Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Annalen der Meteorologie 48

Phenology 2015

Third International Conference on Phenology
5. - 8. October 2015
in Kusadasi (Turkey)

Programme and Abstracts

Organization:
Humboldt-University Berlin (Germany), Adnan Menderes University Aydin (Turkey)

Offenbach am Main 2015
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Greeting

Phenology was and still is a traditional and very important field for Germany and for the Deutscher Wetterdienst (DWD), Germany's national meteorological service. As early as 1791 phenological data had been collected at Hohenpeißenberg, near the Alps, where now a meteorological observatory of the DWD is located. Today the DWD operates a phenological network of about 1200 observers, most of them participating on a voluntary basis. About 160 phenological phases of wild plants, agricultural crops, fruit trees, fruit bushes and grape vines are being collected and archived in DWD's phenological database. Phenological observers who have worked for 40 years on a voluntary basis even get a Medal of Merit of the Order of the Federal Republic of Germany.

In times in which climate change is one of the greatest challenges for mankind, DWD welcomes the use of its phenological data and its knowhow, especially for climate change projects. In this context the DWD is pleased to see that the International Conference on Phenology is already taking place for a third time and wishes all participants good talks, discussions and insights.

Dr. Paul Becker, Vice-president of Deutscher Wetterdienst (DWD)

Preface

This is the third International Conference on Phenology. It was organised by Humboldt-University of Berlin and the Adnan Menders University Aydin. The first conference "Phenology 2010" was hosted by the Trinity College Dublin and two years later the "Phenology 2012 Conference" was held at the University of Wisconsin-Milwaukee.

The overall theme of the conference is "*Challenges in Phenology*" and phenological research is focused on different important topics including

- Phenological observations within different networks, data collection
- Climate variability, climate change and phenological trends
- Match or mismatch in phenology
- Aspects and challenges in marine phenology
- Remote sensing and phenology
- Phenological modelling
- Challenges, new approaches and progress in phenology

Current challenges in phenology are to evaluate the plasticity of plants in order to understand the response of species and communities to climate change. It is important to investigate the interaction between organisms, because they can respond in phenologically different ways to climate change, so that in the future mismatch between species can occur. In this context plant-animal interactions are of fundamental interest. Phenological models are important tools to calculate possible shifts in plant development due to climate change. They are frequently embedded in much more complex models in order to calculate regional and global climate change, vegetation dynamics, changes in carbon balance and in water budged, as well as changes in crop yields. Today's challenges are to develop phenological models which work for present and future climate conditions with the same accuracy. For this reason numerical, experimental and physiological work is necessary to analyse the species-specific key drivers of plant development and to improve the understanding of physiological processes, such as dormancy.

Current challenges in the field "Remote Sensing Phenology" are detailed validations of remote sensed phenological measures with ground-based phenological events, especially using in-situ phenological data sets collected at spatial scales commensurate with satellite data.

Phenology is covering more and more areas from land phenology to marine phenology, from plants to animals and geographically from the tropics to the boreal zones. Global or regional phenological data bases bring these observations together and allow a better and deeper understanding about the interactions between species and regions. Phenological networks form the basis for numerous scientific studies and issues.

A total of 89 papers will be presented at the conference. Participants are coming from 23 countries around the world, from North America to Australia and from Europe to Japan.

Frank-M. Chmielewski and Osman Erekul

Organisation Committee

Humboldt-University of Berlin (Germany)
Faculty of Life Sciences, Albrecht Daniel Thaer-Institute of Agricultural and Horticultural Sciences

Prof. Dr. Frank-M. Chmielewski
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Dr. Mustafa Çelik
Dr. Engin Ertan

Phenology 2015 – Humboldt-University of Berlin and Adnan Menderes University Aydin
https://u.hu-berlin.de/phenology2015

Conference Programme

Monday, 5 October 2015	**Opening ceremony** Prof. Dr. Cavit Bircan (President of Adnan Menderes University) Prof. Dr. Kadir Kizilkaya (Dean of the Faculty of Agriculture) Prof. Dr. Mark D. Schwartz (President of ISB) Prof. Dr. Osman Erekul (Organiser, Adan Menderes University Aydin) Prof. Dr. Frank-M. Chmielewski (Organiser, Humboldt-University of Berlin) **Keynote, Andrew D. Richardson** Phenology, Ecosystem Processes, and Climate change: What we are learning from the PhenoCam Network **Session 1:** Phenological Observations, networks, data collection **Session 2:** Climate variability, climate change and phenological trends
Tuesday, 6 October 2015	**Keynote, H. Nüzhet Dalfes** Phenology in the 21st Century: A Turkish Perspective **Session 2:** continuation **Session 4:** Remote sensing and phenology **Management Meeting PEP725**
Wednesday, 7 October 2015	**Keynote, James Cloern** The Differing Seasonal Patterns of Terrestrial and Marine Primary Producers **Session 4:** continuation **Session 5:** Phenological modelling **Poster Session** **Galadinner**
Thursday, 8 October 2015	**Session 3:** Match or mismatch in phenology **Session 6:** Challenges, new approaches and progress in phenology **Session 5:** continuation **Satellite Group Meeting** **Closing ceremony**
Friday, 9 October 2015	**Excursions**

Keynote Speeches

James **Cloern**
The Differing Seasonal Patterns of Terrestrial and Marine Primary Producers

H. Nüzhet **Dalfes**
Phenology in the 21st Century: A Turkish Perspective

Andrew D**. Richardson**
Phenology, Ecosystem Processes, and Climate change: What we are learning from the PhenoCam Network

1 Phenological Observations, networks, data collection

1.1 Oral Presentations

Gabriele **Cola**, Luigi Mariani, David Maghradze, Ramaz Chipashvili, Levan Ujmajuridze, Osvaldo Failla
Phenological cartography of relevant cultivars of Georgian viticulture

Jonathan **Davies**, Malie Lessard-Therrien
Flowering phenology in the subarctic shows earlier flowering species are less variable

Eero **Kubin**, Jarmo Poikolainen, Jouni Karhu
Long term phenological monitoring in the boral forest in Finland

Harald **Maier**
About the use of phenological phases in practical agriculture in Germany

Lee **Marsh**, Katharine L. Gerst, Ellen G. Denny, Theresa M. Crimmins, David J. Moore, Alyssa H. Rosemartin, Jake F. Weltzin
Phenology data products to support assessment and forecasting of phenology on multiple spatiotemporal scales

Barbara **Pietragalla**, Sabine Güsewell, Regula Gehrig
Do we have enough phenological stations? - Study on the representativeness of the Swiss Phenological Network

Yan Liu, Crystal **Schaaf**, Xiaoyang Zhang, Zhuosen Wang, Angela Erb, Edward Saenz, Qingsong Sun, Ian Paynter
Monitoring tree and understory grass phenological development in California Savannas using daily MODIS and VIIRS NBAR

Markus **Ungersböck**, Thomas Hübner, Anita Jurkovic, Elisabeth Koch
PEP725 www.pep725.eu: Monitoring of phenological 2015 spring events using GP

1.2 Posters Presentations

Mustafa **Çelik**
Phenological data and cumulative Growing Degree Days of some table grapes in Kirazlı Village in Turkey

Iñaki Garcia **de Cortazar-Atauri**, Jean Marc Audergon, Patrick Bertuzzi, Christel Anger, Marc Bonhomme, Isabelle Chuine, Hendrik Davi, Sylvain Delzon, Eric Duchêne, Jean Michel Legave, Hélène Raynal, Christian Pichot, Cornelis Van Leeuwen, Perpheclim Team
PERPHECLIM ACCAF Project - Perennial fruit crops and forest phenology evolution facing climatic changes

Zeynel **Dalkılıç**, Gonca Günver-Dalkılıç, Mustafa Çelik
Endodormancy requirement for white female mulberry (Morus alba L.*)*

Åslog **Dahl**, Ola Langvall, Kjell Bolmgren
The Swedish National Phenology Network

Mijin **Kim**, Changbum Cho, Kyu Rang Kim, Mae Ja Han, Jae-Won Oh, Baek-Jo Kim
Patterns in airborne pollen in Korea

Hilmi **Kocataş**, Engin Ertan
Determination of chilling periods of some fig (Ficus carica L.*) cultivars*

Ola **Langvall**, Kjell Bolmgren, Åslög Dahl
Swedish historical phenology data, a base for indication of regional climate change

Hamed Mehdipoor, Raul **Zurita-Milla**
Checking for inconsistent volunteered phenological observations

Mustafa **Sürmen**, Emre Kara
Yield and quality features of field Pea (Pisum arvense L.*) varieties which was harvested at different phenological stages*

2 Climate variability, climate change and phenological trends

2.1 Oral Presentations

Irene **Garonna**, R. de Jong, D. Schenkel, R. Stöckli, M.E. Schaepman
Evaluating shifting land surface phenology and its climatic drivers at global scale

Regula **Gehrig**, Barbara Pietragalla
Phenological changes between the two climate normal periods 1961-1990 and 1981-2010 in Switzerland

Lenka **Hájaková**, Tomáš Vráblík, Věra Kožnarová, Pavol Nejedlík, Martin Možný
Are there any changes in Betula pendula vegetative and generative phenophases onsets in Czechia and Slovakia?

