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Canopy aging classification of a neotropical savanna using RGB digital images

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Tropical leaf phenology exerts a first order mechanism regulating seasonality of carbon assimilation. This relationship is still unclear for many tropical vegetation, but studies have pointed out the importance of considering leaf-aging parameters in association with phenology. Leaf-age controls a set of mechanisms, such as morphological changes, allocation of chemicals and photosynthetic rates, that influence ecosystem processes. Here, we aimed to seek for a classifier that could potentially predict canopy aging based on features extracted from RGB digital images using a two-year dataset of a tropical neotropical woody savanna (Cerrado *sensu stricto*). We carried out visual inspections within a weekly temporal set of images to extract the onset dates of leaf phenological transitions. We identified four classes of crowns (phenophases) presenting: new leaves (CNL), mature leaves (CML), senescing leaves (CSL), and crowns with no leaves/deciduous (CDE). Each crown was labeled as belonging to a class if more than 50% of the all ROI were visually covered by the given phenophase. We complied a dataset of 420 observations labeled with the canopy aging transitions and associated with a set of features: red, green, and blue digital numbers (RGBDN); RGB chromatic coordinates (RGBcc); hue, saturation, and value (HSV); and two temporal parameters of season (dry or wet) and month of the observation. We used a decision tree approach to find out the best model that could automatically classify our whole imagery data set. A k-fold cross-validation protocol was applied to assess the effectiveness of the decision tree model. We achieved a normalized accuracy of 88.5% of our model. Our first outcomes are promising and open novel opportunities for further investigations. The application of low-cost and easy setup sensors as digital cameras enabling the automatically acquisition of canopy aging status would be critical for a range of ecological studies in tropical vegetations. FAPESP(#2014/00215-0;#2016/01413-5).

Fine-scale reproductive phenology of high altitude Himalayan Rhododendron species: Influence of phylogeny and abiotic factors

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Phenology and Conservation Biology (1), September 25, 2018, 10:30 AM - 12:30 PM

Phenology studies of plants in the high altitudes have gained importance due to their flexible response to environmental cues which reflects its vulnerability to future climate change. Despite the importance of ecological factors, evolutionary history also places a profound constraint on plant phenology event. Most of the phenology studies are limited to few events (e.g. flowering), and currently, we have a poor understanding of how phylogeny and abiotic factors influence the various events of the reproductive phenology. Our study examines the effect of phylogeny and abiotic factors at a fine scale reproductive phenology events which include budding, flowering, initial fruiting, immature and mature fruiting, fruit dehiscence followed by the duration of all phenology events. The study was carried out across ten species of dominant high altitude genus *Rhododendron* distributed along the altitudinal gradient of 3400 to 4230m above sea level in the Sikkim Himalaya, India.

We found that closely related species share the timing of early phenology events like budding, flowering, initial fruiting and also has similar dehiscent duration. In contrast, we found that the later events are strongly associated with environmental variables and are not phylogenetically constrained. We found a strong association of the early events with temperature, while day length and elevation influenced the later events like mature fruiting and fruit dehiscent.

Our findings emphasize the importance of studying the complete reproductive phenology stages to decipher the significance of abiotic factors and the phylogeny. Studying selective phenology stages might provide an incomplete understanding of the role played by various drivers.

Alberta PlantWatch: 30 years of spring phenology data – a potential tool to manage fire

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

In Canada, citizen scientists have tracked spring bloom times for common trees, shrubs, and wildflowers via 'Alberta PlantWatch' since 1987 (plantwatch.naturealberta.ca), and this phenology database includes over 57,000 records. The majority of records were contributed by long-term observers who reported data for a decade or more.
Adding historical data, an analysis of 70 years (1936 to 2006) of central Alberta plant data showed a 2 week trend to earlier pollen shed in spring for Populus tremuloides (trembling aspen tree). Over that time period, mean February temperatures increased by 5.3°C, and minimum temperatures increased 6°C. By monitoring the phenological response to environmental changes, the Alberta PlantWatch database may assist our adaptation to climate warming.
Substantial wildfire management costs in Alberta are associated with the spring fire season. The danger begins with snow melt and ends with forest green-up when foliar moisture content increases. For example, the Fort McMurray fire that occurred in early May 2016 was the most expensive disaster in Canadian history. In 2016, bloom dates were the earliest since the strong El Nino of 1998, and the fire season was also earlier than usual.
We used Amelanchier alnifolia (saskatoon bush) first bloom events as a proxy for forest green-up since PlantWatch observations of this event had good coverage throughout the Boreal biome where wildfire predominantly occurs. An analysis of forest fire incidence in Alberta found that the peak time of human-caused spring fire activity (2001-2016) was strongly correlated with the timing of Amelanchier first bloom. As spring progresses annually, the ability to predict the bloom time of Amelanchier can potentially help inform decisions about managing spring forest fires, thus potentially reducing firefighting costs.

AusPollen: a revolution in Australian aerobiology and understanding of pollen phenology

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Aerobiology, Seminar Room, September 24, 2018, 1:45 PM - 2:45 PM

AusPollen is a transdisciplinary, multi-institutional partnership established in 2013 for the research of airborne pollen in Australia. Its scope spans the full range of aerobiological activities, from pollen monitoring and reporting to forecasting and human health impacts. This presentation compiles the major achievements of AusPollen with a focus on advances in understanding of pollen phenology and seasonality. Through initial synthesis and analysis of Australian airborne pollen data, the partnership has revealed a striking spatial and temporal variability in grass pollen seasons in Australia. These are related to the diversity of Australia's climates and the distribution of C3 and C4 grasses, amongst other things. AusPollen has developed an Australian standard for pollen monitoring which will enhance the quality and improve the comparability (both within and beyond Australia) of Australia's aerobiological data in the future. The impetus for many of AusPollen's planned initiatives has been dramatically boosted in recent months as a result of the deadly epidemic thunderstorm asthma event in Melbourne in November 2016, with airborne grass pollen playing a central role in this event. Significantly enhanced pollen monitoring and the world's first operational thunderstorm asthma forecasting service in Victoria are amongst the achievements that have been contributed to by AusPollen investigators. Finally, the presentation identifies continuing limitations in Australian aerobiology that will need to be addressed to further advance implementation of standardised aerobiology, pollen phenology, and related public health in this country.

Can alleles of VRN1 and PPD1 genes predict flowering time in Australian wheat cultivars?

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

The time wheat flowers is critical in determining grain yield. Early or late flowering significantly penalises yields due to frost, drought and heat stress. Predicting flowering time from varying sowing dates for diverse cultivars and environments is important for maximising yield as seasonal rainfall events become less predictable. However, there are currently no models that can accurately predict flowering time when new cultivars are released. Two Photoperiod1 and three Vernalisation1 genes have been identified as the major genes regulating phasic development in response to temperature and day length. Allelic information has been used to parameterise models to predict flowering time, however it is uncertain how much variation in flowering time can be explained by different alleles of these genes.

We grew 13 elite commercial cultivars of wheat, selected for varying alleles at the major genes, and 13 near-isogenic lines with matching multi-locus genotypes to quantify how much thermal time to flowering could be explained by alleles of the major genes. Cultivars were grown at 22°C in four controlled environments with varying photoperiod (long or short day) and vernalisation (+/-) treatments. Near-isogenic lines explained a large proportion of variation in thermal time to flowering of elite cultivars under long days without vernalisation (97%), moderate amount under short days without vernalisation (62%), and less under short days (51%) and long days (47%) with vernalisation. Photoperiod accelerated development, expressed as reduced phyllochron, thermal time to flowering, and decreased final leaf numbers. Vernalisation did not significantly increase development rates in spring cultivars. The results indicate allelic variation of the five major genes cannot explain enough variation in flowering time to parameterise accurate gene-based models to simulate flowering time in the field. Further research into the genetic control of wheat development is required before reliable genetically derived parameter estimate models can be developed and deployed.

Assessing *Lobesia botrana* voltinism using phenological models at continental scale under climate change scenarios

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Phenological Methods (2), Theatre, September 25, 2018, 10:30 AM - 12:30 PM

Global warming is a general concern as it affects plants and insect in their interactions and phenology. Multivoltine species like *Lobesia botrana*, a major grapevine insect pest, are able to make several generations per year, generating significant economic losses. The development of this insect mainly depends on temperatures and photoperiod. By this reason, some variation are already observed in the speed of growth and the geographical distribution according to latitude and altitude. Indeed, in order to predict how this species will evolve in the future and under climate change conditions, it is necessary to develop predictive phenological models. These models will help us to simulate the number of generations at regional/continental scale.

This study will present a new model allowing simulating *L. Botrana* generations without considering differences in the thermal structure of the insect between the generations. This phenological model consider 6 phases. The first 3 phases (prediapause, diapause and postdiapause) are based on Baumgärtner and Gutierrez's models that integrate photoperiod and temperature. Those phases describe the overwintering date or first flight. Then, we use a simple function (Triangular function) that allow to represent the temperature response and the calculation of the generations (10% and 50% of the total of each generation). The proposed model is able to predict accurately the number of generations of *L. Botrana* without considering their location (over a large latitude range) and the climatic conditions and using a single set of parameters.

This model developed for *L. botrana* voltinism will allow predicting the shift in the timing and in the spatial distribution according to different climatic change scenarios. This study provides important information to develop insect pest management tools as for example, to optimize the treatments period or insect release for an optimal biocontrol using natural enemies.

Pacific Phenology Networks

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Traditional Ecological Knowledge, Seminar Room, September 26, 2018, 10:25 AM - 12:25 PM

Although the indigenous peoples of the tropical Pacific have been observing and using phenological events for many generations, formal phenological networks are relatively new. In this paper, we describe the development of phenological networks in three Pacific countries, Samoa, the Solomon Islands and Vanuatu. These networks are coordinated by the National Meteorological Services (NMS), with the measurements taken by community members – generally volunteer rainfall observers. The observers use standardised methods and forms to predominantly record the flowering and fruiting of plant species linked to traditional weather and climate forecasting, with some sites also recording animal phenology. We discuss the value this data adds to the NMS products and to the community members. Issues associated with running the networks, and approaches for overcoming these, are also covered, including dealing with often limited communication infrastructure, training and maintaining the volunteer network, and the impact of extreme events (such as tropical cyclones) on the monitoring program.

Remotely sensed seasonal canopy dynamics in the tropics: a riddle of many scales

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Tropical Phenology, Seminar Room, September 26, 2018, 1:25 PM - 2:45 PM

Leaf demography has been proposed as a major driver of seasonal productivity and optimal plant function in carbon-rich tropical evergreen forests, yet tropical leaf phenology is complex and poorly understood. By combining leaf, canopy and community scale phenological observations we show that complex and diverse leaf phenological behaviours exhibited by tropical canopy trees challenge our current ability to remotely sense tropical canopy dynamics. At the individual tree canopy scale, we found that (1) age-related phenological changes in leaf reflectance are expressed at the canopy scale but influenced by both canopy leaf area (CLA) and the leaf phenological behaviour of individual trees; (2) the seasonality of greenness VIs such as NDVI and EVI2 are more strongly correlated to phenological changes in CLA then changes in leaf reflectance; and (3) NDWI (water content VI) which was found to be strongly correlated to age related changes in leaf reflectance should complement greenness VIs in phenological studies. At the community scale, vertically complex tropical evergreen canopy communities display complex within canopy leaf phenological behaviours that are difficult to monitor. Furthermore, other community scale phenological sources of reflectance and structural canopy variation such as (1) leaf phenological asynchrony within and between trees; (2) short periods of leaflessness in brevi-deciduous trees that are difficult to detect; and (3) lack of seasonality displayed by particular evergreen leaf phenological behaviours can produce dampening effects on the seasonal amplitudes of annual cycles observed by remote sensing VIs. This highlights

the need for more widespread phenological studies that examine the interaction, covariation, asynchrony and unique behaviours of tropical phenological processes at different scales to achieve a significant mechanistic understanding of what creates and drives different phenological mosaics identified across the Amazonian forests and in modelling their effects on water and carbon fluxes across the Amazon.

Climatic controls of spatial patterns of vegetation phenology in the mid-latitude grasslands of the Northern Hemisphere

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Remote Sensing (1), Theatre, September 24, 2018, 3:20 PM - 4:40 PM

Revealing spatial patterns of the grassland growing season and their climatic controls is crucial for estimating spatial heterogeneity of grassland productivity and carbon sequestration. In this study, we first used satellite-derived normalized difference vegetation index (NDVI) data and a double logistic function to extract the start (SOS), the end (EOS), and the length (LGS) of the growing season in the mid-latitude grasslands of the Northern Hemisphere (30oN-50oN) during 1981-2014. Then, we verified the accuracy of satellite-derived SOS and EOS using ground observed phenological records and gross primary production (GPP) data at some locations. Moreover, we analyzed the spatial patterns of growing season parameters and their climatic controls. Results show that either SOS or EOS appears first in Central and West Asia, then in North America, and finally in East Asia. In North America and East Asia, a delaying tendency of SOS and EOS from north to south was identified, whereas an advancing tendency of SOS and EOS from north to south was detected in Central and West Asia. Further analysis indicates that the spatially synergy effect of spring temperature and precipitation triggers SOS in temperate grassland (TG), cool semi-desert grassland (CG), warm semi-desert grassland (WG), and alpine grassland (AG). By contrast, the spatially synergy effect of autumn temperature and precipitation triggers EOS for TG, WG and AG, whereas the spatially antagonistic effect of autumn temperature and precipitation determines EOS for CG. Moreover, the spatial synergy effect of mean annual temperature and annual total precipitation controls LGS in TG and AG.

Identification and timing of dormancy phases for the sweet cherry cultivar ‘Summit’

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Agricultural Phenology (2), Theatre, September 25, 2018, 2:00 PM - 3:00 PM

Dormancy is the temporal inhibition of meristematic growths which occurs as a surviving strategy of trees in climatic regions where significant changes in day length and air temperature occur. According to Lang et al. 1987 it is divided into para-, endo- and ecodormancy. Thirty years after this definition we were able to detect the average timing and duration of these phases for the sweet cherry cultivar ‘Summit’. This information is basic for the validation and revision of phenological models, since the timing of these phases cannot be simply observed and must be adequately handled in the models.

In a 6-year study we sampled twigs from November to December in order to detect the timing of endodormancy release (t_1) under controlled temperature conditions (climate chamber experiments). Additionally, we weekly analysed the fresh weight (FW), dry weight (DW) and water content (WC) of cherry buds from October to mid-April to define ecodormancy release which indicates the beginning of ontogenetic development (t_1*). This approach enabled us to determine the timing and duration of the dormancy phases for ‘Summit’.

Results show that on average paradormancy (BBCH 87-BBCH 97) lasts 133 ± 11.1 days, endo-dormancy (BBCH 97-t_1) 24 ± 3.4 days and ecodormancy (t_1-t_1*) 83 ± 20.7 days. This means that under the climate conditions in NE-Germany ecodormancy lasted 3.5 times longer than endo-dormancy phase. During endo- and ecodormancy phase no changes of FW (62 mg/bud), DW (29 mg/bud) and WC (53 %) was observed. The first sign of ecodormancy release was a

continuous increase in the bud's water content which was forced by rising air temperatures and occurred on average 26 day before bud swelling.

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Climatic impacts on autumn phenology and the contributor to GSL across the Tibetan Plateau

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Changes in the start and end of vegetation growing season (SOS and EOS) are insightful for assessing ecosystem response to climate change because of the high sensitivity of phenology to the climate and their extensive influences on terrestrial ecological processes. From 1982 to 2011, dramatic climate warming resulted in substantial increases in SOS on the Tibetan Plateau (TP). However, it is unclear how EOS changes during this period. We employed multiple remote sensing methods to estimate EOS and SOS from satellite NDVI and investigated the relationship between EOS and its drivers. We also conducted an analysis on the contribution of EOS and SOS to the change of growing season length (GSL). It showed that EOS was primarily driven by preseason temperature, and partly by precipitation and solar insolation. In the southwestern TP, EOS was significantly and positively related with SOS, suggesting a potentially indirect effect of winter meteorological conditions on the following autumn phenology through the regulation of spring phenology. During this period, on average, SOS remarkably advanced by 0.14 day/year (P = 0.086), whereas EOS showed only slight and insignificant delay (0.08day/year, P = 0.140), implying the regionally averaged extension of GSL was mainly caused by an earlier spring. For spatial pattern, SOS mainly advanced (73%) and EOS primarily delayed (73%). As a result of the variation, 79% of the pixels showed extended GSL, where 67% of them were primarily caused by SOS advance, and the other 33% were mainly caused by EOS delay. Interestingly, areas where the spring was the key factor for GSL extension were mainly distributed in relatively dry western part of TP, and contrarily, autumn contributed more to the GSL were located in the wetter northeastern part. This phenomenon suggests the shifts of GSL are dependent on environmental conditions by the performance SOS and EOS

Changes of flowering phenology and their response to climate in subtropical zone in China from 1963 to 2012

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Phenology and Conservation Biology (2), Seminar Room, September 25, 2018, 2:00 PM - 3:00 PM

Over the past few decades, many studies proved that the first flowering date (FFD) for most plants has advanced in response to global warming in temperate ecosystems. However, reports on flowering phenology in subtropical zone in China were quite limited. Based on data obtained from China Phenological Observation Network (CPON), we investigated the temporal distribution and trends in FFD, the end of flowering date (EFD) and the flowering duration (FD) of 75 time series for 14 plants in 10 sites in subtropical zone in China from 1963 to 2012. Multiple regression analyses were applied to examine the relationships between the flowering phenophases and climate factors during preseason. The results showed that: (1) the mean FFD and EFD ranged from February 26 to September 28 and from March 23 to October 19, respectively. Most of FFD and EFD mainly distribute in April. FD ranged from 7 to 88 days with mean value of 23 days. (2) 84% of FFD of the time series studies displayed earlier trends, with 34.7% showing significant advances ($P<0.05$), while none of FFD were significantly delayed. The mean rate of FFD varied from -12.5 days/10a to 2.26 days/10a. EFD of 73.3% of plant species advanced, with 28% were significant, while EFD of only one species was

delayed significantly. FD of more than half of species extended, with 13.3% showing significant changes, while only 5.3% of FD were significantly shortened. (3) Mean temperature during preseason had a significant and negative impact on variance in FFD and EFD for 60~72% species. For most species, temperature sensitivity of FFD was stronger than that of EFD, which would lead to extended FD. Only for 4~14.7% species, FFD and EFD were correlated with total precipitation during preseason. Therefore, changes in flowering phenology can be attributed to temperature rather than precipitation in subtropical ecosystems.

