva, Renato Diogenes Macedo Paiva (UFERSA, Brazil)**

The present work had as objective study the behaviour of physiological, morphological and blood parameters variables throughout the year in a hot environment. The data were taken during one year, in the morning, in the months March, June, September and December in commercial farms. About 150 ewes on reproductive age were evaluated at each collection. The physiological variables considered were respiratory rate (RR, breaths/minute), rectal temperature (RT, °C) and surface temperature (ST, °C), as well as haematological and biochemical variables. The morphological variables were coat thickness (CT, mm), hair length (HL, mm), diameter (D, μm) number of hairs (NH, hair/cm-²). Data were evaluated using Principal Component Analysis (PCA). The PCA explained 86.2%, and different responses of variables were observed according to months. In PCA 1 it comprised the months March, September and December, but March presented behaviour opposite to September and December. In CAP 2 it was represented by the month of June. In the months of March and June the highest air temperatures were not registered (34.97 and 34.36°C), but they presented higher relative humidity (45.84 and 50.83%), radiant heat load (703.26 and 659, 31 W.m2) and globe temperature and humidity index (92.62 and 90.86) respectively, such characteristics may characterize that the environment in which such animals are is thermally stressful. The animals used with greater intensity the physiological variables ST, RR, RT, thyroid hormones T3, T4 and the morphological characteristics of the hair, during the months of June and March, in order to favour the heat dissipation, when compared with the months of September and December. Therefore, the effect of the month was observed to separate the behaviour of the studied variables, and the most intense use of the mechanisms for heat dissipation occurred in the months of March and June, which are considered the rainy season in the region.

**P47**

*Climate impact on vegetation: the case of the ecological zones of Nigeria*

**Folasade O. Oderinde (Tai Solarin University of Education, Nigeria)**

Climate influences the distribution and composition of plant species. The vegetation of an area is one of the most sensitive indicator of climate most especially precipitation and temperature. Changes in climate would impact on ecosystems, vegetation pattern and livelihoods among others. This study attempts to empirically link the relationship between climatic parameters and vegetation in the country between 2000 - 2015. Considering six weather stations in each ecological zone of the country, climate data was correlated with Normalized Difference Vegetation Index (NDVI) and vegetation land cover value. The statistical package for social sciences (SPSS) was used to investigate the relationship between the climatic parameters and NDVI. A correlation and regression analysis was further carried out to observe the strength of the relationship between the climatic parameters and NDVI. The forest zones were observed to have higher NDVI values than the savanna zones. Overall, there appear to be decline in vegetation health in Nigeria during the period. This study provides an opportunity to identify the impact of climate on vegetation. This will enable adequate provision to be made for effective strategies in other to forestall the adverse impacts of climate change in a developing country where the consequences are likely to be very severe due to poverty and weak adaptive capacity.

Keywords:Climate, vegetation, ecological zone, Nigeria

**P48**

*Bee and willow phenology – using historical data to study species’ phenology drivers and synchrony*

**Sandra Stålhandske1, Kjell Bolmgren2 (1Stockholm University, Sweden, 2Swedish University of Agricultural Sciences, Sweden)**

Phenological change in both plant and animal life cycles are among the most commonly reported responses to ongoing climate change. The cues controlling phenological traits of any given species are likely numerous and with complicated relationships. Interacting species, particularly if they belong to different trophic levels or belong to widely different taxa, are therefore likely to rely on different cues for life cycle control. If such is the case, the interacting species may respond differently to environmental change and synchrony between them may be altered. In this study, we look at historical data of honeybees *(Apis mellifera)* and willow *(Salix caprea)* to study the relationship between the phenology of the two species and temperature throughout the twelve months before. Willow is an important early spring food plant for bees and could be an important driver of bee phenology, and we do show that willow flowering has a significant but weak effect on honeybee phenology. We also looked at each species separately and find that different time periods throughout the year have different effects on the phenology of the two species. Honeybee feeding flight is dependent on winter temperature and temperature during the previous summer season, and though willowflowering also shows an effect of winter climate we found a strong negative relationship to temperature during the month prior to observed flowering onset. This showcases that a well-known, straightforward two-species interaction also represents a complex system of phenological dependence among the interacting species. As there are different drivers of phenology for the two interacting species, we will need a better physiological understanding of the species-specific phenological drivers plus highly resolved climate scenarios to be able to derive tools for adaptive management in the context of phenological change and its effects on ecosystem services.