Aud **Halbritter**, Ørjan Totland, Vigdis Vandvik
Climate change effects on phenology in alpine plant communities

Fangyuan **Huan**, Junhua Hu, Yang Liu
Climate-associated phenological shift across China suggests community assembly changes

Wang Huanjiong, Ge Quansheng, Dai **Junhu**
Spatiotemporal variability in start and end timing of growing seasons in China relating to climate change

David **Inouye**, Jane Ogilvie
Forecasting flowering: How far in advance can phenology and abundance be estimated?

Xuanlong **Ma**, Alfredo Huete
Impacts of large-scale drought and deluge on ecosystem productivity and phenology in Southeastern Australia

Irene **Mendoza**, Carlos A. Peres, L. Patrícia C. Morellato
Climatic drivers of fruiting phenology: a quantitative review throughout the Neotropics

Annette **Menzel**, Christian Zang
Late spring frost risk in a warming world

Rebecca A. **Montgomery**, Peter B. Reich, Roy R. Rich, Artur Stefanski, Karen L. Rice
Interannual variation in the response of tree phenology to experimental warming at the boreal-temperate ecotone in North America

Laura **Radville**, David Eissenstat
Root and shoot phenology may not respond to warming in the same way

Victor **Rodriguez-Galiano**, Jadunandan Dash, Peter Atkinson
Modelling anomalies in the land surface phenology of Europe using inter-annual variations in climatic drivers

Mark D. **Schwartz**
Assessing spring phenological change at continental to global scales

Oddvar **Skre**, Frans Emil Wielgolaski, Finn Måge
Trends for budburst and flowering of woody plants in Norway as related to climate change

Barbara **Szabo**, Matthias Templ, Peter Filzmoser, Annamária Lehoczky, Rita Pongrácz, Eugenija Baksiene, Agrita Briede, Hilppa Gregow, Sabina Hodzic, Katarzyna Jatczak, Gunta Kalvane, Eero Kubin, Pavol Nejedlik, Tadeusz Niedźwiedźz, Vello Palm, Tonka Popovic, Danuta Romanovskaja, Zora Snopkova, Silvana Stevkova, Juhani Terhivuo(†), Visnjica Vucetic, Ana Zust, Bláint Czúcz
Biogeographical regions and their flowering phenological patterns across Europe

Yann **Vitasse**, Geoffrey Klein, Gianluca Filippa, Edoardo Cremonese, Martine Rebetez, Christian Rixen
Impact of snow and temperature on alpine plant phenology in the Alps

2.2 Poster Presentations

Ilona Blinova, Frank-M. **Chmielewski**
Climatic warming in the higher latitudes of Europe between 1951 and 2012 - the case of Murmansk Region

Emma Izquierdo-Verdiguier, Raul **Zurita-Milla**, Toby R. Ault, Mark D. Schwartz
Using cloud computing to study trends and patterns in the Extended Spring Indices

Yakup Onur Koca, Osman **Erekul**
Changes of dry matter, biomass and relative growth rate with different phenological stages of corn under Mediterranean conditions

Massetti **Luciano**, Di Stefano Valentina, Messeri Alessandro, Morabito Marco, Orlandini Simone
Foliar phenology as a sensitive indicator to climate change: a case study to investigate its applicability to the Mediterranean Area

Nathália M.W.B. Rocha, Daniel W. Carstensen, Irene **Mendoza**, G. Wilson Fernandes, Patricia Morellato
Floristic diversity and reproductive seasonal patterns in a tropical altitudinal gradient

Oddvar **Skre**, Frans E. Wielgolaski
Northern treelines as bioclimatic indicators

Vanessa G. **Staggemeier**, Valesca Zipparro, Eliana Gressler, Everaldo Rodrigo de Castro, Patícia Morellato
Flowering and fruiting of Neotropical Myrtaceae

Xiaojing Wu, Raul **Zurita-Milla**, Menno-Jan Kraak
Mapping the main spatio-temporal patterns of spring onset over Europe

3 Match or mismatch in phenology

3.1 Oral Presentations

Ella F. **Cole**, Ben C. Sheldon
Dynamic changes in a keystone resource modulates heterogeneous responses to climate change in a wild bird population

Julia **Laube**, Hanna Weber, Annette Menzel
Match or mismatch: A test with 7 butterfly species, over 300 host and nectar plants and 58 years of phenological observation

Ben C **Sheldon**, Ella F. Cole
The spatial scale of selection on phenology in a wild bird population

Emily **Simmonds**, Ella Cole, Tim Coulson, Ben Sheldon
Experimental manipulation of spring temperature to alter breeding phenology in a population of wild blue tits (Cyanistes caeruleus)

Christine **Tansey**, Albert Phillimore
Using citizen science to quantify spatial variation in ecological mismatch in woodlands

3.2 Poster

Annette **Menzel**, Reinhard Menzel
Climate change impacts on wild boar in Bavaria mediated by abiotic and biotic phenological changes

4 Remote sensing and phenology

4.1 Oral Presentations

Bruna **Alberton**, Jurandy Almeida, Bruno Borges, Marina Müller, Magna Soelma Beserra De Moura, Thiago S. F. Silva, Ricardo Torres, Patricia Morellato
Growing seasons detected by digital cameras along five seasonal vegetation in the tropics

Sarah **Asam**, Mattia Callegari, Armin Costa, Ludovica De Gregorio, Felix Greifeneder, Roberto Monsorno, Bartolomeo Ventura, Claudia Notarnicola
Phenological monitoring of alpine grassland based on innovative biophysical remote sensing products adapted to alpine areas

Jesslyn F. **Brown**, Lei Ji, Alisa L. Gallant
Revealing the influence of drought on spring vegetation phenology

Yetkin Özüm **Durgun**, Sven Gilliams, Anne Gobin, Grégory Duveiller, Bakary Djaby, Bernard Tychon
Crop suitability monitoring with 100 m PROBA-V data

Gianluca **Filippa**, Edoardo Cremonese, Mirco Migliavacca, Marta Galvagno, Fabrizio Diotri, Andrew D. Richardson
Opportunities to assess grassland biodiversity using digital repeat photography

Geoffrey M. **Henebry**, Woubet G. Alemu, Pedro V.C. Oliveira
Phenologies in cool earthlight: How passive microwave time series can reveal land surface phenologies and more

Stein Rune **Karlsen**
Remote sensing based mapping of the growing season in alpine parts of Norway and on the High Arctic Archipelago of Svalbard

Carina **Kübert**, Christopher Conrad, Doris Klein, Stefan W. Dech
Deriving phenological layers for Germany from remote sensing data: spatio-temporal analysis and validity

Gillian **Mountford**, Jadunandan Dash, Peter M. Atkinson, Thomas Lankester, Steven Hubbard
A comparison of ground-based observations and the sensitivity of satellite-derived land surface phenology to variation in spatial and temporal resolution

Shin **Nagai**, Syunsuke Tei, Koji Kajiwara, Hiroki Ikawa, Rikie Suzuki, Kenlo Nishida Nasahara
Detection of spatio-temporal variability of the timing of start and end of growing season by multidisciplinary in situ and satellite observations

Miina **Rautiainen**, Petr Lukes
Seasonality of boreal forest spectra

Christopher J. **Watson**, Natalia Restrepo-Coupe, Alfredo R. Huete
Seeking greener pastures: exploring multi-scale phenology of Australian temperate grasslands

Xiaoyang **Zhang**, Yunyue Yu, Lingling Liu, Geoffrey Henebry, Mark Friedl, Joshua Gray, Crystal Schaaf, Yan Liu, Zhuosen Wang
VIIRS land surface phenology: from climate date record to real time monitoring

4.2 Poster Presentations

Valerio **Basso**, Giorgio Boni, Francesco Silvestro, Fabio Delogu
Impacts of the EO-based representation of the vegetation dynamics on continuous basin scale hydrologic models

Elias Fernando **Berra**, Rachel Gaulton, Stuart Barr
Forest phenology monitoring with digital cameras onboard an unmanned aerial vehicle