Spring heat and winter chill are key to flowering in sweet cherry

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Agricultural Phenology (2), Theatre, September 25, 2018, 2:00 PM - 3:00 PM

Flowering phenology is critical to fruit production as flowering timing can affect fruit set, yield and quality. Most temperate fruit and nut tree species require winter chill to break dormancy and subsequent spring heat for floral development. Climate change could affect flowering phenology through a reduction of winter chill. Cherry (Prunus avium L.), a high-chill species, may be particularly vulnerable. Understanding flowering phenology in response to past temperature conditions enables insights into impacts of climate change.

To investigate flowering phenology of cherry in Australia, data of full bloom (FB) timing of five cherry cultivars, Bing, Lapins, Sweetheart, Sylvia and Van, in 17 orchard locations across Australia were analysed. All five cultivars recorded advanced flowering ranging from –1.2 to –11.8 days/decade, except for Bing which had mixed results. Inconsistent and weak correlations between full bloom day-of-year and chill accumulation were found for all cultivars, while strong significant positive relationships were found with heat accumulation, highlighting the importance of spring heat on flowering phenology in Australia.

A significant negative relationship was found between chill and heat accumulation in determining FB, implying a likely interaction of chill and heat in influencing flowering timing. In warm locations, late FB timing was likely due to low chill accumulation, while in cool locations late FB timing was primarily dominated by low heat accumulation. Greater understanding of the impact of chill and heat accumulation on cherry phenology is important for the cherry industry to successfully adapt to climate change.

Prediction model of Rice Panicle Initiation to Improve Nutrient and Water Management

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Panicle initiation (PI) represents the beginning of the reproductive stage in rice crops. Management strategies need to be implemented at PI including 1) application of nutrients to increase final yields and 2) raising water levels to protect sensitive tissues from cold weather. PI varies by season, largely in relation to temperature.

Prior knowledge of the timing of PI is needed to implement these management strategies. Unfortunately, in field observation of PI is difficult. Given this difficulty, a mismatch between management and crop physiology may occur. As such, a reliable predictive model of PI is required.

Here, observations of PI and associated temperature data from six Australian sites over six years were used to develop and evaluate a model to predict PI using GDD10. Fifty-five data points were used to fit the model and 7 data points for validation.

The focus here was on PI prediction for 'delayed permanent water', a new, lower water, management strategy. This involves an initial wetting up period (aerobic) followed a flooded period (anaerobic). This strategy modifies PI timing compared with the traditional flooded strategy.

A two-stage efficiency model was developed based on the aerobic stage followed by the anaerobic stage. Parameters for each stage were allowed to differ indicating different efficiency of temperature in each stage in predicting PI. The model with the lowest root mean square error (RMSE) was selected and validated.

RMSE for the parameterising and validating data was 3.8 days and 4.9 days, respectively. Parameter values for the aerobic and anaerobic phases were 1.1 and 1.9, respectively. This means temperatures during the aerobic phase were less efficient than those in the anaerobic phase in promoting PI. This model provides good predictive capacity, and in combination with weather forecasts, will assist growers to better anticipate and manage PI leading to improved production outcomes.

Genotype and environment influence on olive flowering phenology

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Agricultural Phenology (3), Theatre, September 25, 2018, 3:30 PM - 4:50 PM

Olive is a wind pollinated species requiring cross pollination to produce commercial fruit set. In Mediterranean-like climates, olive flowering normally occurs in late spring when climatic conditions often included high air temperature and drought, which are not optimal for an efficient pollination. These conditions could get worse in a climate change scenario on when planting olives outside the Mediterranean. Therefore, it seems important to investigate the genetic and environmental influence on flowering phenology. Here we present the preliminary results of a set of four cultivar comparative trials planted in different climatic conditions in Andalusia, Southern Spain. The evaluation for flowering phenology for three consecutive years has shown a much higher environment than genotype effect for full bloom date and the length of flowering period, being the genotype by environment interaction also significant. Flowering phenology was also investigated in 85 cultivars and in 80 wild olives of an Olive Germplasm Bank located also in Andalusia. In this case, the genotype effect was significant for full bloom time. However, the range of variation for flowering time among cultivars and wilds of the Germplasm Bank was lower than the one produced by the environment in the set of cultivar comparative trials above mentioned. Therefore, the high influence of environment on olive flowering indicates the necessity of developing models to forecast flowering behavior of olive in new growing areas different from the Mediterranean and in future climatic scenarios. For that purpose, olive we set up olive trials in Canary Island, in the Tropic of Cancer, with warmer winters than the Mediterranean. The initial results in cultivar 'Arbequina' showed a lack of synchronization on flowering phenology, i.e., trees having unopened flowers together with fruits already set on the same branches.

Incompatible within-species phenology leads to lowered seed output in an invasive shrub

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Phenology and Conservation Biology (1), September 25, 2018, 10:30 AM - 12:30 PM

Pollen-resource equilibrium suggests that female plant fitness has evolved to be limited simultaneously by both pollen and resource acquisition, including heat from the environment. Heat, or surrounding temperature conditions, can also influence the timing of phenological events. In dioecious species, the magnitude of seed output can be affected by changes in phenology, with overlap in male pollen production and female stigma receptivity required for seed set to occur. Because phenological events are influenced by environmental conditions, this overlap may vary in different environments and affect the opportunity for seed fertilisation and subsequent seed output. Since non-native species did not evolve in their introduced environment, they are unlikely to be at pollen-resource equilibrium. Here we observe an invasive willow (*Salix cinerea*) in its introduced range to better understand the effect of environmental conditions on the phenology and pollen-resource trade-off for non-native species.

We measured the phenology and seed output of populations of *S. cinerea* at low (≤410 m) and high (1640 m) elevation in Victoria, Australia. Warm, low elevation populations had an 18% longer period of phenological overlap than those at cool, high elevation, indicating an increased opportunity for seed fertilization. Additionally, low elevation populations showed approximately five times the amount of seed set as the high elevation population. Here, *S. cinerea* does not appear to be at pollen-resource equilibrium, rather the species phenology is affected by resource acquisition (hear accumulation), causing lowered pollen availability at the time of stigma receptivity, which leads to lowered pollen acquisition and seed output overall.

Informing decision-making at local to regional to continental scales

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Phenological Methods (2), Theatre, September 25, 2018, 10:30 AM - 12:30 PM

The USA National Phenology Network (USA-NPN) is a federally-funded, national-scale science and monitoring initiative focused on phenology as a tool to understand how plants, animals, and landscapes respond to environmental variation and change. The Network provides a platform for data collection by professional and citizen scientists and delivers freely available quality-controlled data and products to advance science and to inform decisions.

Although a primary aim of the Network is to inform decisions in a diversity of realms, including natural resource management and human health, much of the Network's first ten years was focused on data products to advance scientific understanding of phenology. Recently, we have embarked on a more concerted effort to facilitate informed decision-making by using stakeholder input to guide data product development and delivery.

Using a co-production framework, we are engaging stakeholders to define new data products designed to fill critical phenology-relevant information gaps necessary for timely execution of management activities. Examples include phenology dashboards tailored to specific US National Wildlife Refuges and 6-day forecast maps for the onset of key life cycles stages of invasive pest species.

New technologies for large-scale integration of plant phenology data

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Plant phenology — the timing of plant life-cycle events, such as flowering or leafing out — plays a fundamental role in the functioning of terrestrial ecosystems, including human agricultural systems. Because plant phenology is often linked with climatic variables, there is widespread interest in developing a deeper understanding of global plant phenology patterns and trends. Although phenology data from around the world are currently available, truly global analyses of plant phenology remain difficult because the organizations producing phenology data use heterogeneous terminologies and metrics during data collection and data processing. To address this problem, we are developing new technologies to support large-scale, automated integration of disparate phenology data, including the Plant Phenology Ontology (PPO) and a highly customizable data processing pipeline. In particular, the PPO provides the standardized vocabulary and semantic framework that is needed for robust integration of heterogeneous plant phenology data. The PPO is applicable to nearly all gymnosperms and angiosperms, is suitable for both single plants and populations of plants, and is compatible with the data and data collection methods of existing national or regional phenology monitoring programs in the USA and Europe. We are using the PPO and data pipeline to lay the groundwork for a global phenology knowledge base and data portal, and to this end, we have assembled a large, preliminary dataset of phenology observations from North America and Europe.

Understanding the resilience of bee-plant phenology in the Western Ghats, India, using long term data.

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Tropical Phenology, Seminar Room, September 26, 2018, 1:25 PM - 2:45 PM

The onset of flowering in plants and appearance of pollinators has been suggested to advance linearly in response to recent temperature increases. Phenological responses to climate warming may or may not occur at parallel magnitudes in plants and pollinators and there can be considerable variation in responses across species. While most studies show similarity in temporal responses, they have also been few cases of mismatch of plant-pollinators interactions which leads one to ask how resilient these systems are. While most of these studies are pertaining to temperate conditions tropical forest species have often been regarded as relatively aseasonal and little is known of the links between weather, flowering phenology and pollinators particularly in complex rainforest habitats. Mismatches in pollination interactions are still rarely explored here and their consequences are largely unknown.
Apis dorsata (Rock bee), is a key pollinator of plant species in the Western Ghats. It is also an elevational migrant which tracks the flowering phenology of tree species which shifts from lower elevation dry forests at 400 m to wet evergreen forests at 1200 m in the Southern Western Ghats, India. Our long-term phenological studies (1991-2016) has shown bee arrival in the rainforests determined by the flowering of the tree *Palaquium ellipticum*. The flowering period coincides with pre-monsoon period in May before the onset of South West Monsoon with occasional drizzle which does not deter the honeybees visiting the flowers. However, there have been changes in the rainfall patterns in the area which could influence this bee-plant association. We therefore examine the probable causative factors of *A. dorsata* and *P. ellipticum* association and also assess how resilient the association is to variations in temperature, rainfall pattern and other biotic factors.

Determining the contribution of shrubs to forest phenology using in-situ observations and newly acquired Venµs-satellite-data

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Remote Sensing (2), Theatre, September 26, 2018, 10:25 AM - 12:25 PM

The start and end of the growing season in deciduous forests have traditionally, been determined by the timing of leaf-out in spring and leaf fall in autumn of the dominant tree species. Subsequently, these parameters are used in ecosystem modelling to define the active carbon uptake period for these ecosystems and when a forest transitions form carbon source to sink and vice versa. However, shrubs, generally, leaf out before trees in order to take advantage of high light levels prior to canopy closure and therefore may be expected to make a significant contribution to the timing and rate of carbon uptake especially in early spring as leaves develop. Surprisingly, given the importance of this role, studies on shrub phenology are few. A range of native and introduced shrub species were identified and monitored in a deciduous urban woodlot on the University of Wisconsin-Milwaukee campus, to determine the timing and duration of key spring (bud-open, leaf-out, full-leaf unfolded) and autumn (leaf color, leaf fall) phenophases. Preliminary results revealed surprising results with buckthorn *Rhamnus cathartica* (an alien invasive species) leafing out later than most native species (currant *Ribes americanum*, maple leaf viburnum *Viburnum acerifolium* and nannyberry *Viburnum lentago*) and taking longer to reach full-leaf unfolded. We propose to use these observations (and others) to validate a dataset from a new Earth observation microsatellite: VENµS (Vegetation and Environment monitoring on a New Micro-Satellite) launched, August 2017. VENµS data will become available in summer 2018 and are provided at high spatial (5 and 10

m) and temporal (every-2-days) resolution allowing for small scale comparison between different phenological metrics. The results of this research could help provide better understanding of the relationship between shrub phenology and the potential for carbon storage in early spring which in turn could result in more accurate carbon budget determination.

Linkages between phenology and reproductive efforts to experimental warming and simulated snowstorms in central Tibet

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Phenology and Conservation Biology (2), Seminar Room, September 25, 2018, 2:00 PM - 3:00 PM

Changes in plant flowering phenology are hypothesized to alter reproductive effort, the maximum number of flowers, but empirical evidence is limited in linking these two, particularly under the global climate change scenarios. We used 7 years' of a fully factorial climate change field experiment to understand: 1) how warming and simulated snowstorms affect the date of first and last flowering in *Potentilla saundersiana* Royle and *Potentilla fruticosa* L.; and 2) how changes in flowering phenological events alter flowering duration and reproductive effort in response to warming and snowstorms on an alpine meadow in central Tibetan Plateau. We found that warming significantly advanced date of first flowering in both *P. fruticosa* and *P. saundersiana*, the effect of warming on the last date of flowering, flowering duration, and reproductive effort were not significant. Simulated snowstorms delayed the dates of first flowering in *P. saundersiana*, but the effects were not significant in *P. fruticosa*. There were no significant treatment interactions in both species. Flowering duration contracted when the first date of flowering occurred later, but expanded when the last date of flowering occurred later in both species. The maximum number of flowers increased in both species when the date of last flowering occurred later and when the duration of flowering was longer. However, the date of first flowering did not affect the maximum number of flowers in either species. These results indicate that climate change may alter alpine plant phenology, but changes in the date of first flowering alone does not guarantee to induce changes in flowering duration, thus the reproductive efforts, suggesting the needs for including the complete components of flowering phenological events in the future studies, and the role that the date of last flowering plays in mediating plant reproductive effort and success needs to be further investigated.

Sprinter and Sprummer: Australia's Changing Seasons

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Phenology and Citizen Science, Seminar Room, September 24, 2018, 10:55 AM - 12:15 PM

Since 1788, Australia has persisted with four European seasons that make no sense in much of the country. We may like them for historical or cultural reasons, or because they are they are (apparently) the same throughout the world, but they tell us nothing, and reflect less, of our natural environment. I argue for a rejection of these seasons and the adoption of a system that brings us more in tune with our plants and animals; a system to help us to notice and respond to climate change.

I propose a 5-season model for southern Australia, starting with sprinter (August and September), the early Australian spring. That's when the bushland and our gardens burst into flower. That's also when that quintessential Australian plant, the wattle, is in peak flowering across Australia. Next is sprummer (October and November), the changeable season, bringing a second wave of flowering. My summer (December to March) is four months long, extending into March. My autumn (April and May) reflects the brief colouring of leaves on mostly exotic trees, but also peak fungal fruiting. Winter (June and July) is for that short burst of cold weather.

I'm not the first to suggest an alternative way to divide up the year. Our Aboriginal communities have watched the world around them over tens of thousands of years, and come up with two to thirteen seasons to suite their local area. I'm also not the first recent immigrant to suggest we need a change. Any system covering such a large area will be a compromise,

and I've based mine mostly on what plants do. Whether my new seasons are adopted or not, I hope they encourage people to take better notice the natural world around us and how it changes.

Traditional Phenological Knowledge in Tonga

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Situated in Polynesia, the Kingdom of Tonga is an archipelago made up of nearly 170 islands. Phenological knowledge in Tonga has been traditionally passed from generation to generation via stories, song and other cultural practices. In recent years, the Tonga Meteorological Service has been working with local partners to document phenological knowledge associated with weather and climate forecasting and seasonal activities, including farming and fishing.

Analyses of photosynthetic phenology of complex Australian canopies derived from a 3D model simulations of seasonal solar-induced fluorescence

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Remote Sensing (2), Theatre, September 26, 2018, 10:25 AM - 12:25 PM

The solar-induced chlorophyll fluorescence (SIF) has been used as an indicator of vegetation photosynthesis. This relationship allows its use for measuring of seasonal photosynthetic efficiency in response to environmental stress, such as extreme heat and drought. Although SIF can be measured from satellite (OCO-2, GOME-2), a complex structure of vegetation layers and optical interactions with non-vegetation landscape components hind its stress. Radiation transfer models have been developed to understand the SIF. However, they are in one-dimension and only assume homogeneous vegetation structures horizontally. One-dimensional models cannot even study the radiation distribution in vertically. A three-dimensional model can scale SIF emitted by single leaf up to canopy level would be more helpful to understand SIF emission under heterogeneous canopies. We integrated the excited fluorescence matrices (EF-matrices) and three-dimensional radiative transfer model (FLiES) based on Monte Carlo method and photon tracing frame. Vegetation structure and the leaf parameters, including chlorophyll content, water content and EF-matrices, were retrieved from LiDAR data and leaf's reflectance transmittance, respectively. We tested this model at Alice Springs Mulga and Cumberland Plains, two flux tower sites in Australia. The results suggested that the scattering effect of fluorescence varied along with the wavelength and it contributed a lot in the far-red region. Also, it showed that the SIF at the top of canopy (TOC) raised according to the seasonal increasing of LAI and chlorophyll content. This model will help understand the variation of SIF by bridging the gap between different scales of data.

Spatio-temporal change in phenology and its impacts on net primary production in temperate China

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Study on phenology changes and their spatial patterns is an important basis for understanding the interactions between terrestrial ecosystems and climatic systems and the mechanisms of increased vegetation activity over the past three decades. Here, we use satellite derived NDVI (Normalized Difference Vegetation Index) data and a terrestrial ecosystem model named CASA ("Carnegie – Ames – Stanford Approach") model to quantify changes in spring and autumn vegetation phenology and their impacts on net primary production (NPP) for China's temperate vegetation. We found that the majority of China's temperate region (80% of the study area) has experienced an increase in growing season length

(GSL) during the past three decades, with an annual mean increase rate of 0.74±1.29 days yr-1 (-0.49±0.89 days yr-1 of spring and 0.24±0.84 days yr-1 of autumn). Our results also show that phenology changes are highly variable across the regions. Generally, the magnitude of spring advancement increases along the elevation gradient. GSL closely correlates with annual NPP, although its effect on NPP varies among different biomes. Over the entire study area, a one-day extension in GSL may lead to a 0.5% increase in annual NPP (or 0.7 g C m-2 yr-1). We also found that changes in onset timing of spring (green-up) and autumn (senescence) play strikingly different roles in vegetation production. Over the entire study area, an earlier start of growing season can considerably increase annual NPP, while a later conclusion of growing season has little impact on annual NPP. Such different roles of spring and autumn phenology changes may have important implications for the global carbon cycle.