**P49**

*Circadian pattern of physiological traits of Jersey dairy cows*

**Sheila Tavares Nascimento1, Alex Sandro Campos Maia2, Vinícius França Carvalho Fonsêca2, Marcos Davi de Carvalho3 (1Universidade de Brasília, Brazil, 2Universidade Estadual Paulista, Brazil, 3Rio Branco Alimentos, Brazil)**

The aim of this work was to study the pattern of physiological traits of dairy cows during 24 hours and how it is related to the metabolic heat production, the sensible heat flow and evaporative heat loss. The study was conducted in the Paulista Agency for Agribusiness Technology (APTA), Ribeirão Preto, Brazil (21°10’ S, 47°48’ W, 546 m altitude). Twelve Jersey dairy cows with 326.28 ± 30 kg body weight, 17.66 ± 1.8 milk yield, and 165.5 ± days in milking were assigned in two Latin Square (LS) design. Subjects were fed a total mixed ration of corn silage (70%) and grain (30%) twice daily. Evaluations were performed from 08:00 to 20:00 (LS1) and from 20:00 to 08:00 h (LS2), protected from solar radiation and rain overnight. Meteorological variables were recorded during the trial. Body temperatures of skin (Tep), hair coat (Ts), nasal (Tn) and rectal (Tr) were continuously measured by thermocouples. Breathing rate (F), percentage of oxygen (O2) and carbon dioxide (CO2) from the exhaled air were measured by an indirect calorimetry system, using a facial mask. From these data, metabolic heat production (q"met, W m-2), sensible heat flow (q’’s, W m-2) and respiratory evaporation (q’’er, W m-2) were calculated. Data were analysed by the least square method. During the trial, air temperature and relative humidity ranged from 22 to 31°C and 27 to 88%. While the q’’met slightly increased between 06:00 h and 20:00 h, q’’s was not the main route of heat loss, although the animals lost heat by radiation and convection throughout the day; q’’er corresponded to a route of little importance used by the animals as an attempt to maintain the thermal equilibrium, suggesting that skin evaporation becomes an important mechanism of thermoregulation of dairy cows during the hottest hours of the day.

**P50**

*Thermal equilibrium of Morada Nova sheep in a tropical semiarid environment*

**Vinícius de França Carvalho Fonsêca1, Alex Sandro Campos Maia1, Bruno Rodrigo Simão1, Carolina Cardoso Nagib1, Severino Guilherme Caetano Gonçalves dos Santos2, Mikael Leal Cabral Menezes de Amorim2, Edilson Paes Saraiva2, Antonio da Costa Pinheiro2 (Sao Paulo State University, Brazil, Federal University of Paraiba, Brazil)**

Tropical semiarid zones are characterized by the high daily thermal amplitude, presenting challenges to the animals’ thermoregulation, especially for wool-less sheep breed. Low thermal insulation and high surface mass relationship are phenotypic traits of these animals. In this study, we evaluated the thermal equilibrium of Morada Nova ewes in a tropical semiarid climate. Twelve Morada Nova ewes with 32.76 ± 3.72 kg body weight were distributed in two Latin squares 12 x 12 (24 day of records and 24 hours). Subjects were assessed from 07:00 to 18:00 (LS1) and from 19:00 to 06:00 hours (LS2), protected from solar radiation, rain and wind overnight. Ventilation rate (VE), breathing rate (F), temperature (TE), the vapour pressure (e[TE]), percentage of oxygen (O2) and carbon dioxide (CO2) from the exhaled air were measured by an indirect calorimetry system with the use of facial mask. Furthermore, meteorological variables were recorded during the trial. Thermal equilibrium components were calculated according to the principles of energy conservation law. Based on respiratory rate, metabolic heat production, sensible and latent heat loss, we separated four groups of air temperature range using cluster and principal components analyses. First and second component presented 94.5% of the variation of all variables. We observed that metabolic heat production remained constant through the day. When the air temperature was lower than 24°C (group 1) sensible ways accounted twice the heat produced by metabolism; on the other hand, at 30°C the latent heat loss became gain importance in the thermal equilibrium of ewes. At temperature above 33°C (group 4) the latent heat flux is the main way to dissipate the metabolic heat. In the range of 22 to 30°C, when protected from solar radiation, wind and rain overnight, Morada Nova ewes maintain the thermal equilibrium at a minimum energy cost.

**P51**

*A way to measure surface area in animals*

**Bruno Rodrigo Simão, Alex Sandro Campos Maia, Marcos Chiquitelli Neto, Eric de Andrade Culhari, Patric André Castro, Vinícius de França Carvalho Fonseca (Sao Paulo State University UNESP, Brazil)**

The relation between surface area and mass are important in many studies, including animal thermal balance and breeding. Nowadays, the surface area is obtained from regression equations based on the body weight of specific animals group. In the present study, we propose a way to find the animal surface area. The method consists of building a three-dimensional (3D) animal model, using photogrammetry and scanning. The Autodesk Remake® and the Artec Studio 11® software with the Kinect of the Xbox One® were used for the photogrammetry and scanning process, respectively. Six Nellore cattle were trained to keep in a stable position and to reduce their reactivity; in addition, it was used the preanesthetic assepran 1%, in a subdose of 3.0mL. The procedure was done following the veterinary protocol, where the animal was fasted for 24h. Forty minutes after the application, the animal was conducted to a corall arena where pictures were taken and scanning was performed. Preliminary results showed animals of 631 kg and 748 kg presented surface areas of 6.0 and 6.69 m² calculated by photogrammetry and scanning, respectively. When these values were compared with those estimated by regression (5.53 m² and 5.93 m²), an error of 8.5 to 12.82% was observed. These differences could be attributed to animal breeding over the years and by the fact that these equations were not developed specifically for the Nellore cattle. Therefore, the 3D modelling seems to be the best way to obtain the animal surface area, and certainly, appears as a tool to improve research involving heat and mass transfer and animal breeding programs.

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