Thomas **Lanners**, Petra D`Odorico, Nina Buchmann
Linking non-destructive measurements to investigate temporal niche complementarity in a grassland biodiversity experiment

Xuanlong **Ma**, Alfredo Huete
Interactions of seasonal sun angle and tropical savanna phenology observed and modelled using MODIS

Laura Stendardi, Stein Rune **Karlsen**, Bernt Johansen
Time-series of Landsat 8 data in mapping the onset of the growing season in Adventdalen valley, on the Arctic Archipelago Svalbard

5 Phenological modelling

5.1 Oral Presentations

Kjell **Bolmgren**, Åslög Dahl, Ola Langvall
Using phenology models to generate transnational baselines for Environmental Assessment Indicators

Frank-M. **Chmielewski**, Klaus-Peter Götz
Insight in the behaviour of phenological models under changed climate conditions

Iñaki Garcia **de Cortazar-Atauri**, Etienne Neethling, Laure De Rességuier, Amber K. Parker, Gérard Barbeau, Hervé Quenol, Andrew Sturman, Mike Trought, Cornelis Van Leeuwen
Assessing prediction quality of several phenological process based models using various types of databases: A case study using Vitis vinifera data

Klaus-Peter **Götz**, Frank-M. Chmielewski, Danuše Tarkowská, Miroslav Stirnad
New insights into sweet cherry's dormancy

Kyu Rang **Kim**, Mijin Kim, Ho-seong Choe, Mae Ja Han, Changbum Cho, Jae-Won Oh, Baek-Jo Kim
A biology driven model for daily pollen allergy risk

Albert **Phillimore**, Jarrod Hadfield, Dave Leech, James Pearce-Higgins
Separating plasticity from microevolution in frogs and birds

Benjamin **Richard**, Jennifer Cunniff, Salvador Girbau, Sarah Purdy, Goetz M Richter, Angela Karp
Budburst modelling in short rotation coppice willows, does modelling chilling matter?

Victor Rodriguez-Galiano, Jadunandan **Dash**, Peter Atkinson
Using satellite derived phenology to model leaf unfolding and autumnal colouring of PEP725 phenological records: A species controlled multivariate approach

Raul **Zurita-Milla**, Emma Izquierdo-Verdiguier, Hamed Mehdipoor
Phenological modelling using volunteered observations and machine learning methods

5.2 Poster Presentations

Karsten **Brandt**
Forecasting the wild daffodil flowering for touristic purposes

6 Challenges, new approaches and progress in phenology

6.1 Oral Presentations

Patricia **Morellato**, Bruna Alberton, Swanni T Alvarado, Bruno D Borges, Elise Buisson, Maria Gabriela G Camargo, Daniel W Carstensen, Diego F Escobar, Patricia Leite, Irene Mendoza, Nathalia MWB Rocha, Natalia Soares, Vanessa G Staggemeier, Betania C Vargas, Carlos A. Peres
Phenology and conservation

This **Rutishauser**, Stefan Brönnimann, Martine Rebetez, Werner Eugster, Andreas Burger, Eric Wyss, Barbara Pietragalla, Regula Gehrig, project collaborators
Embedded plant phenology - Collecting and comparing phenological data with a national observation network and citizen science communities

Vanessa G. **Staggemeier**, José Alexandre F. Diniz Filho, Valesca Zipparro, Eliana Gressler, Everaldo Rodrigo de Castro, Fiorella Mazine, Itayguara Ribeiro da Costa, Eve Lucas, Patrícia Morellato
Evolutionary responses in the phenology of Myrtaceae in the Atlantic forest

E. M. **Wolkovich**, M. J. Donahue
Climate change and coexistence: The role of temporal variability in structuring future communities

C. M. **Zohner**, S. S. Renner
Perception of photoperiod in individual buds of mature trees regulates leaf-out

6.2 Poster Presentations

Karsten **Brandt**
Worldwide pollen forecast

Greice C**.** Mariano, Leonor Patricia C. Morellato, Jurandy Almeida, Bruna **Alberton**, Maria Gabriela G. de Camargo, Ricardo da S. Torres
Storing phenological data: a proposal of database especially suited for tropical vegetation

Yanjun **Du**, Lingfeng Mao, Simon A. Queenborough, Robert P. Freckleton, Bin Chen, Keping Ma
Phylogenetic constraints and trait correlates of flowering phenology in the angiosperm flora of China

Lori M. **Petrauski**, Greg Good, Thomas Rodd, George Constantz, James T. Anderson
Using publicly sourced, archival data to create a baseline phenological database for the West Virginia University Natural History Museum

Keynote speeches

The Differing Seasonal Patterns of Terrestrial and Marine Primary Producers

James E. Cloern

U.S. Geological Survey, Menlo Park, CA (USA)

Land plants at mid and high latitudes are powerful climate sentinels because they are anchored in space, have slow biomass turnover and annual cycles of growth, reproduction and senescence that are finely tuned to the annual cycles of temperature and solar radiation. The application of phenological studies to detect biological responses to changing climate is grounded in the adaptations of terrestrial organisms to the 12-month climate cycle. Phytoplankton, which contribute half of global primary production, are very different life forms that are suspended in water, move with currents and have the capacity to double their biomass several times daily. Does this fast turnover mean that microalgae respond more to short-term fluctuations of the climate system that mask their responses to the annual climate cycle? Do the terrestrial concepts of phenology apply to the phytoplankton, and have we measured changes in seasonal patterns of phytoplankton biomass or production that can be attributed to changes in the climate system? This presentation will be a mini-review of what we have learned from observations of marine phytoplankton communities over the past few decades. Observational programs in some regions, such as the North Sea, have revealed annual cycles of phytoplankton community variability and changes in those communities synchronous with changes in the climate system. However, observations from many other regions, especially coastal waters influenced by connectivity to land, show that phytoplankton do not always follow the terrestrial phenology rules. Exceptions to the rule include: absence of a recurrent seasonal pattern; abrupt shifts in seasonal patterns; and changing phytoplankton patterns associated with human disturbances such as nutrient enrichment, fishing, water diversions and species introductions. Phenological studies of the plankton are just emerging, and considerable work remains to discover if changes in this community are indicators of climate change (or something else).

Phenology in the 21st Century: A Turkish Perspective

H. Nüzhet Dalfes

ITU Eurasia Institute of Earth Sciences, Istanbul (Turkey)

It is becoming clear that the Mediterranean Basin will be one of the regions of our planet most affected by anthropogenic climate change. This change will manifest itself not only in the annually averaged values of climate parameters, but also as subtle changes in the seasonality of the climate. Therefore it is of paramount concern to understand the relationships between the dynamics of ecosystems and seasonality of climate. Phenological observations will play a crucial role in these studies. This talk first will provide a survey of what is available as phenological observations for Turkey. This will be followed by an account of current developments: the TRFeno initiative to build a citizen-science network of observers and efforts to design and implement the embryo of a phenocam network for Turkey.

Phenology, Ecosystem Processes, and Climate change: What we are learning from the PhenoCam Network

Andrew D. Richardson

Harvard University, Department of Organismic and Evolutionary Biology, Cambridge, MA (USA)

Phenology has been shown to be a robust integrator of the effects of year-to-year climate variability and longer-term climate change on natural systems. At the level of organisms, phenology plays a critical role in processes related to growth, reproduction, and competition. At the level of ecosystems, phenology is important because of implications for productivity, carbon sequestration, nutrient cycling, and feedbacks to the climate system. At decadal-to-century time scales, climate change will indirectly cause additional shifts in ecosystem phenology via shifts in community composition and structure.

There is a demonstrated need to better document biological responses to a changing world, and improved phenological monitoring will contribute to achieving this goal. In this talk, I will describe a collaborative research network called "PhenoCam" (http://phenocam.sr.unh.edu/). PhenoCam uses networked digital cameras – webcams – for phenological monitoring in a range of ecosystems (over 100 sites, and 300+ site-years of archived data) across the North American continent. Images are captured every 30 minutes, are uploaded to the PhenoCam server for display in real-time, and are then processed to yield measures of vegetation "greenness".

I will discuss how we are using data from PhenoCam (1) to improve understanding of the environmental controls on phenology at organism-to-ecosystem scales; (2) to relate ecosystem processes (e.g. carbon and water fluxes measured via eddy covariance) to phenology; and (3) to develop predictive models and forecast future climate change impacts on phenology.