TEMPO - A French national long-term network to observe phenology of all the living kind.

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Phenology and Citizen Science, Seminar Room, September 24, 2018, 10:55 AM - 12:15 PM

TEMPO is a French long-term observation and experimentation system for environmental research (SOERE) dedicated to the observation of phenology of all the living kind. Measured variables in TEMPO are phenological variables, i.e. dates of occurrence of phenological events, e.g. for plants: flowering, leafing, fruit maturity, leaves coloring, etc; for animals: date of first appearance, reproduction, etc. TEMPO is the continuity of different national projects that they were developed individually during the last ten years.

TEMPO structures 11 national observatories, ten dedicated to the phenology of a taxonomic group or system: forest, fruit trees, grapevine, annual crops, weed, grassland, pathogens, arthropods, fishes, reptiles; and one citizen science observatory.

The main scientific objective of TEMPO is to understand and forecast how climate change impacts the seasonal rhythms of living organisms, and what are the consequences on ecosystem functioning and production, as well as on population dynamics. The main technical objective of TEMPO is to increase the degree of observation harmonization, and facilitate data sharing and dissemination to the greatest number of users.

TEMPO is relevant to ecologists, agronomists, and more generally researchers in environmental sciences working at INRA (and in other institutes), but also to various economic sectors depending on natural resources.

Finally, TEMPO provides to local, regional and national authorities/stakeholders indicators of climate change impact on the biodiversity of their territories.

Assessing crop feasibility under climate change conditions using ecoclimatic indicators. Several cases studies in France.

Dr Iñaki Garcia de Cortazar Atauri[1], Dr Julie Caubel[2], Dr Marie Launay[1], Dr Patrick Bertuzzi[1], Dr Frédéric Huard[1], Dr Nathalie de Noblet[3], Ms Marine Marjou[1], Mr Augustin Dura[1], Mr Olivier Maury[1]
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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Climate change is expected to affect both regional and global food production, expecting changes in overall climatic conditions and therefore, on the suitability for cropping. Assessment of when and what meteorological stresses will crops

meet in the future is highly useful for planners, land managers, farmers and plant breeders who can propose and apply adaptation strategies to improve agricultural potentialities.
The most common way to investigate potential impacts of climate on the evolution of agrosystems is using agroclimatic indicators, which provide synthetic information derived from climatic variables (classically temperature and rainfall) and calculated within fixed periods (i.e. April first – 31th July). However, the information obtained during these periods does not take into account the plant response to climate. In order to take into account this information, we have developed a suite of relevant indicators (thereby called ecoclimatic), which are calculated during specific phenological phases (e.g. sowing period - flowering, flowering- harvest). These indicators are linked with the ecophysiological processes they characterize (for e.g. the grain filling).

Taking into account the phenology in this calculation allow us to better represent the impact of climate change in the different processes of the plant growth and development.

In this presentation, we will show different examples about how we can apply them to study and understand past, present and future conditions of various crops (grapevine, wheat, maize) in France.

The within-population variability of leaf spring phenology is controlled by temperature.

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

The phenology of leaves is a major driver of various processes in temperate forests, such as ecosystem productivity, population dynamics, species distribution, and trophic interactions. Moreover, phenological traits are considered robust indicators of climate change. Until now, most phenological studies have addressed the inter-annual and inter-population variability of phenology, but the within-population variability of leaf phenology has been far less studied. Beyond its impact on individual tree physiological processes, the within- population variability of leaf phenology can affect the estimation of the average date of the phenological event at the scale of the population. Focusing on spring phenological phases, we postulated that both the average date of budburst and the temperature conditions during budburst would affect the magnitude of the within-population variability of leaf phenology (quantified as the standard-deviation of the distribution of individual dates of budburst, SDBB). Overall, we found that a later average budburst date combined with warmer temperatures during budburst were associated with a lower SDBB. We also found ambivalent influences of cold spells on SDBB with low temperatures occurring during budburst tending to increase SDBB while low temperature occurring before bud development tending to delay the average budburst date and reduce SDBB. Finally, our study revealed that given the natural variability of budburst dates occurring in temperate tree populations, a minimum sample size of 22 and 34 individuals, respectively, are required to estimate SDBB and average dates of budburst with a precision of 3 days.

Cool Old Plants, Warm New World: Assessing Climate Change Induced Phenophase Shifts in Alpine Plants

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Phenology and Conservation Biology (1), September 25, 2018, 10:30 AM - 12:30 PM

Since the botanical pioneering of Ferdinand von Mueller during the 1850s, flora of the Australian Alps has been extensively sampled and stored in herbarium collections. Increasingly, non-conventional data sources such as herbarium records are being drawn upon to make inference about how species may be responding to global environmental change. While there are broad-scale studies of alpine flowering phenology based on digitised voucher labels, qualitative assessments of structural and phenological traits from entire herbarium specimens are lacking. My first-order goal in this project is to use digital images of herbarium specimens to assess whether structural and phenological change has occurred in Australian alpine plant species over time, corresponding to increases in temperature and decreases in snow cover. My second-order goals are to (1) determine if collection altitude is a useful predictor in assessing the velocity and magnitude of reproductive trait shifts; (2) classify the phenological status (phenophase) of herbarium specimens to determine if the timing and intensity of phenophases is changing through time; and (3) determine if phenological and structural trait shifts are phylogenetically conserved among the alpine flora. The study is representative of the mainland alpine flora and includes all growth forms (tree, shrub, herb, rosette, graminoid, cushion) and eighty-eight species from fifty genera representing twenty-four families. In focusing on annually replaced reproductive structures of long-lived alpine plants, the wide temporal range offered by herbarium records provides a rare opportunity to identify meaningful response trends through time.

Trees, Twigs, Temperatures and Saccharides in Sweet Cherry Buds

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Agricultural Phenology (3), Theatre, September 25, 2018, 3:30 PM - 4:50 PM

Plant species vary in their dormancy phenomena. Physiological changes are known to occur during cold acclimation. To withstand low temperatures, plants synthesize osmoprotectants. Sucrose, glucose and fructose accumulation during winter appears to be related to their properties of cryoprotection of buds. Experimental research targeted at revealing mechanisms of tree phenology is facing methodological constrains, since whole trees manipulation in situ are restricted. The aim of this study was to answer the question whether synthesis and catabolism of sucrose in buds is reversible and influenced by air temperature. Buds of trees (A) and twigs ('Summit') were compared. After cut, twigs were kept in the orchard (B) or kept first 3 weeks at 20 °C (controlled conditions) and subsequently placed 3 weeks in the orchard (C). Bud cluster were taken weekly (A-C) for analysis of sucrose (Suc), glucose (Glu), fructose (Fru), raffinose (Raf) and stachyose (Sta).
In buds of trees (A) Suc, Glu, Fru content (32, 20, 22 mg g^{-1}) raised markedly during endodormancy to the beginning of ecodormancy (45, 28, 29 mg g^{-1}, $p<0.05$), whereas Raf and Sta decreased (8, 13 to 3, 4 mg g^{-1}, $p<0.05$). In buds of twigs (B) low temperatures in the orchard (T_{mit} 3.5 °C) lead to degradation of Suc after 3 weeks (34 to 25 mg g^{-1}, $p<0.05$), while Glu and Fru markedly increased (19, 21 to 35, 41 mg g^{-1}; $p<0.05$). Putting twigs in water trigger the demand of Glu and Fru for mechanism, like cell wall defence, osmotic adjustment (vacuole) and oxidative defence related processes (mitochondria). Temperatures of 20 °C resulted in buds (C) in significantly sucrose degradation (29 to14 mg g^{-1}) and a markedly re-synthesis (23 mg g^{-1}) after 3 weeks in the orchard (T_{mit} 2.7 °C). Therefore, comparisons regarding of metabolites between trees and twigs need to be critically considered.

Inaccuracy and Inconsistency of Growing Degree Days in Winkler and Huglin Indices

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Growing degree days (GDD) have been widely used in grapevine phenology and physiology studies. The daily GDD (dGDD) is calculated from temperatures (Ti) above a growing base temperature (Tgb) and the corresponding time interval (Δt). Cumulative GDD (cGDD) is then calculated as the summation of dGDD's over a period of time to model phenology and to investigate climatic impacts. For a set of n Ti's, dGDD can be approximated by rectangular integration, dGDD = ∑_(i=1)^n max(Ti – Tgb, 0) * Δt. In practice, dGDD's are often calculated from daily minimum and maximum temperatures (dTmin and dTmax). dGDD in Winkler Index is based on the mean of dTmin and dTmax (dTmm), dGDDmm = max{(dTmm – Tgb), 0} * 1 day, where dTmm = ½ (dTmin + dTmax). dGDD in Huglin Index is based on the mean of dTmm and dTmax (dTmm.m), dGDDmm.m = max{(dTmm.m – Tgb), 0} * 1 day, where dTmm.m = ½ (dTmm + dTmax) = dTmm + ¼ (dTmax – dTmin). A finite error (FE) exists when dTmm or dTmm.m deviates from the average of continuously measured temperatures. A hidden negative error (HNE) is introduced when dTmin below Tgb is averaged into dTmm or dTmm.m prior to applying Tgb. HNE in dGDDmm.m is smaller than that in dGDDmm because dTmm.m > dTmm. FE in dGDDmm.m is inflated by ¼ (dTmax – dTmin) * 1 day when dTmin Tgb. Errors in cGDDmm are relatively stable over time but become larger over time. The latitude coefficient used in Huglin Index further increases positive error. Both FE an HNE can be reduced when Ti's of a short interval are used for GDD approximation. GDD calculated from hourly temperatures (GDDh) is adequately accurate and consistent. GDD's based on only dTmin and dTmax are inaccurate and inconsistent and therefore should be avoided.

Confidence Envelopes for Trends and their Derivatives Embedded in Phenological Time Series

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Phenological Methods (2), Theatre, September 25, 2018, 10:30 AM - 12:30 PM

A recent focus of phenology is to assess how recent warming affects phenophase developments. One approach to achieve that is by estimating the "warming trends" embedded in relevant time series. To better understand the properties of the estimated trends and to make inferences, we also need to estimate at least their 1st- and 2nd-derivatives and to establish confidence envelopes (CEs), which are challenging tasks because phenological time series are typically nonlinear and nonstationary. This study combines ensemble empirical mode decomposition to estimate trends and their derivatives, and maximum entropy bootstrap to establish CEs. Both methods are data-driven, requiring no structural, distributional, linear, or stationary assumption. An example based on a composite Prunus spinosa L. (blackthorn) first flowering date (FFD) anomaly series from Germany and its corresponding temperature anomaly series is presented. Both extracted trends corresponded well, as did their approximated 1st- and 2nd-derivatives. Both extracted trends were nonlinear with a turning point around 1970, and increased or advanced rapidly afterwards. Furthermore, both trends had a sigmoid velocity curve and a concave acceleration curve. Closer examinations of the CEs revealed that time lags existed between the two trends and between their corresponding derivatives with FFD leading. This lead-lag relationship is puzzling as it contradicts our current understandings about the cause-and-effect connection between temperature and blackthorn FFD. More importantly, the CEs showed that the acceleration began to decelerate quickly soon after we could declare a statistically significant increase in temperature or an advancement of FFD. The functional forms of the estimated 2nd-derivatives indicated that natural variability also contributed to both trends. These results, which conventional statistical methods may be unable to reveal, demonstrate that just to extract and match trends embedded in phenological and meteorological time series is not enough.

Stronger temperature sensitivity of flowering phenology in lower temperature conditions and later stages of development

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Phenological Methods (2), Theatre, September 25, 2018, 10:30 AM - 12:30 PM

Temperature sensitivity of spring phenology is related to the ability of plants to cope with climate change. The previous studies showed that temperature sensitivity varied with period and stations, which can be attributed to the difference in climate conditions. However, the specific relationship (linear, logarithmic or exponential?) between temperature conditions and temperature sensitivity is unclear. In this study, we gathered twigs with dormant flower bud of five woody plants (*Malus halliana*, *Forsythia suspense*, *Crataegus pinnatifida, Prunus cerasifera f. atropurpurea*, and *Berberis thunbergii* var. *atropurpurea* Chenault) in early spring of 2017 at Beijing, and placed them in six growth chambers at same daylength but different temperature conditions (5, 10, 15, 20, 25 and 30°C). The proportion of flowering buds which have burst was documented per day for each species in each temperature condition. The results showed that the proportion of flower buds which have burst followed the logistic function at a given temperature. Therefore, we develop a model to simulate the bud burst proportion at any temperature and date. The models could explain the observed bud burst proportion with $R2>0.9$. Subsequently, the development rate (DR) and temperature sensitivity (TS) was parameterized using the differential method. The simulation results showed that DR became stronger with higher temperature. At a given temperature, DR first becomes faster and then slows down with the process of flower development. TS becomes weaker with the increase in temperature, but the decrease in TS becomes weak when temperature is high enough. Furthermore, TS becomes stronger with the process of flower development. These experimental results are robust when analyzing the long-term flowering data (1963-2016) at Beijing.

Impacts of Snow Cover Duration on Vegetation Spring Phenology over the Tibetan Plateau

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Remote Sensing (1), Theatre, September 24, 2018, 3:20 PM - 4:40 PM

Snow cover duration plays a critical role in regulating alpine vegetation's phenology by affecting the energy budgets of land surface and soil moisture conditions. This study analyzed trends of snow cover duration (SCD) in relation to the start of season (SOS) over 2003-2015 on the Tibetan Plateau. The remote sensing datasets from the Moderate Resolution Imaging Spectroradiometer (MODIS) were utilized to compute the SOS and SCD on the Tibetan Plateau over 2003–2015. Asymmetric Gaussian function was applied to extract SOS. We also explored the spatial pattern and temporal variation of SOS and SCD. Then by using correlation coefficients, we investigated the driving effects of different period's non-growing season SCD on SOS. The Non-growing season SCD slightly decreased during 2003-2015, while SOS exhibited an overall advanced trend. Snowfall exhibited two separate peaks during autumn and late winter over the plateau. Different season's snow cover caused distinct effects on vegetation SOS. Lengthened autumn snow cover duration advanced SOS over the eastern plateau. The slightly lengthened SCD postponed SOS over the western plateau. For the wet meadow regions, advanced SOS was positively associated with SCD during the entire non-growing season, whereas for the dry steppe, SCD over the preseason played a more dominant role. This study confirmed the importance of snow cover duration to phenological processes at the beginning of growing season, and further suggested that role of snow cover should be discriminated for different period and for different heat-water conditions. With these effects considered, predictions on the Tibetan Plateau's spring phenology could be improved.

Interactions of vegetation phenology with the urban heat island in Australian cities

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Urban Phenology, Seminar Room, September 24, 2018, 3:20 PM - 4:40 PM

An urban heat island (UHI) occurs when higher temperatures are encountered in built environments of cities compared with surrounding rural areas. Landscape alterations driven by urbanisation cause changes in radiative, thermal, and moisture patterns of the land surface and by definition, both rural and urban surface changes will impact the UHI, leading to potential uncertainties in UHI measures. Phenological differences among land cover classes, and in particular between urban and rural reference areas will generate asynchronous effects on the derived UHI that may amplify or mitigate surface temperatures and associated UHI.

In this study, we investigated the urban, peri-urban and rural interactions of vegetation phenology on UHI patterns and dynamics of two Australian cities, Sydney and Melbourne. Using land surface temperature (LST) and vegetation index satellite data from MODIS and Sentinel-2 sensors, we monitored greenness, green space areas, and temperatures, at diurnal, weekly, and monthly time scales across the urban to rural transition areas. We found a year-round heat island in Sydney, but with no LST trends over the past 18 years. This contrasted with a significant UHI increase in Sydney, a consequence of rural areas becoming cooler over the same time period, a result of increasing amounts of vegetation, confirmed by satellite greenness values. Similar results were found for Melbourne, but with surrounding pasture areas generating a negative heat island at certain times of the year. In both cities, inter-annual variations in UHI were driven by vegetation dynamics of surrounding areas. We conclude that continued urbanisation induces complex interactions and feedbacks among temperature, greenness, and phenology that impact UHI measures. Further research is needed to interpret the meanings of UHI in such dynamic environments.

Early sowing & winter phenology can adapt Australian wheat production to rainfall decline

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Agricultural Phenology (1), Theatre, September 24, 2018, 10:55 AM - 12:15 PM

Australia is an important region for global food security, annually producing ~25 Mt of rainfed wheat, most of which is exported. Currently, spring wheat cultivars (no vernalisation requirement) are established on late autumn (April-May) rains, and flower at an optimal time in early spring defined by increasing incidence of drought and heat and decreasing frost risk. Australian wheat yield has plateaued since 1990 due to reduced April-May rainfall delaying germination and reducing water supply. If Australia is to increase wheat production in line with projected global population growth and demand, an improvement in yield is required. To this end, we compared a system of sowing winter wheat (obligate vernalisation requirement) in an unusually early sowing window (from early March, at which time rainfall has not declined), with the current practice of establishing spring cultivars in early- to mid-May. We grew near-isogenic lines of wheat which vary in alleles of major development genes in 24 experiments with multiple sowing dates, at 16 sites across the Australian wheat belt from 2012 to 2016. We found the yield advantage of the early sowing strategy over current practice was 0.3 t/ha (10%) in the southern Mediterranean environments of the wheat belt, but not significant in southern temperate environments. There was a yield reduction in the warmer, summer rainfall dominant northern environments. To evaluate the impact of potential practice change at the farm level and extend these results across multiple sites and seasons, we conducted simulation experiments using the APSIM crop production model. In southern Mediterranean and temperate environments, adopting the early sowing strategy increased predicted average farm wheat yield by 0.7 t/ha (range 0-2.5 t/ha) or 27%. Spatially interpolating the optimal strategy (i.e. retaining current practice where no benefit was demonstrated) showed a mean national benefit of 0.6 t/ha (s.d. = 0.4) or 25%.

The Indigenous Phenology Network: Engage, Observe, and Adapt to Change

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Traditional Ecological Knowledge, Seminar Room, September 26, 2018, 10:25 AM - 12:25 PM

The Indigenous Phenology Network (IPN) is a grassroots organization whose participants are interested in understanding changes to seasonality and timing of life cycle events, and forecasting impacts to lands and species of importance to native peoples. The group focuses on building relationships, ensuring benefit to Indigenous communities, and integrating diverse knowledge systems. Recognizing that Indigenous self-determination includes the right to determine the framework under which we collaborate, the IPN's work is guided by the Relational Doctrine, a set of principles founded on the notion that all things are connected.

This presentation showcases the IPN principles and approach, as well the work of our members and their experiences in diverse communities and landscapes facing impacts from a changing climate and extreme weather events. Impacts on water supply, vegetation, wildlife, and living conditions, and ideas for minimizing and responding to the projected impacts of continued change will be discussed in the context of multi-generational, place-based traditional knowledge and community resilience. Scalable, community-based gardens, for example, provide a sustainable source of traditional, locally grown food, most valuable in times of disaster when supplies from the outside world are unavailable. Following the concept of Victory Gardens, the model of small-scale agroforestry (VICTree Gardens - Virtually Interconnected Community Tree Gardens), being implemented in Hawai'i, has the potential to provide a diverse diet of food grown in very limited space. Gardens build resilience by connecting people with each other, with local food, and with nature. We envision community-based projects where local, multi-generational knowledge is applied to adapt the gardens to changing environments. Going forward, direct observation of garden conditions can be combined with satellite and ground-based measurements of environmental conditions, such as soil moisture, soil and air temperature, precipitation, and phenology, to further assess and manage these gardens in the context of the surrounding landscape.

Grassland productivity in response to interannual variabilities of biogeochemical regulators on the Tibetan Plateau

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Grasslands on the Tibetan Plateau (TP) have intensively changed due to dramatic climate warming and human activities over the past decades. However, the trend and amplitude of the variability of grassland productivity exhibited obviously spatial heterogeneity, and the underlying mechanisms have not been fully understood. In this study, remote sensing data adopted used to detect the temporal and spatial pattern of annual productivity of grassland (indicated by MODIS EVI) and its causes during last 15 years. Unlike the previous studies which investigated the relationships between climatic/environmental variables and productivity, we tried to explain the productivity variations in view of biogeochemical regulations, which argues that a variety of biogeochemical processes (e.g. biogeochemical processes and disturbances) directly result in differential changes in ecosystem functions. Here, two phenological variables including start and end of growing season (SOS and EOS) and a physiological variable (annual maximum EVI (EVImax)) were adopted to represent biogeochemical processes. The relative contributions of the biogeochemical regulators to productivity variations were identified based on the first difference method and panel analysis, and the corresponding causes were

discussed. The results showed that 69.9% (30.1%) of the total TP grassland exhibited an increase (a decrease) in annual productivity, and 73.3% (53.5%) of these showed statistically significant ($p<0.05$). We found the phenological and physiological variables could well explain the interannual variability of grassland productivity (76.3±10.7%) across the TP. In general, an annual productivity positively related to an advanced SOS, delayed EOS and enhanced EVImax. Of these regulators, EVImax greatest contributed to the variation of annual productivity, indicating physiology rather than phenology dominated the productivity of the TP grassland. Additionally, both negative and positive contributions of disturbances to annual productivity were found mainly in south-central and east TP, which may be associated to graze and vegetation restoration, respectively.

The influence of intra-urban microclimate on tropical phenology: The city of Kampala, Uganda

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Urban Phenology, Seminar Room, September 24, 2018, 3:20 PM - 4:40 PM

Urban phenological studies are often used for spatial and temporal analysis of urban heat islands. However, plants growing in urban microenvironmental conditions can also be used for the assessment of future climate change impacts on phenology more generally. Much urban phenological research is undertaken in cities experiencing temperate climates where phenology is largely temperature dependent. Urban phenological studies in tropical cities, where precipitation is a key phenological driver, are relatively rare. The little that is known about phenology of trees in the tropics primarily emanates from studies undertaken in natural habitats. Consequently, it is unclear whether the often downplayed influence of temperature frequently found in tropical phenology literature, remains true in an urban context. The few studies which have been undertaken in tropical cities compare phenology between urban and rural areas and report indistinct phenological differences. The main challenge faced by using the urban-rural dichotomy is that it overlooks the role of local land cover in regulating the factors that control phenology.
Here we present results from research that aimed to determine to what extent urban morphology, and thus urban climate, influences phenology in a tropical city. Specifically, we monitored the seasonal development of two tree species (*Jacaranda mimosifolia* and *Tabebuia rosea*) across distinct local climate zones (LCZs) in Kampala, Uganda during the 2017 growing season. Each of the LCZs represented a different form of urban climate and thus overcome the urban-rural dichotomy. Using hierarchical cluster analysis, our findings reveal variation in leafing and fruiting patterns between LCZs. Shorter leaf growing seasons are observed in LCZs that are heavily built and have high impervious surface cover than LCZs that have high vegetation cover and pervious surface cover. The internal local mechanisms that drive phenological variation in LCZs within a tropical context will also be discussed.

Locating and restoring remnants of potential micro-refugia in the range edges of vegetation formations as public good

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Assessment shows a 90% decline in the dry woodlands of Pakistan over the last hundred years. The natural environment in these areas has become overwhelmingly cultural and conventional methods of restoration seem to have limited potential under the present scenario. The objective of this work was to propose and locate 'climatic micro-refugia' to use as pilot sites especially, on range edges or ecotones. The overall goal is to enhance natural regeneration of remnant dry woodlands, allowing the species and population to interact with a changing environment to maintain their evolutionary fitness under the prevailing threats of climate change. Another goal was to bolster greater public awareness of Pakistan's dry forests, four degraded dryland ecosystem were identified and restored: i) Flood plains thorn forests at a salt affected archaeological site in Harappa; ii) Desert thorn forest on sand dunes in Thal. iii) Scrub forests at four sites in the Salt range. iv) Endangered tropical dry deciduous forests at Shakargarh. These sites, in spite of their small scale seem to have impacted upon behavior of the individuals and institutions. It is hoped that a network of such areas would support and contribute to national, regional and international conservation policies, through documentation, research and advocacy and towards pluralistic representation in planning and management of threatened ecological communities.

Flowering and flowering order in an Australian understory

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

A warming climate is causing the timing of first flowering day to shift in some species. This shift may also change the flowering order within a community, which can alter competition for pollinators, the timing of food sources for fauna etc. However, evidence of shifts in flowering and flowering order is limited in Australia.

We used linear regression to determine whether there had been a change in first flowering dates (FFD) of 81 understorey species from Beaconsfield, Victoria over 32 years (1983 to 2014). We also used CUSUM to see if there was a specific year in which FFD changed. We used rank-biased overlap (RBO) to examine the stability of mean flowering order (FO) between two periods (1983-1998 and 1999-2014).

Nineteen species showed a change in FFD ($P \leq 0.02$): 17 to earlier (range: 0.18 to 1.29 days/decade) and 2 to later (0.36 & 0.39 days/decade). Change point years associated mainly with drier years were detected in 29 species ($P \leq 0.03$) ranging from 1987 to 2013. CUSUM identified a significant shift at the community level in 2006 to a mean earlier FFD ($P = 0.03$; 11.2 days).

When comparing the two periods the range of FFD at the community level in the second period was shorter by 2 months. In total 68 species change their FO: 31 species advanced (mean=7.5 places) and became later in 37 species (mean=6.3 places) but FO remained highly stable (RBO value = 0.80).

A stable FO but much shorter period FFD period indicates an increase in competition - both for pollinators and plants - which would impact on reproductive success, community structure etc. However, to fully understand these interactions, peak and end of flowering observations are required- in Australia these data are even rarer than FFD.

On quantifying the temperature sensitivity of plant phenological events

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Phenological Methods (2), Theatre, September 25, 2018, 10:30 AM - 12:30 PM

How should we best characterize the influence of temperature on phenology? Temperature sensitivity metrics are most commonly used, which quantify the influence of temperature as a proportional change in phenological timing per temperature change. Here, we examine the implications of this approach. We show that characterizing a 'days-per-degree' sensitivity of phenology can lead to results that have nothing to do with the underlying biology. The result is due to several mathematical considerations, including the length of the integration period, the fact that the temperature metric used is never the exact temperature to which phenology is responding to, and the unaccounted-for influence of underlying changes in temperature variance. We show how the resulting artefacts can lead to spurious long-term changes, and artificial spatial gradients. Finally, we suggest alternative methods quantify the sensitivity of phenology to temperature.

Assessment of field-specific agricultural weather risk according to fruit tree phenology in spring

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

The abnormally warm winter resulting from climate change is accelerating the flowering time of fruit trees, and damaged cases caused by low temperature, which suddenly appears before and after the germination-flowering time, are increasing. Even at the same temperature, the ability to withstand low temperatures varies according to the current development status of fruit trees, thereby leading to different degrees and aspects of fruit tree damage in response to low temperatures in the same orchard. The early warning service was developed so that farmers could respond in advance by predicting weather risks based on crop phenology. Above all, it is necessary to have a technique for precisely estimating the temperature distribution in the orchard and a technique for accurately predicting the growth state of fruit trees to assess the risk level of fruit trees according to low temperature. Geospatial schemes based on topoclimatology were used to scale down the 0600 and 1500 LST forecasts of the Korea Meteorological Administration (KMA) to the local scale (~30 m) across a rural catchment. Using the downscaled real-time temperature data, the service has started to provide field-specific weather information tailored to meet the requirements of small-scale farms. The phenology (dormancy, germination, flowering stages) of fruit trees was estimated using the DVS or Chill days model. The service subdivides the growth process from germination to flowering and assesses risk level according to limit temperature in each growth stage every day. If the morning temperature exceeds the pre-defined threshold, the service sends a warning and countermeasure to the grower's cellular phone in advance to help protect crops against low temperature injury.

Process-based modelling of autumn leaf senescence timing of woody and herbaceous plants in the Qinghai-Tibet Plateau

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Phenological Methods (1), Theatre, September 24, 2018, 1:45 PM - 2:45 PM

Predicting autumn phenology is crucial for accurately assessing global carbon cycle and its sensitivity to climate change. However, because the mechanism of leaf senescence is not clearly understood, the existing models may not describe the leaf senescence process accurately. In this study, we developed two types of new process-based models to fit 67 autumn phenological datasets of 27 woody and herbaceous species at 18 stations of the Qinghai Tibet Plateau from 1981 to 2012, and selected the optimum model for each species at each station. Then, we evaluated the robustness of all optimum models by means of cross validation analysis. Moreover, we used the robust optimum models to reconstruct historical autumn phenology time series over 1952-2012 period. Results show that as arithmetic product of daily minimum air temperature and photoperiod decreases, the leaf senescence rate is exponentially increased. At stations with longer photoperiods, leaf senescence process is predominantly induced by daily minimum air temperature, while at stations with shorter photoperiods, leaf senescence process is predominantly induced by daily photoperiod. In general, the new models can more accurately simulate autumn phenology than previous models. The historical autumn phenology time series indicate a delayed trend in 68.9% of datasets, and the delayed rate of autumn phenology depends highly on the increase rate of autumn temperature.

Long-term standardized forest phenology in Sweden, a climate change indicator and used in forestry

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Agricultural Phenology (1), Theatre, September 24, 2018, 10:55 AM - 12:15 PM

Standard assessments of phenology, by monitoring the dates when specific changes of phases are seen in nature has valuable benefits and is often promoted for citizen science monitoring of phenology. However, such data may have rather low precision and does not describe gradual changes well.

Many of the important phenology traits that can be seen in forest trees and forest berries change over an extended period of time. Thus, monitoring of the gradual transition is therefore important, to resolve timing of the tree status to other traits, e.g. susceptibility to nocturnal frosts, insects and fungi, and berries as food source to animals.
Swedish Experimental Forests have for more than a decade intensely monitored the start of the growing season of Scots pine, Norway spruce, downy and silver birch by weekly assessments of the growth of apical and branch buds and the elongation of shoots. Furthermore, the development and abundance of bilberries and lingonberries during the growing season, from flowering until the last berry has disappeared, has been monitored. By using a quantitative method for monitoring, i.e. measuring the length of bud/shoot and counting berries, respectively, the development may easily be interpolated between assessment dates and the average development and the inter-annual variation be assessed for each trait.

Results show e.g. an 8 and 13 day delay of the active growth period of pine, from latitude 57° to 61° and 64°, respectively. The Swedish Forest Agency has based recommendations of origins of plant material and on possible susceptibility to fungal decease during the growing process. Ripe berries reach maximum numbers after approx. 2 weeks after ripening begins, decrease to 50% during the following month, and almost all berries are gone after 2 months. Berry data has been used in research concerning feeding and reproductive success of brown bears in Sweden.

Seasonal Patterns of Dryland Vegetation Under Extreme Climate In Central Australia Using Multi-Satellite Observations

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Remote Sensing (2), Theatre, September 26, 2018, 10:25 AM - 12:25 PM

Extensive areas in the arid/semi-arid interior of Australia are exposed to the most extreme climates with infrequent intense rainfall events. In contrast to temperature-driven vegetation phenologies, precipitation drives vegetation greening in arid Australia. An exceptionally big wet event in central Australia was recorded in 2010-11, triggering a massive global land carbon sink anomaly, of which half was contributed by Australia. Additionally, another extreme wet pulse occurred in central Australia during the 2016-17 monsoon season, apparently of larger intensity than that of 2010-11. Here we investigated the response to these extreme climate events of two major plant function types (PFT) of dryland vegetation (Mulga woodland and Hummock grassland) and characterized their spatial-temporal traces of greening and drying through multi-scale satellite observations. MODIS provided an 18-year, long-term baseline vegetation profiles, for comparison of these wetting or drying events and evaluating their spatial patterns of greening and drying. Assessments of soil moisture with data from the SMAP mission and precipitation from IMERG were employed to examine the impacts of extreme wet pulses and droughts on vegetation.

Our results show the two PFTs, mulga woodland and hummock grassland, lacked regular seasonal patterns and exhibited high inter-annual variability. The 2011 wet event resulted in the highest annual integrated EVI (iEVI) relative to the 2016/17 wet event, through this 18 year study. However, in contrast to the 2010-11 wet event, in which Hummock grasslands were found to be the most responsive PFT, in the 2016/17 wet event, the mulga woodlands were much more

responsive than hummock grasslands in terms of both greening and drying. This study shows that satellite observations provide meaningful information on the response variability of arid-zone vegetation to extreme events, thus improving our ability to understand and detect ecosystem alteration under future changing climates.

Observations and Applications of Climate Adaptation in Temperate Plant Phenology

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Phenological Methods (1), Theatre, September 24, 2018, 1:45 PM - 2:45 PM

To better understand the geographic patterns of plant phenology, one needs to investigate both variability in meteorological variables and heterogeneity in plant genetics over space. Plant genotypic variations, as being expressed at the species level among different populations, or at the ecosystem level across different vegetation types and plant communities, are tied to respective local climate conditions through the process of long-term adaptation. Therefore, climate adaptation patterns of plant phenology can help reveal the varied phenoclimatic relationships (e.g. differential chilling and forcing for budburst phenology of temperate trees) across spatial gradients. The study area is focused on the temperate regions of the United States.

The presentation will first discuss the observation methods of climate adaptation patterns using common gardens, spatially extensive observations, and remote sensing. This will cover species-level results from studies of a white ash (Fraxinus americana) common garden in Kentucky, comparison with USA-National Phenology Network data, and ecosystem-level approaches using long-term satellite remote sensing records and phenological model predictions. Part of the effort is to facilitate developing continental-scale phenological models that can take into account both climatic and genotypic variations across space, thus to enable more accurate prediction of phenological timing over broad geographic regions. Further, the presentation will address potential applications of phenology-based climate adaptation patterns, which will include not only spatially-explicit phenological modeling, but also quantification of ecological impacts of human activities.

Optimal flowering periods for canola in Australia

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Recent trends in agronomic practice towards earlier sowing systems highlight the need to better define optimum start of flowering dates (OSF) for canola. We define the OSF as the range of dates in which it is optimal to start flowering to maximise yield. Crops which flower too early may have insufficient biomass or suffer frost damage, while late flowering increases heat and water stress. Despite its importance, OSF for canola has not been comprehensively defined for canola across Australia's cropping zone, especially for crops sown prior to the traditional sowing window (late April to early May). Identifying the OSF is a first step to establish appropriate variety by sowing date combinations to optimise yield in different environments. Recent research has characterized the phenological, growth and yield responses of modern commercial cultivars to the environment and developed updated APSIM parameters for these cultivars. We used the APSIM-Canola model to simulate yield and flowering date of crops sown at daily intervals from mid-February to late June using 50 years (1966-2015) of climate records at 75 locations in Australian canola cropping regions. Reductions in yield were applied for frost and heat damage based on air temperatures during sensitive periods. The OSF varied with location and season and was largely driven by seasonal water supply and demand, while effects of temperature extremes varied in importance across the regions. The midpoint of the OSF varied from 5 July (Mullewa, WA) to 23 August (Young, NSW) and the duration from two weeks in central NSW to seven weeks in high rainfall zones of WA, NSW and Victoria. This research has provided recommendations to growers to match sowing dates with varieties of suitable phenology to optimise potential canola yield.