1 Phenological Observations, networks, data collection

1.1 Oral Presentations

Phenological cartography of relevant cultivars of Georgian viticulture

Gabriele Cola[1], *Luigi Mariani*[2], *David Maghradze*[3,4], *Ramaz Chipashvili*[3], *Levan Ujmajuridze*[5], *Osvaldo Failla*[1]

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A high number of local peculiar varieties are grown in Georgia and give rise to well appreciated wines. Since these varieties play a fundamental role for the national wine sector, it is important to develop and spread state of the art tools to support winegrowing and winemaking activities. This activity is also important because Caucasian varieties keep in many cases trace of the ancient process of primary domestication of grapevine that involved the Caucasus region, as stated by a growing corpus of archaeological remains.

In this context, phenological observation and modelling are interesting in order to upgrade the knowledge of the behaviour of local varieties that at present is based on observational activities carried out during the cold phase of the XXth century, before the climate shift that affected the European climate of the end of the ’80s. Current climate conditions suggest that is time to carry out new analyses also in order to evaluate the potential of underused varieties.

The primary aim of this work was to describe the BBCH phenological dataset gathered during the period 2012-2014 in the context of the COST Action FA1003 – ‘GRAPENET: East-West Collaboration for Grapevine Diversity Exploration and Mobilization of Adaptive Traits for Breeding’. The phenological dataset and a suitable thermal dataset were used to calibrate and validate specific phenological models based on the Normal Heat Hours approach. Validated models were applied to the 1981-2013 thermal time series in order to obtain phenological maps for the Georgian territory in the context of the National project ‘REASERCH AND POPULARIZATION OF GEORGIAN GRAPE AND WINE CULTURE’.

Keywords: Georgia, grapevine phenology, traditional varieties, cartography

Flowering phenology in the subarctic shows earlier flowering species are less variable

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Phenological studies are rarely reported from arctic and subarctic regions, but projections suggest that these ecosystems might be subject to rapid warming. Here, we present a phylogenetic analysis of flowering phenology across an elevational gradient in the Canadian subarctic. We show that the timing of first flower is best explained by a combination of snowmelt, elevation and growing degree days. However, we also show that early flowering species have lower intraspecific variability in their response to climate cues in comparison with late flowering species. Previous work has suggested that early flowering species are more variable in their phenology, but these studies have mostly examined variation in phenology over time, whereas we examined variation in phenology over space. We suggest that both patterns can be explained by the tighter coupling between phenology and climate cues for early flowering species. Thus variability in first flower between seasons over several years demonstrates an opposite trend to variability in first flower over a single growing season, but the underlying mechanisms are the same. Early flowering species have low intraspecific variance in flowering times within a single growing season as individuals respond more uniformly to a common set of cues in comparison to late flowering species. These same species may show large variance between years reflecting interannual variation in climate.

Keywords: phenological plasticity, intra-annual variation, growing season

Long term phenological monitoring in the Boral forest in Finland

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The Finnish National Phenological Network was established in 1995 by the Finnish Forest Research Institute in collaboration with other institutes and universities. The monitoring was done twice a week taking place in the same individual plants originally at 30 observation sites across Finland. The monitoring covers eight tree species: *Betula pubescens*, *Betula pendula*, *Pinus silvestris*, *Picea abies*, *Populus tremula*, *Juniperus communis*, *Prunus padus* and *Sorbus aucuparia* and flowering of *Vaccinium vitis-idaea* and *Vaccinium myrtillus* and the ripening of berries. The first results indicated that the onset of downy birch leaves occurred in northernmost part of the country about a month later compared with southern Finland and began to turn yellow already at the beginning of September. The annual monitoring has been continued in the Finnish National Phenological Network now 20 years.

The results of the network indicate that spring phenophases have especially in northern Finland advanced with respect to climatic conditions. No trends are observed in the timing of autumn phenophases. However, there occurs great variation of phenophases between the years and sites causing uncertainty for the use of data. The observation term of twenty years is long but it is still too short to tell whether the advancement of spring is a constant phenomenon or a consequence of normal climatic variability. To detect long-term trends in the impacts of climate on plant phenophases, the Finnish National Phenological Network has therefore collaborated with the Finnish Museum of Natural History responsible for historical phenological data based on voluntary monitoring since 1752. This long-term data shows for example that the onset of flowering in the rowan (*Sorbus aucuparia*) and in the bird cherry (*Prunus padus*) has become earlier in Finland at the rate of three days and five days per century, respectively. The results of the National Phenological Network fit well with this historical data.

Phenological monitoring by using field observations is nowadays more important than ever especially in the boreal regions, where spring temperatures are elevated. Compilation and documentation of observations on plant phenophases play a key role in working out responses and the rate of global climate change. The timing of phenophases and the animations showing on the green wave will be discussed and presented in the symposium as well as to use integration of digital technologies into everyday phenological monitoring.

Keywords: long-term monitoring, climate change, Finnish National Phenological Network, digital technologies

About the use of phenological phases in practical agriculture in Germany

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Phenology looks back to a long tradition in Germany. In the early time of atmospheric data collection besides weather data were phenological data collected to get information about how nature reacts to different weather conditions. Practical agriculture has always used observation-based information on non-cultivated plants to plan the work in the fields. Phenological data are needed by scientists, agricultural consulting agencies and institutions as well as in practical agriculture. It is used as a framework in models, e.g. crop models, special agrometeorological models, in reports and training materials and for the timing of production-related activities. Models for agricultural and agro-meteorological consultancy: In crop models especially for arable crops, e.g. in DSSAT-models, phenology often provides a frame. Phasic development is used to determine the duration of the major stages of plant growth. In every phase of arable crops, so-called yield components are produced. Crop yield is the arithmetic product of the individual yield components. The lengths of the separate phases and the duration of the total growth are important to determine potential crop yields.

In agro-meteorological models of the German Weather Service (DWD) phenological phases are used for the timing in models. Those models simulate the incidence of plant diseases and pests, crop moisture, soil moisture, moisture of the grain, radiation distribution in plant covers, etc. The results of the models are used for DWD’s consultancy.

Practical agriculture: Because the development of plants varies substantially in different years (due to different weather), climate zones and varieties, in practical agriculture phenological phases (BBCH-Scale) are very fundamental in controlling and timing plant growth and in monitoring and fighting pests. Phenology is widely used to plan management activities such as timing and amount of fertilizers, plant growth regulators and pesticides as well as the timing of mechanical weed control. Hence the farmer has to be able to identify phenological phases on the basis of the BBCH scale.

Here are some examples:
Nitrogen fertilization of cereals (winter wheat): There are four particular phenological stages at which nitrogen fertilizer is applied to control the growth of yield components: tillering, beginning of stem elongation, flag leave stage and full flowering. Moreover the farmer needs more detailed information about the state of the crop, e.g. number of shoots per square meter.

Plant growth regulators in red wheat: Plant growth regulators are used to modify crop growth rate and growth pattern during various stages of development. They are applied in many plant species and are normally active at very low concentrations. Moreover the effect depends very much on the phenological stage of the plants which have to be treated (besides weather conditions). In high-yield varieties of winter grain growth regulators are particularly used to influence the numbers of tillers per plant or to prevent lodging. For example, Chlorocholine Chloride (CCC), a gibberellin biosynthesis inhibitor, is used to prevent lodging by shortening the length of the lower internodes. If plants are treated too early, i.e. during main tillering, they produce too many tillers, which may increase instead of decrease the risk of lodging.

Pest management: Spray decisions are often made based on the crop’s growth stage. Best practices are the IPM models. These models aim at optimizing plant protection treatments on the basis of specific epidemiological control thresholds in phenological phases. Hence the farmer must be able to diagnose the various wheat pathogens and the phenological phase (BBCH scale). The type of fungicide chosen depends upon whether the threshold for one or several pathogens is reached.

Keywords: phenology in agriculture

Phenology data products to support assessment and forecasting of phenology on multiple spatiotemporal scales

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The USA National Phenology Network (USA-NPN; www.usanpn.org) serves science and society by promoting a broad understanding of plant and animal phenology and the relationships among phenological patterns and environmental change. The National Phenology Database maintained by USA-NPN now has over 4.8 million records for plants and animals for the period 1954-2014, with the majority of observations collected since 2008. These data have been used in a number of science, conservation and resource management applications, including national assessments of historical and potential future trends in phenology, regional assessments of spatio-temporal variation in organismal activity, and local monitoring for invasive species detection.

Customizable data downloads are freely available, and data are accompanied by FGDC-compliant metadata, data-use and data-attribution policies, vetted and documented methodologies and protocols, and version control. While users are free to develop custom algorithms for data cleaning, winnowing and summarization prior to analysis, the National Coordinating Office of USA-NPN is developing a suite of standard data products to facilitate use and application by a diverse set of data users.