Tracking grass phenology and pollen sources with phenocams over Victorian pastures

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

The seasonal progression of periodic biological occurrences in plants, like budburst and senescence, is generally referred to as vegetation phenology. Flowering, pollination and pollen release are important phenology stages of the grass life cycle and grass pollen is a major trigger for aeroallergens and is among the highest in Australia. On the first hot day of Spring 2016, Victoria experienced the largest recorded epidemic thunderstorm asthma event, a forceful interaction of meteorologic and grass pollen- induced biologic factors, that resulted in thousands of people experiencing immediate breathing difficulties in a very short period of time.

As part of a multi-disciplinary project to better understand this complex ecological-human health interplay, a set of time-lapse digital RGB phenocams, were deployed over 4 grass pasture areas, north and west of Melbourne in the state of Victoria. Within and cross site variations in grass phenology were analysed through computed green chromatic coordinate (GCC) time series made over 3-4 regions of interest (ROIs) per site. Our objective was to characterize grass phenology variation and couple key greenness phenophases with flowering information over the range of pasture conditions.

Significant variations in the GCC profiles were found in terms of greenness amplitude, greenness peaks, flowering, and curing. Visual phenocam assessments of grass flowering were found to significantly lag peak greenness and were coincident over a range of curing phenophase stages. Within site analysis demonstrated complex heterogeneity with non-synchronised flowering patches in both space and time. Proximal phenocam GCC results were found to be in good agreement with 10m satellite data from Sentinel-2, however site heterogeneity influences were lost in the coarser-scale Himawari-8 geostationary data. Our results demonstrate the potential of phenocams for proximal monitoring of grass phenology, as well as to validate satellite derived phenology, and thus contribute to the development of more accurate pollen forecast models.

Phenology and Culture

Dr Lynda Chambers[1], **Ms Siosinamele Lui[2]**, Mr David Hiriasia[3], Mr Philip Malsale[2,4], Ms Melinda Natapei[4], Ms Rossy Mitiepo[5], Mr Lloyd Tahani[3], Mr Tile Tofaeono[6]
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Traditional Ecological Knowledge, Seminar Room, September 26, 2018, 10:25 AM - 12:25 PM

The seasonal timing of key life cycle events in plants and animals is culturally important to many indigenous peoples, including those of the Pacific. Here we look at the role of phenology in culture in Melanesia and Polynesia. Cultural festivals are often linked with phenology; one of the Pacific's largest is Samoa's Teuila Festival that is named after the red ginger flower that blooms every September. But phenology also influences other aspects of the lives of Pacific Islanders, including seasonal fishing or reef closures and farming practices. Plant fruiting and flowering also features strongly in traditional weather and climate forecasting methodologies, enabling islanders to be resilient to weather and climate extremes. Inter-generational changes, climate change, land-use change and extreme events are all impacting on phenology and the transmission of this knowledge in the Pacific, which, in turn, can have cultural consequences.

New Perspectives on Predicting Ecosystem Phenological Metrics based on Sentinel-2 satellite data

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Climate change cause a shift in ecosystem phenology which has a direct impact on the annual carbon budget dynamics. Land surface models have difficulties in predicting these dynamics since the drivers of the Start and End Of the Season (SOS, EOS) are not fully understood. Greenness based vegetation indices (VIs), such as the Normalized Difference Vegetation Index (NDVI), are often used to parameterize land surface models, but in fact they are not ideal proxies for canopy photosynthesis and structure. These VIs fail in predicting the correct SOS and EOS especially when greenness and photosynthesis become uncoupled (e.g. drought, needle-leaf trees). Furthermore, the validation of VI based phenology estimations is complicated by the coarse spatial (1 km) and temporal resolution (bi-weekly to monthly) of many satellite sensors (like MODIS). The emerge of novel very high resolution (10-60 m) platforms (e.g. Sentinel-2) allow us to track phenology more accurately. In addition, the use of more spectral bands by Sentinel-2 allows us to calculate VIs related to pigment content such as the Modified Terrestrial Chlorophyll Index (MTCI).
In this study, we tested several structural and chlorophyll sensitive VIs derived from Sentinel-2 to improve the estimation of the SOS/EOS for three different plant types in Belgium. Five phenological extraction methods (Savitzky-Golay, Polynomial function, Harmonic Analysis of time series, Piecewise, and double logistic) with different functions for estimating the SOS and EOS (e.g. Percentile, first derivative function) were applied. The new VI-based prediction of seasonal metrics were validated against in-situ observations of Leaf Area Index (LAI) and Gross Primary Production (GPP), derived from eddy covariance measurements.

Keywords: Sentinel-2 product; Gross Primary Productivity; Greenness; Structural and chlorophyll indices; Smoothing function methods; Start and end of Season.

Phenology of flower colors in a seasonal Cerrado community

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Flowering patterns are important to understanding temporal changes in a community related to plant reproduction and resource availability to flower visitors. Seasonality and pollinators pressure may constrain the flowering patterns of woody cerrado savanna. Flower colors are the main floral trait driving plant-pollinators interaction and considering it, we analysed temporal patterns of flowering and flower colors in a woody cerrado community, South-eastern Brazil. Based on six years of flowering phenology observations of a woody cerrado community, subjected to marked dry and wet seasons we aimed to investigate the flowering patterns and how is the flowers colors seasonality according to the main pollinators. Over six years, 35% of the 105-observed species flourished. Flowering patterns were markedly seasonal, peaking in the beginning of the wet season ($Z= 11.45$; $p<0.01$; mean group: October), as observed for other tropical seasonal vegetations, and was similar among years. White, yellow, cream and green were the most common flower colors in the woody cerrado community. White and green flowers presented a significant highly seasonal pattern, peaking in October and August, respectively (vector $r = 0.70$ and $r = 0.68$ respectively). Yellow and cream were observed throughout the year, peaking in December and March, respectively. Pink flowers presented a bimodal pattern peaking in September and March. Our results showed an association between the flowering-peak season and flower colors, with white and green flowers more overlapped in time. A high diversity of flower colors were offered during the year, even when less species were flowering during the dry season, making resources for pollinators available all year long. We intend to conduct

further analyses using more years of flowering phenology, and flower colors considering the pollinators' visual system, flower contrasts and seasonal changes in the coloration of the leaf background. (FAPESP-number#2017/15152-1)

Opposite effects of winter day and night temperatures on early phenophases

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Uniform global warming has a significant effect on ecosystems but distinguishing the effects of uniform warming on phenology are largely unexplored. Theoretically, however, temperature changes in preseason may have opposite effects between day (TMAX) and night temperature (TMIN), by changing chilling and heat requirements. Here, using partial correlations and a three-year (2008-2010) continuous observation of early phenophases at species- level based on reciprocal transplant experiment on Tibetan Plateau, we found winter TMAX and TMIN had opposite effects on early phenophases (i.e., onset of leaf-out, first flower bud emergence and first flower blooming) under warming. Furthermore, effects of winter TMIN could offset 6.86 d / °C of winter TMAX advancing on early phenophases of six common species (i.e. two early-spring flowering (ESF) sedge species (*Kobresia humilis* and *Carex scabrirostris*) and four mid-summer flowering (MSF) species (two grasses: *Poa pratensis* and *Stipa aliena* and two forbs: *Potentilla anserine* and *P. nivea*) under warming. The opposite effect may be caused by trade-off between heat hour requirements (HHR) and chilling hour requirements (CHR), because decreased and increased CHR could increase and decrease HHR, respectively. Therefore, future phenology study should consider opposite effects of preseason day and night temperature and HHR-CHR relationships.

Allergenic pollen – how to avoid critical seasons at "pollen safe" sites

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Aerobiology, Seminar Room, September 24, 2018, 1:45 PM - 2:45 PM

Allergenic pollen constitutes a major health risk for the population in industrialized countries since up to 30 % of the population is affected. Symptoms can be minimized by immunotherapy, during the pollen season by medication and / or avoidance of allergenic pollen at home or outdoors. We compare the different strategies of evading the flowering period for selected allergenic pollen types in mountain areas or indoors for several sites and years in southern Germany. Airborne pollen concentrations were monitored with fixed pollen traps mounted >10 m above ground on flat roof tops at the Environmental Research Station Schneefernerhaus, at the meteorological station Zugspitze as well as at research institutes in Garmisch and in Freising in the lowlands. During several campaigns, the personal pollen exposure of people staying inside the respective buildings was monitored by portable pollen traps in rooms involving different window ventilation schemes. Meteorological data were retrieved from nearby climate stations and directly in front of the rooms.

The studies revealed a clear reduction in atmospheric pollen concentrations at the mountain sites in 2650 and 2960 m a.s.l., although varying between years, depending on the season, periods of long-range transport as well as diurnal cycles driven by local wind systems. Surprisingly the reduction of pollen concentrations indoor was in a similar range, although with higher variation among rooms, and strongly depending on exposition, ventilation and meteorological conditions.

The future pollen safety of high mountainous and indoor sites will be strongly linked to climate change impacts, potentially altering timing, length and strength of the pollen season, shifting ranges of allergic plant species, modifying pollen transport conditions and altering their allergenicity. In addition, mitigation measures such as adaption of buildings and urban structures (e.g. low-energy-houses, urban greening) may impact the total pollen exposure indoor as well as the pollen emissions outdoor.

Phenology in Citizen Science Projects – Key factors for success

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Phenology and Citizen Science, Seminar Room, September 24, 2018, 10:55 AM - 12:15 PM

From the 1990s onwards, many citizen science projects on plant phenology have been (re-)started such as the USA NPN, the Swedish National Phenology Network, De Natuurkalender / Nature Today in the Netherlands and many others. A comprehensive survey on their main features is presented and comparatively summarized. We concentrate hereby on user identification and tracking, app development, visualization options, link to existing or previous observational networks and comparison with baseline data, digitalization of historical data, possibilities of establishment of local / regional user groups and / or predefined observation sites (e.g. phenological walks, trails), associated educational programs as well as the involvement of volunteers as citizen scientists. Consequently, this review will provide approved ideas and role models for setting up new phenological citizen science programs.

BAYSICS - Bavarian Synthesis-Information-Citizen Science Portal for Climate Change Research and Science Communication

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Far-reaching consequences of recent climate change require extensive adaptation and climate protection measures, which will only successfully be put into practice in democratic societies if they are considered by citizens to be legitimate, acceptable and feasible. The recently started project BAYSICS will set up a Synthesis-Information-Citizen Science Portal for Climate Change Research and Science Communication for Bavaria (southern Germany) following the motto "Conveying Knowledge - Promoting Perception - Communicating Complexity". Selected groups of actors (e.g. those seeking recreation, pollen allergy sufferers, nature-loving citizens, pupils) are targeted in this Citizen Science approach via the novel BAYSICS portal. The main goal is to make climate change noticeable and perceptible in their concrete environment supported by the results of their own observations.
The interdisciplinary empirical, experimental and theoretical research approaches from the natural sciences, biology and geography didactics and environmental sociology enable attractive offers for the user groups and at the same time the generation of relevant knowledge on climate impacts, adaptation and protection with modern crowdsourcing media. BAYSICS aims at innovative, digital forms of citizens' broad participation in current research topics and science, the transfer of knowledge on the complexity of climate change and its regional consequences in society, and the combination of scientific and environmental education goals. The joint project will closely cooperate with international partners, national and regional stakeholders in the field of environmental education, schools, teacher training, NGOs, authorities and companies.

Traditional Phenological Knowledge in Niue

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Niue, or the "Rock of Polynesia", is one of the world's largest coral islands. Retention of Niue's culture and traditions is seen as nationally important and in recent years, the Niue Meteorological Service has been working with local partners, including the cultural department Tāoga Niue, to document phenological knowledge associated with weather and climate forecasting and seasonal activities, including farming and fishing.

Methods for ground-based tropical plant phenology: a worldwide review

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Phenological Methods (2), Theatre, September 25, 2018, 10:30 AM - 12:30 PM

Phenology, the study of life cycles events of live organisms, has wide applications for research from ecological interactions, ecosystem functionality and C budget to evolutionary biology and biodiversity conservation, and has a key role in monitoring and detecting species' responses to climate change. Despite the marked increase in the number of tropical phenology-related articles in the last 20 years, temporal and spatial large-scale comparison of phenological patterns are still rare. The main difficulty relays on major differences on the methodology applied for ground-based phenology monitoring. Each study includes a different sampling and analytical methodology, which seriously preclude inter-site comparisons. In addition, tropical ecosystems show a high diversity of species, life forms and reproductive systems, which makes even more difficult the comparative approach and imposes special warnings for some cases. Standardization of methods applied to phenology is key for disentangling the drivers affecting the timing of organisms. Consequently, we still have a large gap of understanding of the main drivers of tropical plant phenology. Here we present the first general overview of methodological approaches used for ground-based plant phenology studies in the tropics. We address their properness and flaws and propose general guidelines of how phenological studies should be carried out in a more accurate and comparative way. First, we discuss the different scales of phenological studies (from individual to ecosystem) and the implications for phenological monitoring. Second, focusing on ground data collection, we describe different spatio-temporal aspects of sampling designs and the main types of phenological observations (direct vs indirect). Third, we synthesize the statistical methods used for analyses of phenological data, exploring their advantages and warnings. A final perspective section explores the forthcoming advances in tropical phenological research, including new analytical and observational approaches such as experiments, near-remote phenology and citizen science. Funded by: FAPESP (#201350155-0), CNPq, CAPES

The circular nature of phenological data: statistical implications and limitations

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

The well-known species diversity in the tropics has revealed a complexity of phenological patterns and reproductive strategies in plants. To adequately describe and analyze species phenology in heterogeneous systems we need to use appropriate statistical metrics. In this study, we have detected some pitfalls in the definition of phenological parameters that may lead to erroneous conclusions in this topic. We illustrate these problems with simulated data and explore how the definition of "first flowering date" can be complicated in tropical systems where there is no real starting point for the flowering season (i.e. communities can reproduce throughout the whole year). Thus, we demonstrate the importance of considering the year as a continuous using angles to represent species phenology rather than day of the year (DOY). Specifically, we showed in phylogenetic signature analyzes the use of DOY may overestimate the phylogenetic signal in phenology for all signal metrics tested (Mantel correlation, phylogenetic regression and K statistic). Circular statistics is essential to accurate describe plant phenology in large geographical scales and to build comparisons across vegetations and it is especially useful to identify phenological patterns structured over the evolutionary history. It is urgent the necessity for developing evolutionary models that can deal with the circular nature of the phenological data (FAPESP #2014/13899-4, #2013/50155-0).

Next challenge of enhancing phenological observations and land use and land cover change studies by integrating near-surface and satellite remote sensing and citizen science

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Remote Sensing (2), Theatre, September 26, 2018, 10:25 AM - 12:25 PM

To evaluate the ecosystem functions and services, and biodiversity under rapid climate change and human activities, accurate detection of spatio-temporal variability of plant phenology and land use and land cover change is important. Towards this aim, near-surface and satellite remote sensing is useful. However, our ecological understanding of remote sensing observations are still not sufficient and remote sensing observations include uncertainties caused by such as spatio-temporal resolution of sensors and noises caused by cloud contamination and atmospheric conditions. To enhance the development of phenological observations and land use and land cover change studies, we have established the Phenological Eyes Network (PEN; http://www.pheno-eye.org) and the Site-based dataset for Assessment of Changing Land cover by JAXA project (SACLAJ). As a result of our activities, validation and calibration of satellite remote sensing observations for plant phenology and land use and land cover change were well developed. However, the collection of ground-truth by our activities is still limited, especially mountainous and remote regions, where are strongly affected by climate change. In addition, the collection of ground-truth around and inner cities, where is familiar with our life and strongly affected by human activities, is still limited. To further enhance the development of phenological observations and land use and land cover change studies in those hotspots by remote sensing observations, we need further collection of ground-truth by collaborating with citizen science. In this presentation, we will present our results of integrated analysis of remote sensing observations and open-access citizen science data, and then discuss our future tasks and challenge with you.

Traditional Phenological Knowledge in Vanuatu

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Vanuatu is a Y-shaped archipelago of over 80 islands, stretching over eight degrees in latitude, in Melanesia. Throughout most of Vanuatu, traditional cultural knowledge and practices remain strong and there is great diversity, including the highest density of languages per capita in the world. Over 80% of the population lives in isolated rural villages that generate their own food supplies. Phenological knowledge in Vanuatu is traditionally passed from generation to generation via stories, song and other cultural practices. In recent years, the Vanuatu Meteorology and Geo-Hazards Department has been working with local partners to document phenological knowledge associated with weather and climate forecasting and seasonal activities, including farming and fishing.

Agroclimatic conditions and grapevine (*Vitis vinifera*) phenological development in northern Carpathians

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Agricultural Phenology (3), Theatre, September 25, 2018, 3:30 PM - 4:50 PM

South slopes of Northern Carpathians in Central Europe have befitting agroclimatic conditions for grapevine growing in the altitude range 100-300 m a.s.l. Presented work evaluates the phenological development of early, mid-late and late varieties of grapevine during the growing season and models their development towards changing climate conditions. The beginning of the phenological phases as well as their changes were tested on data coming from the vineyards in most northern part of Pannonian basin in the elevation of 165 m a.s.l. All phenological phases showed shift to earlier dates since the 1960s.

Future phenological development was based on the climate scenarios. This showed the shift of bud swelling to earlier dates by 22-26 days and maturity dates by 28-30 days for early varieties and 42-49 days for late varieties in next 50 years with shortening of the growing season by 5 to 25 days.

Due to increasing temperature sums during the grapevine growing season the sugar content in the grape increases and the quality of the vine has risen. However, climate changes bring also some negative impacts. Modelling the formation of reproductive organs of the most common diseases; specifically grape downy mildew (*Plasmopara viticola*) and powdery mildew (*Uncinula necator*) showed the shift of the beginning of maturity of overwintered oospores of downy mildew to 4-15 March and the germination of the conidia of powdery mildew to 10-25 February. The pathogens will be mature before the bud swelling of grapevine and due to expected increased humidity in spring the infection risk could increase.
In addition to the risk of diseases, there will be increased risk of damage by late frosts which keep the date of their occurrence. Furthermore, due to changes in precipitation patterns and increase rate of potential evapotranspiration, the increase frequency and magnitude of dry spells is expected.

Spatiotemporal representativeness in grassland phenology derived from phenocam images with respect to pollen trap's footprint

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Remote Sensing (2), Theatre, September 26, 2018, 10:25 AM - 12:25 PM

Grass pollens from invasive species are recognized as the main allergens in Australia. In 2017, we deployed phenocams in 4 pastures across Victoria to track timings of grass greening, flowering and pollen emissions. All phenocams are 40-60 km away from the nearest pollen trap. This study investigates the spatiotemporal variabilities of the phenocam-derived phenology within its field of view (FOV) and with respect to the closest pollen trap's landscape.

Focusing on two sites with the same dominant grass species, we select 10 regions of interests (ROI) from each camera's FOV. For each ROI, we compute a time series of the green chromatic coordinate (GCC = green / (green + red + blue)) and extract grassland phenological metrics. We visually assess flowering from the images and compare the phenological profiles of phenocam greenness to evaluate how timings of greening and flowering vary across sections of the same phenocam FOV.

We derive the dominant wind direction from wind data collected at the closest weather station to the pollen trap at each site and select 2017's Landsat pixels within 100km of the pollen trap in that direction. For each pixel, we extract phenological metrics from satellite-based Enhanced Vegetation Index. We then compare the phenocam-based and

satellite-based phenological metrics to explore how much phenocams have captured the landscape level phenology derived from Landsat.

GCC profiles vary in greenness amplitude, timings of peak greenness and flowering within-site and cross-site, between foreground and background and across camera types. Asynchronous flowering episodes lag peak greening by up to 30 days. Large spatiotemporal heterogeneity exists in satellite-derived phenology at the Landsat scale. The spatiotemporal variability within phenocam-based phenology and the correspondence between phenocams and satellite phenology have important implications in how we site phenocams to best represent the surrounding landscape and complement point measurements of grass pollens.

Pasture phenology and coverage changes contributed to periodical and directional changes in Melbourne's grass pollens

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Aerobiology, Seminar Room, September 24, 2018, 1:45 PM - 2:45 PM

The 1991-2016 pollen record from Melbourne, Australia displays both periodicity and linear trends in total annual pollen, peak pollen date and the number and duration of days with extreme counts. This alternating pattern is hardly reported before for grass pollens and cannot be fully accounted for by meteorology. Land use change has been traditionally overlooked as driver of variabilities in pollen counts and timings. In this study, we characterize land use change with respect to Victoria's pastures and test the hypothesis that changes in pastures phenology and locations influence timings and magnitude of grass pollen counts.

We combine 1991-2016 Landsat Enhanced Vegetation Index (EVI) data, Australia's Dynamic Land Cover data, hourly wind measurements closest to the pollen trap in Parkville, Melbourne to investigate the effects of land use land cover change on observed patterns of pollen counts and timings. We calculate daily mean wind speed and directions and analyze the contribution of wind direction to total pollen counts. We employ a suite of continuous change detection and classification methods that characterize directional and break point changes in the trends and seasonality of pasture EVI. Landsat provides us with the longest satellite time series and the spatial resolution for historical land cover changes.

Extreme daily pollen counts in October and December occur on days with northerly and easterly winds while those in November occur on days with southerly winds, pointing to possible historical changes in pasture phenology and coverage in these areas. High pollen and low pollen years differ by temporal lags between peak greenness and start of the pollen season. Per Landsat pixel time series show years with double EVI peaks. Finally, regional pasture area increases between 2000 and 2014. Better characterization of pollen sources and vegetation conditions will help develop effective monitoring framework and models for asthma risks.

Integrating germination, growth and flowering phenology: implications for *Eucalyptus* species response to climate change

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Phenology and Conservation Biology (1), September 25, 2018, 10:30 AM - 12:30 PM

Flowering, germination, and growth represent critical stages in a plant's life cycle. For eucalypts, phenology during these stages have demonstrated sensitivity to climate variability and climate change. Understanding how phenological sensitivity in any given stage interacts with another stage is critical for understanding the demographic resilience of species to pending climate change. In this study, we used the TACA-GEM model to explore how the interactions between flowering, germination and growth phenology influence the resilience of three eucalypt species that co-occur in southeast Australia.

Phenological responses at each life stage varied within and between species in response to climate variability suggesting that phenological sensitivities at one life stage may overwhelm neutral or positive response at another. Our results indicate that phenological responses at one life stage may be sufficient to reduce demographic resilience and facilitate changes in species distributions under a warmer and drier future in southeast Australia.

Plasticity in reproductive phenophases of two native understory species in response to elevated temperature

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Plasticity in the reproductive phases of *Coronidium scorpioides* and *Cynoglossum suaveolens* was assessed between a ~5°C elevated temperature (glasshouse) and unheated environment. Both species displayed plasticity in flowering phenology, advancing average First Flowering Date (FFD) by approximately 60 days and peak flowering time by 50 days in the elevated temperature environment. Flowering duration was highly significantly increased by >20 days in both species with this plasticity partially compensating for flowering date advancement by reducing the difference in seed dispersal date between experimental environments. Plasticity in the duration of seed maturation was observed in *Coronidium* only, which displayed greater plasticity than *Cynoglossum* in the duration of the total reproductive phase. Highly significant increases in floral disc diameter of *Coronidium*, seed weight of *Cynoglossum*, and inflorescence height of both species was also observed in the elevated temperature environment.

Various methods of determining Growing Degree Day (GDD) accumulations for phenological stages were explored but none displayed a good correlation between the elevated temperature treatment and control, suggesting the influence of environmental variables not included in the analysis such as moisture and temperature x moisture interactions. We compared our data to long-term (27 year) observations from a field monitoring site, however, a poor correlation between FFD GDD accumulations was also observed and similarly suggests environmental variables other than average temperature are also important for these species.

Glasshouse methods may be easily upscaled to assess changes in reproductive phenophases of Australian native herbaceous species in greater detail, using higher numbers of replicates and treatments, and with relatively lower cost than is practically possible with most in situ methods, with moisture level treatments also easily incorporated. Such methods can complement in situ methods, increasing the robustness of conclusions and providing insights into the various limitations of in situ and ex situ assessments of reproductive phenophases.

Determining the chill requirements for Sauvignon blanc bud burst

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Uniform budburst of the grapevine normally requires a period of chilling necessary to satisfy endodormancy then a period of warming to overcome ectodormancy. Chill and heat requirements differ among grapevine cultivars and it is important to assess (i) the potential variability of budburst which may lead to non-uniform fruit development and (ii) the susceptibility of vines to early season frost, especially under winter temperature conditions that may results from climate change. The aim of this study was to characterise the temperatures and duration of chill required to satisfy the dormancy of the grapevine cultivar Sauvignon blanc.

Single node Sauvignon blanc cuttings were collected shortly after harvest, and subjected to a range of base temperatures -2, 4, 8 and 20°C – and durations - 0 (no chilling – continuous at 20°C), 119, 330, 592, 784 and 1007 hours at each chilling temperature. After each chill duration, the cuttings were transferred to 20°C.
Chill requirements were met (measured by 50% of bud burst) when cuttings were subjected to temperatures of less than 4°C for 330 hours or more. The time to bud burst under warm conditions (20°C) was reduced when the chill duration was longer than 330 hours at 2 and 4°C. Likewise the uniformity of budburst was increased. At 8°C or 20°C less than 50% of buds burst, regardless of duration. This indicates a base temperature of less than 8°C is required for Sauvignon blanc to break endodormancy and higher temperatures will result is reduced and irregular budburst. Furthermore, this value differs to those reported for other cultivars and emphasizes the need to characterise the chill requirements of individual cultivars. The results are being integrated into a model based on chill and heat accumulation to predict budburst for Sauvignon blanc.

Aboriginal Seasonal Calendars

Jim Poulter

Traditional Ecological Knowledge, Seminar Room, September 26, 2018, 10:25 AM - 12:25 PM

Jim Poulter's family has had a continuous involvement with the Aboriginal community in Melbourne since 1840 and he has been privy to their stories and oral history. A great deal of cultural knowledge has been lost, but with the help of Elders Jim has often been able to reconstruct the remaining fragments into coherent knowledge systems. His work on the Aboriginal seasons in Melbourne is testament to that. For the first time, Jim has been able to reconcile Aboriginal seasons to the lunar calendar or thirteen twenty-eight day months, with the year beginning on the Summer Solstice at December 22.

Also, of crucial importance has been understanding that Aboriginal seasons are not just identified by the weather patterns during a particular period, but also what tasks needed to be undertaken in each period. Each of the eight seasons identified in the Melbourne area are therefore associated with various necessary tasks such as fish trap maintenance, inter-clan business, rug making, burning-off, artefact making, bark harvest, women's initiations and men's initiations.

Each of these seasons is also signalled by the flowering of particular plants, the migratory behaviour of particular birds or the behaviour of particular animals. These ecological patterns are the fragments of knowledge that have survived the most intact and have now been placed within an overall timetable that fits astonishingly well within the thirteen month lunar calendar. This thus gives a clear indication of the level of sophistication within indigenous knowledge systems.

Detecting phenological response to forcing and chilling temperatures in subtropics and tropics of China

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Tropical Phenology, Seminar Room, September 26, 2018, 1:25 PM - 2:45 PM

Process-based phenology models for temperate trees assume that spring phenology is triggered by chilling temperatures during the dormancy period, followed by forcing temperatures during the growth period. In what extent this assumption is suitable for trees growing in subtropics and tropics is still unclear, which greatly limits accurate modelling and prediction of spring phenology in these regions. In this study, we employed Partial Least Squares (PLS) regression to detect responses of spring phenology of Melia azedarach to forcing and chilling temperatures at 45 stations in the subtropical and tropical zones of China from 1981 to 2012. Then, we identified the attributions of spatial differentiations of phenological responses to forcing and chilling temperatures. Results show that forcing temperature is the key influencing factor for bud burst and leaf unfolding at all stations, and the forcing temperature effect starts earlier at stations with higher spring temperature (March-May). Moreover, the negative responses of bud burst and leaf unfolding to forcing temperatures were stronger at warmer locations than at colder locations. By contrast, chilling temperature affects bud burst and leaf unfolding only at 51% and 29% stations, respectively. In general, bud burst needs more chilling days (number of days with daily mean temperature between 0°C and 12°C) than leaf unfolding, and chilling days required by bud burst and leaf unfolding are less at stations with higher winter temperature (December-February). In addition, the positive responses of bud burst and leaf unfolding to chilling temperatures were stronger at warmer locations than at colder locations. Further analysis revealed the compensation effect of chilling and forcing temperatures in triggering bud burst, namely, bud burst requires more forcing accumulated temperature at stations with less chilling days. Our study provides a new insight for suitability of traditional process-based spring phenological models in subtropical and tropical regions.

Phenological mismatch of a rare orchid and its bee pollinator under climate change

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Phenology and Conservation Biology (1), September 25, 2018, 10:30 AM - 12:30 PM

Pollination by insects is a vital ecosystem service that underpins many aspects of ecology, conservation and horticulture. Pollination success depends on synchrony between insect activity and flowering time: if plants and their pollinators show different phenological responses to climate warming pollination could fail. The specific deceptions evolved by orchids that attract a very narrow range of pollinators allow direct examination of the potential for climatic warming to disrupt synchrony.

Natural history collections in herbaria and museums are important potential sources of long-term data for such study but required independent validation. We demonstrate the first direct corroboration of these data by quantifying relationships between climate and flowering derived from herbarium records and from direct field-based observations, for the terrestrial orchid *Ophrys sphegodes*.

Pollination of *Ophrys sphegodes* by sexual deception of male *Andrena nigroaenea* bees depends on male bees emerging before females and before flowering, and on flowering preceding female bee emergence. Analysis of museum specimens (1893–2007) and recent field-based observations (1975–2009) showed that flight date of the pollinator bee Andrena nigroaenea is advanced more by higher temperatures than is flowering date in the orchid. We model flowering and bee emergence dates from 1659-2014. Using this 356-year dataset we demonstrate a significant potential for this coevolved plant-pollinator relationship to be disrupted by climatic warming. All phenological events advanced significantly, accompanying a pattern of warmer springs. The interval between male and female flight decreased over time, whereas that between male flight and flowering increased. Following very warm springs, female flight preceded male flight and orchid flowering. Our results show that such phenological reversals have become more frequent over the last 356 years. We suggest that continuing climate warming will increase the frequency of reproductive failure in this rare orchid species.

ClimateWatch: a national phenology program enabling Australian citizens to participate in climate change research

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Phenology and Citizen Science, Seminar Room, September 24, 2018, 10:55 AM - 12:15 PM

Since 1982, Earthwatch Institute Australia has focussed on building networks of citizen scientists to generate data that address major biodiversity issues, including climate change. Due to the scale of the data collection task, there is currently a significant lack of knowledge within Australia on climate change impacts on biodiversity. Success in gathering this data is only possible with an approach that engages the community.

Supported by corporate, government, non-profit, private and education sectors, ClimateWatch involves the public in gathering phenology data useful to climate change scientists. Since its establishment in 2009, the program has created a network of over 23,000 people and monitored over 105 species. The data are submitted through an app and web platform, and are analysed for quality by Earthwatch and a scientific advisory team. To date 75,000 records have been made freely available on a national biodiversity database, the Atlas of Living Australia.

ClimateWatch has become a powerful nature-based citizen science educational tool. The program has developed free secondary school lessons, facilitating high quality learning around phenology and climate science using real world research. The program has also provided professional development, empowering teachers to embed climate change and biodiversity learning into school curricula, as well as connecting schools with local community groups to undertake ongoing phenology data collection.

Other successes of the program include integration into university courses, projected climate change species distribution maps, and national uptake by botanic gardens networks, local government and corporate groups.

ClimateWatch delivers scientific and social significant outcomes across Australia and harnesses the power of citizen science to address climate change knowledge gaps for the Southern Hemisphere. Wide-reaching partnerships between scientists and end-users have been key to the ClimateWatch program's success. The presentation will provide a broad overview of the program, sharing lessons learned and future directions.

Causes of variance in in-situ FPAR measurements in tropical and boreal deciduous broadleaf forests.

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Phenological Methods (1), Theatre, September 24, 2018, 1:45 PM - 2:45 PM

One of the most observable impacts of climate change in boreal and tropical environments are changes in phenological patterns. These changes on phenological expressions are coupled to increased temperatures during the winter months in Northern latitudes, and an increase in the severity, and frequency of droughts which have caused notable effects on tropical ecosystems. Increased temperatures and their intensification across seasons can have drastic effects on canopy dynamics, such as the fraction of Photosynthetic Active Radiation (fPAR) absorbed by vegetation. fPAR is a variable associated with forest productivity and as such is linked to many ecosystem services such as carbon sequestration. As the scientific community then attempts to comprehend these effects, it is important first to untangle what causes variations in the measurement of fPAR, before, attributing any measured variance to climate change.

Here, we present the outcome of two studies of fPAR at two environmental monitoring super-sites: the Santa Rosa National Park (Guanacaste Costa Rica), and the Peace River (Alberta, Canada). The study is aimed to determine the causes of variance in the in-situ measuring of fPAR using a new technological approach driven by wireless sensor networks (WSNs), and local meteorological towers. The WSN used in this study is capable of measuring the incoming, transmitted, and reflected photosynthetic active radiation (PAR) that interacts with the canopy along with other several micro-meteorological variables. Our study concludes that wind speed, the solar zenith angle, along with sample size, and sampling distribution can have a substantial effect on the measurement of fPAR and its variance. Recommendations on the meteorological variables that are necessary to co-monitor with in-situ samples of fPAR, along with sampling distributions and sampling sizes, are outlined towards establishing standard protocols for in-situ measurements of fPAR.

Tropical Dry Forest Resilience and Water Use Efficiency

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Remote Sensing (2), Theatre, September 26, 2018, 10:25 AM - 12:25 PM

Tropical dry forests (TDFs) worldwide have a strong phenological signal, which easily marks their response to the changing climatic conditions, both in terms of precipitation and temperature. Using TDF phenology as a proxy, we aim to evaluate two main questions: (1) What is the current continental response of TDFs to climate change across the Americas using a meta-analysis of EVI-MODIS and in-situ litterfall data, and (2) will TDFs be resilient under future projections of climatic change in the Americas. Our first analysis evaluates the TDF season lengths and their proxy-productivity trends using meteorological variables combined with EVI to evaluate TDF's ability to maintain leaf area under differing water availability conditions. Trends were evaluated using parametric and non-parametric statistical tests. Our second analysis evaluates the future climate in Costa Rican and Brazilian TDF using statistical models, compared against the IPCC AR-5 report, to assess changes in Water Use Efficiency, Gross Primary Productivity, and resilience under these new projected conditions. Our results indicate that statistically significant phenological changes are observed in TDFs away from the equator. Our MODIS vegetative index and hydro-climate analysis indicates that the drought-adapted TDFs are resilient to the current climate change across all sites in the Americas. There also appears to be other adaptive strategies being implemented by the forests, with changes in the growing season length in Brazil based on water availability. The future of the climate is variable across the Americas, especially with regards to precipitation, making it difficult to say with certainty that the entirety of this biome will remain resilient. The future precipitation of Costa Rica and Brazil and their associated water use efficiency do indicate the resiliency of this biome moving forward under climatic change.

Detection and Attribution of anthropogenic Climate Impacts on Phenological Phases

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

An important effect of climate change is associated with its impact on phenological events during spring. Although there is scientific agreement that mankind plays a major part in global warming and that phenological occurrence dates are largely driven by temperature, the direct linkage between anthropogenically driven changes of the atmosphere’s chemistry and alterations in phenological entry date has not yet been shown quantitatively.

This study aims at providing this evidence by carrying out a one-step attribution to external forcings. This approach links increasingly earlier occurrence dates of phenological spring events to changing climate conditions (increasing temperature) and - in turn - to external (anthropogenic) forcings. Technically this shall be attained by a so-called ‚optimal fingerprint’ technique, which detects and attributes external (anthropogenic) forcings shifting phenological occurrence events towards earlier dates.