This presentation provides a progress report on data product development, including: (1) Quality controlled raw phenophase status data; (2) Derived phenometrics (e.g. onset, duration) at multiple scales; (3) Data visualization tools; (4) Tools to support assessment of species interactions and overlap; (5) Species responsiveness to environmental drivers; (6) Spatially gridded phenoclimatological products; and (7) Algorithms for modeling and forecasting future phenological responses. The prioritization of these data products is a direct response to stakeholder needs related to informing management and policy decisions. We anticipate that these products will contribute to broad understanding of plant and animal phenology across scientific disciplines.

Keywords: data products, data visualization, phenometrics, modeling

Do we have enough phenological stations? Study on the representativeness of the Swiss Phenological Network

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Representativeness is a key requirement for climatological monitoring systems in general. It is essential to know if the number of stations is sufficient to detect spatial differences in plant reaction with a reliable accuracy and if the different altitudes and regions are well represented. This knowledge is important in the context of data quality control, for the decision of the location of new stations and for climatological analyses of the data.

This study analyses data from the Swiss Phenological Network, which was implemented in 1951 by MeteoSwiss, and which currently includes 167 stations and 69 phenophases. The onset dates of these phenophases are recorded annually at each station by volunteering observers, leading to a data set with 186171 observations. The study evaluates the representativeness and precision of results obtained from the Swiss Phenological Network. It analyses the spatial structure of phenological variation (considering mean onset dates through time, between-year variation and long-term trends) and similarities in phenological time series between stations.

Results show that phenological variation across Switzerland is determined by altitude, large-scale spatial trends and local factors (including variation among individual plants and observation error), whereas small-scale spatial dependence is weak. The number of stations currently included in the Swiss Phenological Network is sufficient for precise estimates of mean onset dates of each phenophase and of long-term trends for the entire country and for three altitudinal layers. More stations would be needed in some regions for a precise analysis of regional differences. The network does currently not include groups of stations with similar patterns of between-year variation for all phenological stages, i.e. no redundancy. Neighbouring stations are hardly more similar to each other than any other pair of stations. It is concluded that the precision of results obtained from the Swiss Phenological Network depends more on the number of stations included in the network than on their exact geographic distribution. However, given the important effect of altitude on phenological variation, the availability of phenological stations over a broad altitudinal range is a particular asset of the Swiss Phenological Network, which should be maintained.

Keywords: representativeness, phenological network, phenological variation, spatial correlation, neighbouring stations

Monitoring tree and understory grass phenological development in California Savannas using daily MODIS and VIIRS NBAR

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The savanna ecosystem is composed of dominant understory grass and widely spaced trees. We use satellite observations from both the Moderate Resolution Imaging Spectroradiometer (MODIS) and Visible Infrared Imaging Radiometer Suite (VIIRS) to monitor the phenological developments of the grasses and trees in this ecosystem. The Collection V006 MODIS Bidirectional Reflectance Distribution Function (BRDF), Albedo and Nadir BRDF-Adjusted Reflectance (NBAR) algorithm provides daily global quantities for the entire archive since 2000. The MODIS algorithm has recently been adapted to produce daily BRDF, Albedo and NBAR quantities from the Visible Infrared Imaging Radiometer Suite (VIIRS) on board the Suomi-NPP satellite, (launched on October 28, 2011). Because the products from both the MODIS and VIIRS data are provided as 500 m gridded data, the phenological stages detected in individual pixels over savannas represent coarse mixtures of tree and grass. In contrast, images from the PhenoCam Network can provide detailed and accurate surface observations, which are able to separate the tree and grass phenological development within a MODIS or VIIRS pixel. In this study, we explore the capability of the MODIS and VIIRS time series to monitor tree and grass phenology in a savanna ecosystem by focusing on two semi-arid PheoCam network sites, located at Tonzi and Vaira in California. Through fits to piecewise logistic functions, time series of EVI and EVI2 from NBAR observations were used to detect phenological onsets of greenup, maturity, senescence and dormancy timing. The phenological timing detected from the green chromatic coordinate (gcc) values from the PhenoCams at these two sites were then compared with the timing from MODIS EVI and VIIRS EVI2, respectively, to further evaluate the agreement and discrepancy of the satellite derived values in monitoring land surface phenology. Furthermore, we applied a mixture modeling approach to separate time series of grass and tree EVI/EVI2 from the mixed MODIS pixels and VIIRS pixels. The corresponding separated EVI/EVI2 time series and phenological timing events were also compared with PhenoCam tree gcc and grass gcc data. To better understand the vegetation growing cycles in these savannas ecosystem, the time series of VIIRS EVI2 and MODIS EVI were also associated with temporal variation in rainfall and land surface temperature. The preliminarily results show that the time series of either MODIS EVI or VIIRS EVI2 are well able to capture the different phenological developments of the understory and tree species in savannas ecosystem and are comparable with high resolution time series of PhenoCam gcc data.

Keywords: phenology monitoring, MODIS, VIIRS, PhenoCam, savannas

PEP725 www.pep725.eu: Monitoring of phenological 2015 spring events using GP

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The main objective of PEP725 (Pan European Phenological database) is to promote and facilitate phenological research by delivering a pan European phenological database with an open, unrestricted data access for science, research and education. The project is funded by ZAMG, the Austrian ministry of science, research and economy and EUMETNET, the network of European meteorological services. So far 20 European meteorological services and 7 partners from different phenological network operators have joined PEP725.The first datasets in PEP725 date back to 1868; however, there are only a few observations available until 1950. From 1951 onwards, the phenological networks all over Europe developed rapidly. So far more than 10 000 000 of observations are stored now in the PEP725 database.

In spring 2015 PEP725 has started to develop an online monitoring of selected phenological events in Austria, Germany and Switzerland. Since recently Deutscher Wetterdienst and Meteoswiss offer their observers to upload their observations via web in real time mode. In Austria ZAMG introduced this web-based feature already in 2007 and offers a contemporary visualization tool (www.zamg.ac.at/ phaenologie). Also some other European countries as for instance Italy, Sweden, The Netherlands, UK has been doing visualizations of ground phenology in real time for some years. But these efforts always end at the national borders. Here we will present a transboundary visualization of selected spring events of 2015.

Keywords: ground phenology, monitoring, real time

1.2 Poster Presentations

Phenological data and cumulative Growing Degree Days of some table grapes in Kirazlı Village in Turkey

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Kirazlı village belongs to Kusadası town and Aydın province in Turkey. Kirazlı village has Mediterranean climate as well as Aydın province. In addition that Kirazlı village is cooler than Aydın province in summers. This situation helps to be produced better quality cherry, local wine and table grapes in Kirazlı. Some of the mostly produced table grapes (*Vitis vinifera* L.) are Alfonse Lavalèe, M. Palieri, Red Globe, Italy, Early Cardinal, Superior Seedless, Barıs (bred by Tekirdağ Viticulture Research Station in Turkey as hybrid of Cardinal X Beauty Seedless in 1993). Phenological data in the grapes were observed at budburst, flowering, verasion and harvest times in 2010 and 2014. One of the heat accumulation indices, standard growing degree days (Amerine and Winkler model, 1944) have been calculated that passing days between budburst-harvest and flowering-harvest time multiplied by average monthly temperatures subtracted 10 °C minimum development temperature for grape.

Cumulative growing degree days for grape through the vegetative period (between 1 April and 30 October) in Kuşadası town were 2745 and 2418 degree days in 2010 and 2014, respectively. Cumulative growing degree days between flowering-harvest time among the table grapes cvs. ranged 930-1563 and 852-1756 degree days in 2010 and 2014, respectively. In the future, phenological observations of table grapes in the region will continue in order to understand global warming effects.

Keywords: grape, growing degree days, Kusadası, climate, phenological observation

PERPHECLIM ACCAF Project - Perennial fruit crops and forest phenology evolution facing climatic changes

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Phenology is a bio-indicator of climate evolutions. Measurements of phenological stages on perennial species provide actually significant illustrations and assessments of the impact of climate change. Phenology is also one of the main key characteristics of the capacity of adaptation of perennial species, generating questions about their consequences on plant growth and development or on fruit quality.
Predicting phenology evolution and adaptative capacities of perennial species need to override three main methodological limitations: 1) existing observations and associated databases are scattered and sometimes incomplete, rendering difficult implementation of multi-site study of genotype-environment interaction analyses; 2) there are not common protocols to observe phenological stages; 3) access to generic phenological models platforms is still very limited.

In this context, the PERPHECLIM project, which is funded by the Adapting Agriculture and Forestry to Climate Change Meta-Program (ACCAF) from INRA (French National Institute of Agronomic Research), has the objective to develop the necessary infrastructure at INRA level (observatories, information system, modeling tools) to enable partners to study the phenology of various perennial species (grapevine, fruit trees and forest trees). Currently the PERPHECLIM project involves 27 research units in France.