This requires historical Global Climate Model (GCM) simulations driven by various forcings. Pre-industrial (piControl) simulations are needed to assess internal climate variability. GCM runs driven by natural forcings alone on one hand and GCM runs forced with natural and anthropogenic forcings on the other hand are required to detect effects on climate addressable to mankind’s activities. The attribution part of this technique is based on consistency checks, which involve climate’s internal variability too, and yields confidence levels revealing the significance of the anthropogenic impact.

In case the null hypothesis - that the observed shift in phenological occurrence dates can be simulated by natural forcings alone – has to be rejected with high confidence and observations can be well reproduced via natural and anthropogenic forcings, it can be inferred that mankind is responsible for recorded changes concerning the timings of phenological phases.

“Nature’s Calendar”, a modular phenological smart phone app for collection of phenological observations by citizen scientists

Mr Thomas Hübner[1], Mr Klaus Wanninger[2], Mr Philipp Hummer[3], **Mr Helfried Scheifinger[1]**
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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

The collection of phenological observations through volunteers or citizen scientists (CS) in Austria dates back to 1851, where the first phenological network was organised by Karl Kreil, the director of the newly founded Austrian national weather service. Phenological data collection has always relied on volunteer observers, who were willing to regularly visit their selected plants and places, working with pencil and paper, filling in and sending the observational sheets to the national weather service. This traditional way of phenological data collection has been challenged by a number not well known sociological factors, which altogether caused a dramatic drop in observations from about 1950 to 1995 in Austria. As a first step to appeal to new observers the web – portal for entering phenological observations was opened for the public in 2006, with not much effect. The recent development of mobile smart phones have a great potential to increase the stream of phenological observations. Thereby means have become available, which in fact have already facilitated CS ecological data collection enormously.
In a cooperation between SPOTTERON, LACON and ZAMG the smart phone app “Nature’s Calendar” has been created. The app has already been released for Android and IOS, along with an interactive map for desktop users at www.naturkalender.at. It is not just an app, but an app system, which allows to create apps for a range of individual citizen science applications with minimal effort. New features implemented for one application can easily be transferred to other applications. Amongst others it offers instruments for communication between the network operator and observers (push messages), for communication within the observer community and to upload photographs. The extensive observational manual with a detailed description of species and phenophases can be found on the Naturkalender home page.
Time will tell, if our efforts will bear fruit.

Observation of phenological phases with Sentinel-2 and MODIS

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

The photosynthetic activity of the plant cover can be observed very well in the infrared range from space, e. g. via the NDVI, which is the Normalized Difference Vegetation Index. This paper is concerned with establishing a relationship between satellite-based land surface phenology (LSP) and ground phenology (GP) in such a way that individual phenological phases can be determined in the vegetation cycle across Europe, for example the leaf unfolding of birch and beech from space. In addition, MODIS satellite data previously used, which have a spatial resolution of 250m, will be compared with the high-resolution data of the new Sentinel-2 satellites with a spatial resolution of 10m. The spring phases 2016 and 2017 for Tyrol, southern Germany, 2017 for Upper and Lower Austria are considered. The phenological ground observations are provided by PEP725 and cover Austria, Germany, Switzerland and Sweden.
For the year 2017, the PEP725 database shows the highest number of phenological ground observations for leaf unfolding of birch and beech. In Austria, the birch begins to sprout its first leaves about end of March. At the beginning of April, the beech trees will also start to green in Central Europe. The time series of leaf unfolding in Austria shows a trend for birch and beech to an earlier entry dates of about 10 days during the last 40 years. In the mountainous part of Austria leaf unfolding starts much later than in flat areas, about 30 days/1000 m elevation. The main focus of this work will be to evaluate whether the spatial resolution of 10m and temporal resolution of 10 days of the NDVI index calculated from the Sentinel-2A data is sufficient to determine the entry dates of leaf unfolding of selected deciduous tree species from satellite data.

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

Dr Helfried Scheifinger[1], Mr Thomas Hübner[1], Dr Elisabeth Koch[1], Mag Anita Paul[1], Mag Markus Ungersböck[1]
[1]*ZAMG, Wien, Austria*

POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

"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, 20 European meteorological services and 6 partners from different phenological network operators have joined PEP725.
In many 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 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 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.

Continental to Global Scale Assessment of Spring Phenological Change

Prof Mark D Schwartz[1]
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KEYNOTE PRESENTATION: Dist. Professor Mark D. Schwartz, Theatre, September 26, 2018, 9:05 AM - 9:50 AM

Biography:
Mark D. Schwartz is a phenoclimatologist and distinguished professor of Geography at the University of Wisconsin-Milwaukee. He is the immediate Past President of the International Society of Biometeorology, and co-founder of the USA National Phenology Network. His research interests are focused on plant phenology lower atmosphere interactions during the onsets of spring and autumn in mid latitudes, detecting climatic change, and assessing vegetation condition with remote sensing imagery. His scholarship includes over eighty peer-reviewed publications, mostly in journals, and a 2nd edition of the edited book Phenology: An Integrative Environmental Science. Prof. Schwartz received his Ph.D. from the University of Kansas in 1985.

Phenological research provides valuable approaches for understanding Earth systems interactions and facilitating global change studies. As a simple expression of seasonal biology, phenology offers another independent measure (along with climate records and remote sensing observations) of the extent and impact of climate change. However, phenological data are still not collected and recorded in spatially comprehensive and comparable ways around the world. Thus for now, phenological models can allow simulation of general plant responses, facilitating testing of broad hypotheses in locations and at times when actual phenological data are not available, but with more detail than possible when using remote sensing-derived measures.

One set of phenological models that have been successfully applied to assess impacts of climate change on the onset of the spring growing season across temperate regions around the Northern Hemisphere are the Spring Indices (SI). This suite of metrics includes several sub-models and associated measures, all of which can be calculated using daily maximum/minimum surface temperatures and latitude. SI models process weather data into a form mimicking the spring growth of many plants that are not water limited but are responsive to temperature increases. This paper summarizes recent work using longer and denser station network data since 1900 and more recent high-resolution spatially gridded data across the continental USA, which has shown: 1) the SI onset of spring growing earlier overall since the late 1950s; 2) regional differences in the Western and Southeastern USA; and 3) spatial aspects of the large inter-annual variability of spring's onset in recent years. Finally, the latest developments from on-going work will be presented that uses gridded air temperature data and SI to provide near real-time monitoring and long-lead forecasting of the onset of the growing season.

Long-term monitoring of honeybees (*Apis dorsata*) and phenology of flowering in Western Ghats India

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Phenology and Conservation Biology (2), Seminar Room, September 25, 2018, 2:00 PM - 3:00 PM

Honeybees play an important role in the forest ecology of tropical forests, besides supporting livelihood of the people. *Apis dorsata* contributes more than 80% to the total honey production in India. Populations are known to migrate distances of 50 to 100 km and forage around 200 species. The indigenous Soliga community that resides in the research site harvests around 15 to 18 tons of honey per annum from wild. To estimate the number of bee colonies seventeen one-kilometer transects were laid along streams of evergreen and dry deciduous forests, additional 13 rock cliffs were also marked permanently and 250 trees of 50 species were monitored for phenology. To determine the inter-annual variability in bee colony numbers, colonies were counted before and after harvest from 1995 to 2017 (22 years). Monthly phenology data were collected on flowering, leafing and fruiting for the same number of years.

The density of bee colonies in the forest landscape coincides with the flowering season. When flowering in the forest ends, honeybees migrate to the agricultural plains. Bee colonies distribution showed distinct spatial variability related to habitat types. The highest densities were recorded in evergreen forests, followed by dry deciduous forests. The level of extraction was high in dry deciduous forest, followed by evergreen, and least in rocky cliffs. For their nesting, bees preferred species like *Acrocarpus fraxinifolius, Albizia odoratissima, Garuga pinnata, Terminalia bellerica* and *Syzygium cumini*. Number of bee colonies decreased significantly from 1995 to 2017 in evergreen forest ($R^2 = 0.77$) and dry deciduous forest ($R^2 = 0.76$) but remained unchanged on rock cliffs ($R^2 = 0.24$). Decrease in bee colonies number might be linked to increase in density of invasive species *Lantana camara* in the forest as well as the loss of nesting trees.

SAR and Optical satellite sensors to detect phenology in Alpine areas

Miss Laura Stendardi[1], Dr. Stein Rune Karlsen[2], Dr. Georg Niedrist[3], Dr. Marc Zebisch[3], Prof. Renato Gerdol[4], Dr. Claudia Notarnicola[3]
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Remote Sensing (1), Theatre, September 24, 2018, 3:20 PM - 4:40 PM

Temperature variation influences the length of the growing season in Alpine areas, causing shift in phenological phases of vegetation, with a reduction of ecosystems resilience. Notably, changes of the start and end of the growing season might have a significant impact on fragile mountain ecosystems.

Optical remote sensing, through spectral vegetation indices, has been extensively used for monitoring vegetation dynamics. However, there are challenges of processing optical data, namely clouds and their shadows, which interferes

with remote sensing studies. As opposed to optical images, Synthetic Aperture Radar (SAR) can provide a systematic data source of land surface and land cover changes that are insensitive to cloud contamination.
Moreover, the free data policy adopted for the Copernicus programme allows us to use time-series from Sentinel-1 and Sentinel-2 with 20 and 10 m of spatial resolution, respectively.

In this study we analysed the vegetation phenology in the alpine areas of South-Tyrol (Italy) by constructing time-series from both SAR and optical sensors, validating subsequently our results with a network of ground stations at different altitude (i.e. phenocams, NDVI sensors and temperature - soil moisture data loggers).
After a noise removal using different techniques, several filters were applied to SAR and optical time-series.
From the modelled values we extracted the Start of Season (SOS), Maximum and End of Season (EOS), and we validated our results using information from NDVI sensors and phenocams. From our study we can assume that multitemporal SAR signal and specifically the VH polarization can be used to detect phenological dynamics in grassland and multitemporal SAR signal is well correlated to the NDVI from Sentinel 2 and ground observations of vegetation indices.

Use of phenocams in arctic and alpine parts of Norway

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

In remote areas as, alpine parts of Norway it is expensive to have people in field for phenological observations. In 2013 we started with phenocams (trail cameras, mostly LTL Acorn), and the main goal is to collect in-situ validation data for MODIS and Sentinel-2 satellite based mapping of the growth season. We use phenocams in two mountains in southern Norway, one oceanic mountain (Sundalsfella) and one continental (Dovrefjell). All 17 cameras in southern Norway are located above the forest line, and cover the main vegetation types and dominated species (as *Betula nana*, *Salix* spp, *Vaccinium myrtillus*, *Carex aquatilis*). In most cases we have two cameras at each site, one on distance for automatic detection of phenophases, one close up for visual inspection of phenophases. For the camera on distance, within the image we select a polygon with dominance of one species. Most cameras cover two or three species and we select a polygon of each of the species. Then we calculate indices (python script) from the red (R), green (G) and blue (B) values. The images are not calibrated, and to reduce atmospheric noise we use median values from 10am to 2pm every day, and then 7-days moving average before calculating thresholds for detecting phenophases. The GEI index (2*G-(R+B)), is useful both for spring and autumn phenophases, in particular for shrubs. The GRVI index (G-R)/(G+R) shows good dynamic in autumn, and the rG index (G/(R+G+B)) is in particular useful for detecting phenophases on graminoids. The results show about three weeks in difference between the earliest (2018) and latest (2015) onset of growth, defined as budburst on dwarf birch (Betula nana). On the high arctic island of Svalbard (78°N) we use nine phenocams, however only small variation between the years in timing of onset of growth is found on Svalbard.

Traditional Phenological Knowledge in the Solomon Islands

Dr Lynda Chambers[1], Mr David Hiriasia[2], **Mr Lloyd Tahani[2]**, Ms Siosinamele Lui[3]
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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Situated in Melanesia, the Solomon Islands consists of six major islands and hundreds of smaller ones. In many parts of the Solomon Islands, traditional cultural knowledge and practices remain strong with differences observed according to island, topography and ethnic origin. Phenological knowledge in the Solomon Islands has been traditionally passed from generation to generation via stories, song and other cultural practices. In recent years, the Solomon Islands Meteorological Service has been working with local partners to document phenological knowledge associated with weather and climate forecasting and seasonal activities, including subsistence farming and fishing.

Evaluating a near term ecological forecast of plant phenology

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

There is a growing desire for near-term ecological forecasts, but there are few implementations that make regularly updated forecasts. We implemented a continuously updated forecasting system for the flower and leaf phenology of 66 plant species throughout the United States. Species specific phenology models were built using data from the National Phenology Network. Forecasts are made several times every week using temperature from the most current NOAA climate forecasts, which are themselves updated every 6 hours. Visual maps of forecasted dates across species ranges are available at http://phenology.naturecast.org. Using observations from 2018 we can calculate the skill of the forecasts compared to baselines, the contribution of variance from forecasted mean temperature, and the forecast horizon of plant phenology.

Preliminary results are available with observations submitted as of May 3, 2018. Of fourteen species with an adequate 2018 sample size for validation (> 20 observations), only two show some degree of predictability. For forecasts up to 60 days in advance, the predicted day of leaf out for Acer saccharum and Quercus rubra had lower error than naive models. For the remaining species a naive model, using only the mean day of year without integrating climate forecasts, proved to be a better prediction of when phenological events would occur. Further analysis will show whether high uncertainty in the climate forecasts or in the phenology models themselves contributed to such low predictability.

Developing, testing and applying phenology models for the Australian Almond industry

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Agricultural Phenology (3), Theatre, September 25, 2018, 3:30 PM - 4:50 PM

The Australian almond industry has expanded rapidly in recent decades and yet there is no phenology model from dormancy to maturity. A robust phenology model would assist crop protection, pollination management, assessing irrigation requirements and scheduling operations, especially harvest and post-harvest management. Australian almonds are mostly grown in inland irrigation districts and these regions are experiencing significant warming, especially in spring. A model would assist in modelling future changes in a warming world. There are phenology models for discrete stages of almond development in Californian conditions. We combined these separate models into a continuous model and tested the simulations against observations in Australia; Virginia, SA (1977-1984), Nagiloc, Vic. (1979-1984), Walker Flat, SA (2015-2018), Loxton, SA (2015-2018), Lindsay Point, Vic. (2015-2018), and Robinvale, Vic. (2016-2018).
We also tested the model by measuring temperature and phenology in elevation dependent meso-climates in the same orchards and in large pot trials with passive solar heated chambers. The prediction of flowering dates was better than ability to predict dates of hull split and of fruit maturity. Harvest, and to an extent physiological maturity are pseudo-phenostages because they are the interaction of management decisions and the environment.
A phenology calendar was developed that related typical month of phenological development and the weather and climate events that may impose a risk. Climate indices of these risks were identified. A phenology model for Almonds was created from existing separate models of flowering and time to hull split (early maturity) for Californian Almonds. Climate change projections were then imposed and the timing of key phenological events examined. The risks from the projected climate and weather were altered due both to the change in phenology affecting the timing of sensitive pheno-stages, and by the severity of the altered climate.

Long term phenology from the rainforests of Western Ghats: Some broad trends and patterns

Dr Ganesh Thyagarajan[1], Mr Saravanan Amavaasai[1], Dr Soubadra Devy[1]
[1]ATREE, Bangalore, India

Tropical Phenology, Seminar Room, September 26, 2018, 1:25 PM - 2:45 PM

Phenology of trees in the humid forests is both complex and variable. The patterns of flowering and fruiting are difficult to predict even after many years of observations. This is further confounded by lack of long term data from tropical regions limiting our ability to explore and validate many theories pertaining to phenology and climate cues that trigger phenological events. Here we describe the broad patterns of flowering and fruiting of 70 species of canopy, sub canopy and understorey trees from a rainforest in the Western Ghats mountains of India spread over 26y from 1991-2017.We relate intensity of phenological events to rainfall and temperature and describe some major events such as pest outbreak, masting events and response of pollinators and frugivores to it which would not have been possible without sustained monitoring. Preliminary analysis of the data indicates high variability in flowering at the individual tree level that does not synchronize at the population level. Supra annual flowering was predominant. Rainfall is important but dry period preceding major rainfall events may be crucial in triggering flowering. These and other observations relating to extreme climatic events on phenology and productivity of the forests will be discussed.

Maintaining Phenological Networks in the Face of Climate Change and Natural Disasters

Ms Siosinamele Lui[1], Dr Lynda Chambers[2], **Mr Tile Tofaeono[3]**
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Traditional Ecological Knowledge, Seminar Room, September 26, 2018, 10:25 AM - 12:25 PM

This paper looks at the newly developed phenological networks in the Pacific, with a particular emphasis on Samoa's experiences. Based in the tropical Pacific, these networks are likely to experience extreme natural events, including cyclones and tsunamis. These extreme events can have big impacts on phenological networks, including significant damage or even complete destruction of the plants that are being monitored, as was the case for Samoa's network, following Cyclone Gita (February 2017). Longer term environmental changes, including climate change, can also impact on the networks. Designing and maintaining a phenological network in face of these challenges is not easy and is the focus of this presentation.

Traditional Phenological Knowledge in Samoa

Mr Tile Tofaeono[1], Ms Faapisa Aiono[1], Ms Siosinamele Lui[2], Dr Lynda Chambers[3]
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Situated in Polynesia, Samoa consists of two major islands and four smaller ones. The traditional Samoan way, fa'a Samoa, remains a strong driver of Samoan life and many historical cultural customs remain significant. Phenological knowledge in Samoa has been traditionally passed from generation to generation via stories, song and other cultural practices. In recent years, the Samoan Meteorological Division has been working with local partners to document and monitor phenological knowledge associated with weather and climate forecasting and seasonal activities, including farming and fishing.

Impact of sun-sensor geometries on satellite retrievals of phenology in Southeast Asia tropical forests

Mr Ngoc Nguyen Tran[1], Mr Alfredo Huete[1]
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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

The Moderate Resolution Imaging Spectroradiometer (MODIS), with high temporal resolution, provide a useful tool to study tropical forest dynamics, including seasonality and inter-annual variation. However, optical satellite data have cloud, aerosol and Bidirectional Reflectance Distribution Function (BRDF) effects that create uncertainty in vegetation studies. In the Amazon, some researchers demonstrated the difficulties in separating true forest dynamics from BRDF artefacts and seasonal cloud and aerosol influences. Lastly, optical reflectance saturation in dense vegetation may restrict the retrieval of phenology information.