The main activities currently developed are: define protocols and observation forms to observe phenology for various species of interest for the project; organizing observation training; develop generic modeling solutions to simulate phenology (Phenological Modelling Platform and modelling platform solutions); support in building research projects at national and international level; develop environment/genotype observation networks for fruit trees species; develop an information system managing data and documentation concerning phenology. Finally, PERPHECLIM project aims to build strong collaborations with public (Observatoire des Saisons) and private sector partners (technical institutes) in order to allow a more direct transfer of knowledge.

Keywords: modeling, network, perennial plants, fruits, grapevine, forest, database

The Swedish National Phenology Network

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The main goal for the Swedish National Phenology Network (SWE-NPN) is to collect, store and provide long-term environmental assessment data on Nature's calendar. We use a three-tier monitoring system, where professional observers, citizen scientists and anonymous observers submit their observations either on the web site www.naturenskalender.se or in the smartphone application “Naturens kalender”. Observations are also acquired through school-oriented mass experiments, specific project collaborations, and from historical archives.

The agencies responsible for the Swedish Environmental Assessment and Environmental Objectives participate in SWE-NPN and use our data for phenology-based environmental assessment indicators on the regional and national level. University partners within the SWE-NPN have organized research symposia and stimulated the use of SWE-NPN data in research.

Nature`s calendar has a strong position among the Swedish public and SWE-NPN are actively using Facebook, Twitter and Instagram for outreach, support, feedback and recruitment of citizen scientists.

Important upcoming steps for SWE-NPN is: (i) to integrate the phenology database with the Swedish, national database for species data (Species Gateway, www.artportalen.se) and (ii) to develop common quality criteria and common quality assurance schemes for volunteer-based environmental monitoring.

SWE-NPN is an expanding collaboration between Swedish universities, governmental agencies and NGOs. The Swedish University of Agricultural Sciences, who has the official national responsibility for species data, is the acting host of SWE-NPN.

Keywords: national phenology network, phenological database, transdisciplinary research, citizen science, historical archives, environmental indicators

Endodormancy requirement for white female mulberry (*Morus alba* L.)

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The aim of this study was to calculate chilling hour requirements for satisfying endodormancy using modified Weinberger's Standard Method with hardwood cuttings laboratory forcing test in white female mulberry (*Morus alba* L.). Mulberries belong to Moreae tribe, Urticaceae (including Moraceae) family in Urticales order VIJAYAN et al. (2014). More than 68 species exist in *Morus* genus DATTA (2000). White mulberries are usually diploid (2n=2x=28) VIJAYAN et al. (2012). Mulberries are grown between 50° N and 10° S latitudes altitude ranging from sea level to 4000 m in tropical, subtropical, and temperate climatic regions TIKADER and DANDIN (2005). Mulberries are trees and shrubs with milky or watery sap with monoecious, dioecious, or polygamous flowers ZOMLEFER (1994). Perennial plants, especially adapted to temperate zone, have a tendency to rest called dormancy before they flower. Endo- (winter), eco- (spring) and paradormancy (summer) are three types of dormancy LANG et al. (1987). During the literature search, any unequivocal record for white mulberry endodormancy requirement has not been found. The Weinberger's Standard Method used the temperatures between 0.0 ºC and 7.2 ºC KOCATAŞ (2014). The modification was made to calculate chilling requirement for white mulberry in this study. The reason for this is the tropical-subtropical characteristic of some mulberries which might have low chilling requirement or not at all. Hardwood cuttings containing 3-4 nodes were made from a single white female mulberry tree every 7-10 days from 01 December 2014 through 28 February 2015. Dormancy requirements were calculated on 18 December 2014, which was the date of budbreak observed in laboratory forcing test. Chilling hours calculation was started on 20 September 2014 when the temperature dropped under 13.0 ºC. The hourly calculations were made when daily minimum temperature dropped under thresholds of ≤5.0 ºC, ≤7.2 ºC, ≤9.0 ºC, ≤11.0 ºC, and ≤13.0 ºC. The endodormancy requirements were calculated above thresholds as follows: 60, 158, 289, 504, and 860 hours, respectively. According to the Weinberger's Standard Method, the endodormancy requirement of white female mulberry buds was 158 h below 7.2 ºC in 2014-2015 dormant season. Although white mulberry trees are deciduous in unfavourable winter conditions in temperate climate, their endodormancy might be satisfied by accumulation of the chilling hours higher temperatures than 7.2 ºC. Since mulberries could be grown under tropical and subtropical climates, their endodormancy requirement might be 60-860 hours. The results obtained here does not contradict to conventional sense of the chilling requirement of mulberrries is low. The endodormancy requirement in white female mulberry was calculated at the first time in this study. More detailed research is needed to find out the exact dormancy requirement of different *Morus* spp.

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Keywords: chilling hours requirement, cuttings, endodormancy, laboratory forcing test, *Morus alba* L.

Patterns in airborne pollen in Korea

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As there are more and more people who take outdoor activities, pollinosis patients having bronchial asthma, allergic conjunctivitis, and allergic rhinitis are increasing. The pollen is produced by various plants. Especially, anemophilous pollen is mostly related to allergic diseases. In Korea, pollinosis is mainly caused by pollen from both trees in spring and weeds in fall, respectively. Oak, birch, and cedar are the main tree species generating allergenic pollen and ragweed, mugwort, and humulus are the main weed species.

National Institute of Meteorological Research (NIMR) and the Korean Academy of Pediatric Allergy and Respiratory Disease have jointly operated the Nation-wide pollen observation network. Currently, fourteen Hirst type traps (Burkard Seven-day recording volumetric spore trap) are operating at twelve cities. Airborne pollen was collected every day from all samplers at all collection sites. Each pollen species was morphologically identified and classified by its size, color, pore shape, and surface pattern. The observed pollen is composed of fifteen tree species including pine, and nine weed species.

Based on the observed data, NIMR has established a system issuing day-to-day warnings of allergenic pollens from trees and weeds and offers the risk index of allergic pollen from a dedicated web page. The pollen risk index has four risk levels as mild, moderate, severe, and dangerous based on the symptom levels of pollen allergy patients. Continuous observation through the pollen monitoring network will support both long-term changes in the allergenic plants and the improvement of the day-to-day pollen forecast.

Keywords: airborne pollen, Hirst type trap

Determination of chilling periods of some fig (*Ficus carica* L.) cultivars

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This study was carried out to be determined the aim defining chilling period of some fig cultivars with different methods in the ecology of Aydin city which is produced the furthest fig production in Turkey and the world. Within the scope of the trial, it started to phenological observations in conjunction with fall of the leaf in the last of vegetation period in 2012, and also these studies had been continued in 2013 and 2014 in Sarılop, Bursa Siyahı, 208 Siyah, Beyaz Orak, and Siyah Orak fig cultivars. According to different calculation methods for chilling requirements placed in the literatures, chilling periods of the fig cultivars were evaluated in the ecology of Aydin city. The calculations were performed in terms of Classic method, Richardson method; Bidabe method and Aron equation based on estimation using the temperature data obtained from the climate station relation with the dates of the fig trees entering dormancy in conjunction with fall of the leaf in winter and showing come up along with bud uprising in spring. According to Classic method, Richardson method, Bidabe method, it was determined that while minimum chilling requirement is in Bursa Siyahı fig cultivar, maximum chilling requirement is in Sarılop fig cultivar compared with all cultivars in 2013 in these calculations. It was estimated that while minimum chilling requirement is in Bursa Siyahı fig cultivar, maximum chilling requirement is in 208 Black fig cultivar as regards to Aron Equation. According to Classic method, Richardson method, Bidabe method, it was determined that minimum chilling requirement is in Bursa Siyahı fig cultivar, maximum chilling requirement is in Sarılop fig cultivar compared with all cultivars in 2014.

Keywords: fresh fig, dried fig, chilling requirement, phenology

Swedish historical phenology data, a base for indication of regional climate change

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The Swedish National Phenology Network (SWE-NPN) provides a nationwide phenology database, publicly available from the beginning of 2015. The database consists of two datasets. The bigger dataset includes historical data collected in a network organized by Uppsala University and (the predecessor of) the Swedish Meteorological and Hydrological Institute, mainly between 1873 and 1919. The dataset has 345 000 observations of animal, plant and agricultural phenology made by volunteers. Just over 200 000 reports were made of the budburst, flowering, fruit ripening and/or autumn-colored leaves of 49 species of plants and trees, 75 000 observations of agriculture crop (timing of panicle, spike and flowering) and activities (spring tillage, sowing, harvesting begins and ends), 62 500 spring and autumn migration observations of 23 bird species and nearly 6 000 observations of insect (mainly bees) and frog activities. Over 90% of the historical dataset is considered being high accuracy reports and only 0.5 % was identified as outliers or not being possible to evaluate, in a preliminary data analysis. The second dataset consists of present-day observations from 2008 and onwards, now more than 50 000 records of plant observations and growing. The present-day data is reported by a combination of professional and volunteer observers, where some are dedicated to the SWE-NPN protocol and yet others are anonymous observers.