In this study, we investigated Southeast Asia (SEA) tropical forest phenology and the impact of BRDF effects on phenology retrieved by MODIS vegetation indices (VI). We used 16-year data of MODIS BRDF (MCD43C1, MCD43A1) collection 6 product, a kernel-driven model product that allows us to retrieve VI values for a range of fixed solar zenith angles (SZA). Then we compared these with the standard VI products (MOD13C2, MOD13A1) to analyse BRDF influences in both 5km and 500m resolutions. Results show significant forest disturbance impacts and associated BRDF effects on SEA natural vegetation phenologies. BRDF-induced impacts on the retrievals of phenology parameters for fixed sun angles, included shifts in greening profiles and peak vegetation activity. Moreover, seasonal variations in sun angles were found to reverse vegetation trends over forest areas between wet and dry seasons. Compared with intact forests, disturbed forests showed a stronger greenness seasonality with pronounced lower VIs in dry season and higher VIs in wet season. Overall, forest disturbance was found to amplify BRDF effects, especially with NDVI measures, whereby BRDF had no influence on NDVI of intact forests but showed significant seasonal impacts over disturbed areas. Our findings highlight that both sun-sensor geometries and disturbance have considerable impact on SEA tropical forest phenology and related studies need to consider them to avoid biased outcome.

Phenology in a warming world: a view from the Northern Hemisphere

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KEYNOTE PRESENTATION: Professor Dr. Marcel E Visser, Theatre, September 24, 2018, 9:35 AM - 10:20 AM

Biography:
Prof. Dr Marcel E. Visser is an evolutionary ecologist who works on seasonal timing of growth and reproduction. He combines field studies on the fitness consequences of timing in his long-term (1955-present) study populations of a small songbird, the great tit (Parus major), with work under controlled conditions to study the cues used in reproductive timing and with genomic work, to look at the genetics underlying timing. He furthermore addresses how global climate change impacts not only the timing of reproduction of the great tit but also one of its main prey species, the winter moth, and the host plant of the winter moth, the oak. Visser is head of Department of the Animal Ecology department of the Netherlands Institute of Ecology (NIOO-KNAW) and professor of Seasonal timing of behaviour at Groningen University and of Ecological genetics at Wageningen University.

Spring temperatures are increasing due to climate change and in the Northern Hemisphere this has had profound effects on the spring phenology of many organisms. These shifts in phenology however vary substantially among species, with predatory species shifting only at half the rate as their prey. This leads to so-called phenological mismatches: the phenology of predators and their prey get out of synchrony. I will give an overview of these mismatches, the evolutionary consequences and the population consequences using data from our long-term study (1955-present) on a small song bird, the great tit (*Parus major*). I will present data of birds, caterpillars and trees to show that to understand patterns of selection on the phenology of the birds we need to take the phenology of the entire food chain into account. Next, I will switch gears and focus on the potential for genetic change in response to selection on phenology in great tits. We have been studying the genetics and physiology underlying phenology by creating selection lines of early and late reproducing great tits, using genomic rather than phenotypic selection. We breed great tits of these selection lines under controlled conditions and look at their lay dates as well as at RNA expression. As a final step we introduced selection line eggs into our wild population and in 2018 we will have the first F4 offspring breeding in the wild and we can then measure their fitness depending on their phenology. Next, I will present data on how phenological mismatches have knock-on effect at the population level. In the last part of the talk, I will discuss these finding in the light of the theme of the meeting: One Planet, Two Hemispheres, Many Regions.

Grapevine phenology and agroclimatic indices in Croatia under climate change

Dr Visnjica Vucetic[1], Mr Marko Vucetic[1], Mr Branimir Omazic[2], Assis. Prof. Maja Telisman Prtenjak[2], Mr Ivan Prsa[3], Prof Marko Karoglan[4]
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Research worldwide indicates that future climate changes will not have an identical impact on all cultivation areas. As wine production has a long tradition in Croatia, it is important to determine whether the part of the country, which is suitable for grape cultivation, continues to be favorable in the future. In order to observe the changes, seven developmental stages of eight phenological stations for the well-known Croatian grapevine varieties (Riesling Italico, Chasselas Blanc, the Queen of Vineyard, Istrian Malvasia, Plavac Mali, Blatina and Trbljan) have been analysed in the period 1961-2017. To identify the effect of climate change, agroclimatic indices: Huglin heliothermal index (HI) and growing degree-days (GDD), which are frequently used to indicate suitable areas for wine production, have been evaluated in the period 1987-2016 compared to the normal 1961-1990. Linear trend analysis of phenological data showed that dates of leaf unfolding, beginning 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. The duration of the ripening period has been reduced by half (on 17-20 days) over the last 30 years. The shortening of the vegetation period is more due to the harvest beginning earlier in the summer than to the earlier onset of vegetation in the spring. In the period 1961-1990 HI was up to 2500°C and GDD up to 2300°C for the mid-Adriatic, up to 2050°C and 1500°C respectively for the continental area and below 1600°C and 1000°C for mountainous area. In the last 30 years, the increase of HI and GDD is evident in the whole Croatia (up to 300°C). 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 some mountainous parts

Trends of the phenological phases and growing degree days for olive trees in Croatia

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Weather conditions in the recent years less and less follow known annual and seasonal cycles and more and more extreme weather events endanger agricultural production. The Adriatic coast with the islands is the most vulnerable area in Croatia on the climate change. The olive cultivation and oil production are particularly economically important for this area. How much olive marks Croatian coastline shows that the Mediterranean climate is also referred as the olive climate. The aim is to determine the trends in phenological phases of olive and the changes of heat accumulation from one phase to next using growing degree days (GDD) with the temperature thresholds of 7°C in the period 1986-2015 related to normal 1961-1990. Five phenophases from seven stations have been analyzed in the period 1961-2015. The beginning, full and end of flowering are a week earlier in the mid-Adriatic than northern. First ripe fruits are usually by the middle of October, while the picking is in the first ten days in November. Linear trend analysis shows earlier flowering by 2 days/decade in northern Adriatic, while in mid-Adriatic by 3 days/decade. Earlier olive ripe 3 days/decade is observed in

mid-Adriatic, while earlier picking (2-4 days/decade) is not just a result of weather conditions, but it depends on market demand for certain oil quality. The spring phenophases require in average around 750-1000°C growing-degree days, 3100-3400°C for the first ripening and 3200-3600°C for picking over last 30 years. GDDs for flowering are similar for both periods but GDDs for the autumn phenophases increase by 150-300°C in the recent period. Using the phenological data (1961-2015) and GDD for each phenophases (1877-2015) for the mid-Adriatic station of Hvar, the olive phenophases has been reconstructed in the past. The trends in estimated autumn phenophases (21-27 days/century) are faster than for flowering (5-6 days/century).

Asymmetric response of flowering and relatively stable response of fruiting to warming and cooling in alpine plants

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Phenological Methods (3), Theatre, September 25, 2018, 3:30 PM - 4:50 PM

Isolated phenological events would restrict our understanding of plant entire life cycle. Responses of phenological sequence to temperature change (i.e., warming and cooling spells), however, are still unclear. We thus conducted a reciprocal transplantation experiment (from 2008 to 2010) to expose seven phenological sequences of six common species (i.e., two early-spring flowering (ESF) sedge species (Kobresia humilis and Carex scabrirostris) and four mid-summer flowering (MSF) species (two grasses: Poa pratensis and Stipa aliena and two forbs: Potentilla anserine and P. nivea)) from Tibetan Plateau responses to both warming (i.e., transplanting to lower elevation) and cooling (i.e., transplanting to higher elevation). In general, our results shown only first flowering had asymmetric responses to warming and cooling across six species. Meanwhile, first flowering of ESF was more sensitive to cooling than to warming (-2.1 d / ℃ under warming VS 8.4 d / ℃ under cooling), while MSF was more sensitive to warming than to cooling (-8.0 d / ℃ under warming VS 4.9 d / ℃ under cooling). Especially, the first fruit-set dates, however, did not change significantly compared to early and late phenophases for both ESF and MSF under warming and cooling. These results suggest that ignoring nonlinear temperature responses may overestimate or underestimate temperature warming on flowering for differing life strategies (ESF VS MSF) among plant species. In addition, alpine plants maintaining relatively stable timings of fruit set compared with other phenological events contribute to maximize the success of seed maturation and dispersal in response to short-term warming or cooling.

Contrasting responses of autumn leaf senescence to daytime and night time warming

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Phenological Methods (3), Theatre, September 25, 2018, 3:30 PM - 4:50 PM

Plant phenology is a sensitive indicator of climate change and plays significant roles in regulating carbon uptake variability by plants. Previous studies have focused on spring leaf-out by daytime temperature and the onset of snowmelt time, but the drivers controlling the leaf senescence date (LSD) in autumn remain largely unknown. Using long-term ground phenological records (14536 time series since the 1900s) and satellite greenness observations dating back to the 1980s, here we show that rising preseason maximum daytime (Tday) and minimum night time (Tnight) temperatures had contrasting effects on the timing of autumn LSD in the Northern Hemisphere (>20°N). If higher Tday leads to an earlier or later LSD, an increase in Tnight systematically drives LSD to occur oppositely. Contrasting impacts of daytime and night time warming on drought stress may be the underlying mechanism for this opposing relationship. A new LSD model considering these opposite effects improved autumn phenology modeling and predicted an overall earlier autumn LSD by the end of this century compared with traditional projections. Our results change the paradigm of prolonged growth by higher autumn temperatures, and that leaf senescence in the NH would begin earlier than currently expected, causing a positive feedback on climate change.

Providing access to agricultural phenological records in Australia: First steps

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In previous projects run through the University of Melbourne, substantial efforts have been made both to discover and assemble a comprehensive collection of viticultural and horticultural phenological datasets from across the Australian region. Relationships with farmers, as well as farmer networks and businesses, were necessitated, with travel to various sites around the continent required, in order to gain access to this valuable information. The records were then sorted, processed and digitised. These datasets have been employed to quantify associations between biophysical and environmental factors through time.

To ensure greater utility of these data-sets, they should be made available, with appropriate permissions, to further advance science and education. Providing access for researchers to these data for exploration and use will save much time and expense and advance knowledge beyond the scope of the original research projects, potentially in unforeseeable directions.

Using an internationally accepted data standard, the data are described by plant type, location, phenological stage and time frame of the records. Other biophysical factors or even some matching derived climate variables could also be made available.

Currently, more than one hundred datasets are being prepared for eventual provision to other researchers. These have been sourced from a diverse geographical range, across a range of perennial plant species.
This is a first step into organising datasets from the University of Melbourne. This will provide scope for global analyses of phenological information through connections with other established databases (e.g. PEP725).

Exploration of the chill overlap model for sweet cherry flowering

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Agricultural Phenology (2), Theatre, September 25, 2018, 2:00 PM - 3:00 PM

Many key phenological stages of temperate fruit trees are highly dependent on environmental conditions. This includes the timing of dormancy release and flowering which are essential to ensure good fruit production and quality. Global changes in environmental conditions include warmer winters and higher risks of frosts in the early spring, and may lead to a wide range of problems, including poor flowering, fruit set and cross-pollination, and novel host-pest interaction.
In this context, one of the challenges will be to better understand the possible impacts of climate change on flowering and subsequently to breed fruit trees adapted to future climatic conditions. Predictive models for flowering phenology will represent a valuable tool to assist in the process.

Following the collection of sweet cherry flowering data recorded across Europe and Australia, we present an exploration of the chill overlap model for several cultivars. The model was tested for a wide range of chill requirement potential values and optimisation results were compared to phenotypic observations. The best fits were obtained for critical chill requirements that do not correspond to the value estimated with forcing experiments. These results highlight that further investigation is needed for both phenological models and experimental analyses of dormancy and flowering in order to develop more robust models based on biologically-sound parameters.

Predicting canola phenology in warm environments

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Agricultural Phenology (1), Theatre, September 24, 2018, 10:55 AM - 12:15 PM

The geographic and seasonal range of Australian canola production is expanding, with crops sown earlier and in areas that experience warmer winters. The use of simulation models to help match canola genetics to the local environment have been used successfully to identify opportunities for early sowing and to determine the optimal flowering time to minimise frost, heat and water stress and maximise potential yield. However, are these models accurately representing the environment experienced by the plant within the warmer environments?
Detailed phenological study of Australian canola cultivars used the diverse environments of Canberra, ACT and Gatton Queensland, combined with lights to create varying photoperiods and temperatures. These experiments easily identified cultivars exhibiting vernal (cold) and photoperiod responses (day length).

Currently, the majority of Canola phenological models use the average daily temperature to calculate vernal time, accumulating one vernal day at 2°C and 0 at 0°C or 15°C. However, in warmer environments that have cool mornings and warm days the average temperature method can mask the accumulation of vernal time. Fitting a circadian curve between the maximum and minimum temperatures is one way to account for the vernal time accumulated on a sub daily basis.

Results from the detailed phenological studies identified many Australian canola spring types that respond to small amounts of vernal time. When these are grown in warmer environments the average daily method does not represent the distribution of flowering times observed. Using the sub-daily method improved the prediction as it accounted for the fractions of vernal time accumulated during the cool mornings experienced in these environments.
The use of modelling to investigate opportunities for canola production (early sowing, warmer regions), highlights the importance of calculating vernal time accurately to ensure the physiology of the plant is represented correctly.

MODIS and Sentinel-2 spatial assessments of phenology in fragmented grass / pasture landscapes in Australia

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Agricultural Phenology (1), Theatre, September 24, 2018, 10:55 AM - 12:15 PM

The grass and pasture lands in eastern Australia are essential contributors to the productivity and biodiversity of Australia as they support the agricultural production of wool, lamb, and beef. This highly productive eastern Australian belt consists of modified and fragmented landscapes with dryland management uses, heterogenous patches, and prevalence of invasive species. Remote sensing provides a means for monitoring these grass / pasture over a large area. MODerate-resolution Imaging Spectroradiometer (MODIS) 250 m global vegetation index product at 16 days temporal resolution is one of the mostly used satellite data for phenology research. The Sentinel-2 mission acquires spectral data globally at as fine as 10 m resolution every five days, providing a new chance for phenology research, particularly over heterogeneous landscapes. We also took advantage of the SMAP (Soil Moisture Active Passive) mission, which delivers global daily composite soil moisture at 9 km resolution. In this study, MODIS phenology of grass / pasture areas was analyzed across a precipitation and latitudinal temperature gradient encompassing warm season (C4) and cool season (C3) grass functional types. Using combined MODIS and Sentinel-2 derived phenologies at multiple scales, we tested the hypothesis of shifting phenologies associated with C3-C4 grass compositional changes with temperature and grass productivity changes due to rainfall gradients. In these water-limited dryland environments in eastern Australia, phenology is largely driven by available soil moisture. Therefore, we analyzed the relationship between grassland phenology and SMAP soil moisture measurements. The results showed excellent relationship between SMAP soil

moisture and MODIS / Sentine-2 EVI. Our study demonstrates the potential of the Sentinel-2 data for providing spatially-detailed retrievals of phenology, as well as the potential of the SMAP data for prediction of vegetation phenology.

The seasonality of large-scale droughts in Argentina based on SMAP soil moisture

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POSTER SESSION, September 24, 2018, 12:30 PM - 1:40 PM

Drought is one of the costliest natural disasters that seriously affects not only ecological systems but also national economies and political unrest. Consequently, drought research and monitoring are of increasing interest, especially over the agricultural area. Soil moisture is the main variable to define and identify agricultural drought. Currently, it is possible to use remote sensing to obtain global and daily frequency soil moisture maps, especially for the newest SMAP (Soil Moisture Active Passive) data launched in 2015. In this study, we used SMAP Enhanced L3 Radiometer Global Daily 9km EASE_Grid Soil Moisture, Version 3 (SPL3SMAP_E) to define a new Soil Water Deficit Index (SWDI) to illustrate the seasonality of a big drought that struck Argentina in 2018. SMAP was capable of extracting the seasonality and temporal evolution of this big drought, including the phases: onset, peak, end. The study area was divided into three parts according to the seasonal dynamics of the drought: (1) the northern area, where most of the drought started from Sep or Oct, and ended within one or two months duration; (2) central area, where most of the drought started from Nov 2017 resulting in a long duration of four months and a late end.; and (3) southern area, where a large area was characterized by late onset and end time with comparable short length. Additionally, we used the peak of the amplitude of SWDI during the drought to define the severity index and most of the severe drought was located in the southern La Plata Basin. Finally, we used remote sensing data, MODIS-derived EVI (Enhanced Vegetation Index) to study the vegetation responses to this extreme drought event. Cropland exhibited more sensitivity to this severe drought, while natural ecosystems seemed least affected by the extreme drought.

Biological and climate factors co-regulated spatial-temporal dynamics of vegetation autumn phenology on the Tibetan Plateau

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Remote Sensing (1), Theatre, September 24, 2018, 3:20 PM - 4:40 PM

Climate change is an important topic for natural sciences, and is receiving much attention from various fields. Phenology is a commonly used parameter indicating vegetation responses to climate change. Previous phenology studies have mostly focused on vegetation greening-up and its responses to climate change, while autumn phenology has been barely touched upon. In this study, phenological metrics were extracted from MODIS NDVI data to analyze the temporal and spatial changes of vegetation phenology in TP from 2000-2015. The results showed that the start of season (SOS) has significantly advanced and that the end of season (EOS) has slightly advanced but not significant. Similar patterns were also identified spatially. Additionally, SOS plays a more significant role in regulating vegetation growing season length than the EOS. The EOS exhibited a spatially heterogeneous pattern and each driving factor plays a distinct role in different regions. Biological factor is the dominant factor determining the spatial distribution of EOS, while climate factors control the inter-annual variation of EOS.