The SWE-NPN phenology database can, when combined, form progressing indicators of ecological effects of climate change on national and regional scale. The Swedish Environmental Objectives, both at the national and regional level, will be evaluated by the use of the database. The historical phenology dataset form 'baseline' levels, i.e. reference values that are compared to present-day values of several indicators used to estimate the effects. These indicators will comprise phenological parameters such as the length of the growing season and the timing of spring flowering, spring leaf-out and autumn leaf coloring. The observations, both the historical and present-day ones, are unevenly distributed both geographically and temporally. We have investigated two approaches for the estimating the baseline values, a mixed model regression analysis and a geographic interpolation approach. The mixed model approach use features of the geographical position of the observation; longitude, latitude, altitude and distance to sea or big lakes as independent factors, while the interpolation approach use the strength of many years of observations at the same place and places nearby. The two approaches have different advantages and disadvantages, depending on scale and distribution of observations.

The database has also been used in several research studies already, e.g. concerning changed behavior of migrating birds and hay harvesting strategies.

Keywords: phenological network, historical phenology observations, indicator of climate change, statistical analysis, geographical interpolation

Checking for inconsistent volunteered phenological observations

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An ever increasing amount of volunteers contribute to data collection efforts that support the study of a wide range of environmental processes and systems. Phenological observations are collected by volunteers in multiple countries, mostly to support citizen science initiatives to study climate change. These observations have a great value but their quality needs to be checked before they are used for scientific studies.

Current approaches to check the quality of volunteered observations are costly and time consuming as they heavily rely on human interventions. Here we propose a consistency checking workflow for volunteered phenological observations. The workflow relies on the availability of a wide range of environmental contextual information for the locations where volunteers observed the phenological events. In short, the proposed workflow consists of three main steps: dimensionality reduction using the t-SNE algorithm, model-based clustering to group the observations according to their contextual conditions, and identification of inconsistent observations for each of the clusters by means of the Tukey boxplot. The hypothesis behind this workflow is that the variability in the timing of phenological events recorded for similar environments must be small (allowing for biological/genetic diversity). Observations that differ too much from the values found in each cluster are therefore deemed inconsistent. This workflow is demonstrated using volunteered phenological observations of first leaf and first bloom of Lilac shrubs in the United States from 1980 to 2009 and the environmental conditions were of each site/year were obtained from DAYMET, a high spatial resolution daily gridded dataset.

Although this dataset was already curated and checked for abnormal values, our results indicate that it contains about 2 % of inconsistent observations. A careful analysis of the inconsistent observations revealed that these were unusually late or early for their geographic locations, probably indicating local microclimatic effects or that volunteers reported second leafing/blooming events.

Keywords: VGI, citizen science, quality, clustering, contextual information

Yield and quality features of field Pea (*Pisum arvense* L.) varieties which was harvested at different phenological stages

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This study was conducted to determine dry matter yield and forage quality of eight field pea (*Pisum arvense* L.) species which was harvested at three different phenological stages (beginning of flowering, 50 % of flowering, full of flowering) in Aydın. The trial was planned at completely randomized design with three replications. In this research, plant length, branch number at per plant, leaf width and length, ratio of leaf/stem, dry matter yield, ratio of crude protein, ADF, NDF, crude protein yield was measured.

Important differences were found between in examined field pea species with regard to yield, yield components and forage quality. Also, harvesting at different phenological stages was found statistically different in all parameters. Forage quality values were reduced by the delay time of harvest.

As a consequence of this study, Kirazlı and Ürünlü field pea species has come to the fore. It has been concluded that, 50 % of flowering stages as phenological is the appropriate for harvesting when dry matter yield and forage quality was evaluated together.

Keywords: *Pisum arvense* L., phenological stages, dry matter yield, crude protein ratio

2 Climate variability, climate change and phenological trends

2.1 Oral Presentations

Evaluating shifting land surface phenology and its climatic drivers at global scale

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Understanding the climatic controls that drive phenological change is central to estimating the effects of climate change on vegetation activity and, therefore, on the terrestrial carbon sink ZHU and MENG (2014). Rapid spatial shifts in climatic controls also reconfigure plant-species` niches, impacting the distribution of plant communities and ecosystems SCHIMEL et al. (2013). Despite the growing attention on this topic, many uncertainties remain concerning what physical processes drive leaf onset and senescence, and how these may vary between and within species. Adding to this, both long-term and global datasets of phenology are scarcely available. This makes it hard to draw connections between climatic trends and phenological trends at the large scale and, therefore, to accurately represent a variable leaf phenology in terrestrial ecosystem models RICHARDSON et al. (2012).

In this study, we examined the inter-annual variability in Land Surface Phenology (LSP) and in three general climatic constraints to phenology, as well as their trends. From a global phenology reanalysis STÖCKLI et al. (2011), we derived three general climatic constraints to phenology - radiation, moisture and temperature - at global scale and over the past 30 years. We assessed how spatial patterns of LSP change derived from the longest continuous record of vegetation activity available at global scale (NDVI3g), PINZON and TUCKER (2014); GARONNA et al. (2015) correlate with spatial patterns of the simulated climatic phenological constraints. Contrarily to most phenological models that predict specific events of leaf development (like budburst or flowering), the reanalysis data describe canopy development throughout the year, allowing us to directly compare modeled climatic constraints and observed LSP. We pursued two main objectives: (1) examining the changing distribution of climatic constraints to plant growth in the last 30 years (1982-2012); and SCHIMEL (2013) establishing links between large-scale trends in LSP and in climatic constraints to plant growth.

The reanalysis data revealed that global temperature limitation to plant growth has decreased by 5 % from 1982 to 2012, while moisture limitation has increased by 10 %. Substantial shifts in moisture constraint over some regions suggest an increasing role of water limitation on global vegetation phenology. We focused in more detail on hotspot areas of LSP change as case studies, namely the boreal Northern Hemisphere and the Sahel.

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Keywords: land surface phenology, climatic drivers, phenological trends, global, NDVI

Phenological changes between the two climate normal periods 1961-1990 and 1981-2010 in Switzerland

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For describing the climate of a region, measurements are averaged over longer time periods. The calculated averages are known as normal values. According to the World Meteorological Organisation (WMO), the same 30-year standard periods are used around the world to determine climatological averages, currently the period from 1961-1990. In a changing climate, the WMO suggested to provide other normal values whose period is adjusted every ten years, currently 1981-2010. The increase in yearly mean temperature for whole Switzerland between these two normal periods is 0.8 °C, with higher than mean values for spring and summer months and lower for autumn and winter months.

The Swiss Phenological Network was implemented in 1951 by MeteoSwiss and currently includes 167 stations and 69 phenophases. The onset dates of these phenophases are recorded annually at each station by volunteers. Continuous data series since 1961 exist for 28 phases and 58 stations, but with varying completeness. The goal of this study is to provide mean climatological values for different phenophases for the two normal periods (1961-1990, 1981-2010) and to quantify the differences between these periods. Correlations with temperatures based on interannual variations provide information about the phenological response to temperature change.

Phenological data was averaged to mean values for Switzerland for altitude layers < 600 m, 600 - 1000 m and > 1000 m, because phenological variation across Switzerland is determined mainly by altitude. Late winter and spring are best represented by the phenological data. Averaged over 17 phases, the vegetation development in spring advanced between these two normal periods by 3.2 days for locations below 600 m and by 5.3 days for locations above 1000 m. In early summer (4 phases) the difference is 7.1 days for locations below 600 m, but data availability is much lower. Beech leaf coloration and fall was delayed in lower altitudes by 2.3 - 2.7 days, and advanced in higher locations by 2.8 - 3.2 days. Highest correlations of the onset dates with mean monthly temperatures for whole Switzerland were reached with mean temperatures of the two or three preceding months ($r \geq 0.9$) and for autumn phases with September temperature ($r = 0.6$) . The phenological response to temperature warming of these months is for spring phases -5.5 (±1.0) days/°C and for early summer phases -7.0 (±0.8) days/°C. The sensitivity of the autumn phases of beech in relation with September temperatures is +2.3 days/°C. But this connection does not explain the observed changes in autumn phenology. Additionally, September temperature increased only by 0.3 °C between the two normal periods.

The normal period 1981-2010 is actually used in Switzerland to describe the “phenological climate” and is used as baseline for indicating yearly deviations of the vegetation development.

Keywords: normal period, thermal sensitivity, phenological trends

Are there any changes in *Betula pendula* vegetative and generative phenophases onsets in Czechia and Slovakia?

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Phenology is an important adaptive trait since it determines the duration and timing of the growing season as well as the period of reproduction CHABOT and HICKS (1982); LECHOWICZ (1984); KIKUZAWA (1989); HÄNNINEN (1990); REICH et al. (1992). In the last 30 years, many studies have developed and predictive models of tree phenology using climate variables such as temperature and photoperiod e.g. MURRAY et al. (1989); CHUINE et al. (1998). Phenological observations has a long tradition in the Czech Republic (the first phenological notes have been already carried out in the 18th century) and the Czech Hydrometeorological Institute manages phenological network and as a whole, 45 plant species are observed, they are perennial herbs, grass or ground bushes growing widely. Some of the observed species belong to the group of so-called allergens, as e.g. birch (*Betula pendula*). In this paper were evaluated the phenological phases first leaf (BBCH 11), beginning of flowering (BBCH 61), leaves yellowing (BBCH 92) and leaves fall (BBCH 97) of birch at the research plot Mlýny, Chřibská (50° 52' N, 14° 29' E, 350 m), Hodonín (48° 51' N, 17° 08' E, 162 m) and Pohorelá (48° 52' N, 20° 01' E, 765 m). All stations are located in different climatic conditions - in the north Bohemia (Mlýny, Chřibská), south Moravia (Hodonín) and north part of Carpathian Belt (Pohorelá). The meteorological data were used from the meteorological station Varnsdorf (48° 56‘ N, 16° 35‘ E, 367 m), Lednice (48° 47‘ N, 16° 47‘ E, 177 m) and Telgárt (48° 51‘ N, 20° 11‘ E, 801 m).

The aim of this work is to assess which meteorological parameters influence the phenological onsets and to analyze the shifts of dates of phenophases onsets during 1961-2014. The average date of beginning of flowering in the period 1961-2014 is 10th April with standard deviation 8.2 days (Hodonín), 27th April with standard deviation 9.9 days (Mlýny) and 9th of May in higher elevated Pohorelá with standard deviation 10.3 days; the first leaf comes on 10th April with standard deviation 7.5 days (Hodonín), 13th April with standard deviation 8.8 days (Mlýny) and May 6th with standard deviation 12.6 days in Pohorelá; leaves yellowing on 8th October with standard deviation 11.2 days (Hodonín), 27th September with standard deviation 8.1 days (Mlýny) and 25th of September with standard deviation 14.7 days in Pohorelá; the leaves fall on 10th November with standard deviation 12.2 days (Hodonín), on 6th November with standard deviation 7.2 days (Mlýny) and on 2nd October with standard deviation of 14.7 days in Pohorelá. The highest deviations (positive and negative) from the long-term average (1961-2014) shows leaves fall at Hodonín station: +36 days in the year 2001 and -39 days in the year 1967. The interphase interval between first leaf and leaves fall lasts 216 days on average with the maximum and minimum value 174 (1967) and 247 days (2001) at Hodonín station and 195 days on average with the maximum and minimum value 176 (1986) and 213 days (1974) at Mlýny station. The vegetation time is shrinked in Pohorelá with the average in between first leaves and leaves fall only 145 days and minimum 112 days. The shift of spring phenophases to earlier dates is greater at Mlýny station (station situated in the north of the Czech Republic), on the other side the shift of autumn phenophases to later dates is greater at Hodonín station (station situated in the south of the Czech Republic).

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Keywords: phenology, phenophase, phenological trends, Czechia, Slovakia, *Betula pendula*

Climate change effects on phenology in alpine plant communities

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Phenology in plants is sensitive to changes in temperature and generally trends towards earlier spring phenology have been observed in the Northern Hemisphere. However, changes in precipitation patterns can be important at high elevation, because increased snowfall during winter can shorten the growing season. Accelerated flowering after late snowmelt indicate plastic phenological responses in many plants. In addition, transplant experiments indicate that the timing of flowering is to some extent genetically determined.

We studied phenological responses in alpine plant communities, using a climate grid that combines a temperature and a precipitation gradient to assess the independent and joint impacts of both variables. The start, peak and duration of flowering and seed set was assessed for 40 plant species on vegetation turfs that have been transplanted to warmer, wetter and both warmer and wetter conditions. We explicitly asked, to what extent differences in phenological responses are plastic or genetically determined. Understanding to what extent species will respond to future climate change by phenotypic plasticity or adaptation is important, because it could affect their ability to persist. Furthermore, changes in the timing of flowering can disrupt plant-pollinator interactions with consequences for both plants and insects.

Keywords: climate change, temperature, precipitation, phenological trends, alpine plant communities

Climate-associated phenological shift across China suggests community assembly changes

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Global climate change is believed to profoundly affect the assembly of ecological communities through altering species' spatial distribution patterns. Rarely discussed is the potential temporal pathway for climate change to affect community assembly by changing species temporal co-occurrence patterns. This pathway is highly likely given the widely observed phenological shifts and interspecific variations in such shifts associated with climate change. Here we analyzed a 29-year phenological data set on 17 taxa from 329 weather stations across China that provides information on taxa's span of temporal occurrence at the community level. We show that climate change is associated with community-wide, extension-dominated changes in the span of inter-taxonomic temporal overlap, and that most of these changes are the outcome of taxa's altered span of temporal occurrence rather than differential phenological shifts. Our findings highlight the largely overlooked and potentially consequential temporal pathway through which climate change can influence community assembly, and suggest that climate change may have led to less phenological mismatch than generally presumed. Our findings also suggest that changed inter-taxonomic temporal overlap could ensue even under concerted phenological shifts, thus the context under which to discuss the ecological consequences of phenological shifts should be expanded beyond asynchronous shifts.

Keywords: phenological changes, community assembly, China, fauna

Spatiotemporal variability in start and end timing of growing seasons in China relating to climate change

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Plant phenological observations are of increasing value as indicators of climate change and variability. Remote sensing data is widely used to study large-scale change in vegetation phenology. Using third generation GIMMS NDVI from AVHRR sensors (NDVI3g) dataset, we estimated start of growing season (SOS) and end of growing season (EOS) in China for the period 1982-2012 based on Midpoint method. Subsequently, the empirical orthogonal function (EOF) analysis was applied to extract main patterns of phenology and climate and their annual variability. Meanwhile, the impact of climate parameters such as temperature and precipitation on the phenological development was investigated using a multivariate statistical model. The first EOF modes of phenology were dominated by a relatively homogeneous structure, i.e. an earlier or later SOS and EOS for almost the whole country. The SOS firstly advanced from 1982 to 1996 then delayed since 1997, but it advanced again from 2008 to 2012. Regarding EOS, it revealed a later EOS in recent years, mainly since 1994 when a clear shift in EOS occurred. In contrast to the first EOF modes, the second EOF modes revealed considerable regional effects. Temperature was found to be the main driving factor for such spatiotemporal variability in phenology. The EOF mode of preseason temperature show similar spatial pattern with corresponding dominant phenology mode. Meanwhile, the principle component (PC) time series of preseason temperature were able to explain 45 % and 57 % of the variance in the first SOS and EOS PC time series, respectively. Therefore, temperature is the dominant factor influencing large-scale vegetation phenology.

Keywords: growing season, phenology, remote sensing, the empirical orthogonal function (EOF) analysis

Forecasting flowering: How far in advance can phenology and abundance be estimated?

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The ability to forecast phenology can provide both ecological insights and potential economic benefits, mediated by consequences for species interactions, ecosystem management (e.g., fire danger), recreation (e.g., wildflower tourism), or health (e.g., allergies to pollen). The phenology of flowering in temperate ecosystems is determined by a variety of variables, typically environmental, such as temperature, precipitation, and daylength. In the high-altitude (2 900 m) environment where we work in the Colorado Rocky Mountains, the timing of the growing and flowering seasons can vary by six weeks from one year to the next, and this variation is almost completely a consequence of the timing of snowmelt. We analyzed the relationship between winter snowpack, measured at several dates from 1 January to 22 May, and timing of flowering from 1975 to 2015. We compared wildflower species that flower at different times of the season, including *Claytonia lanceolata* (*Portulacaceae*), which flowers within days after snowmelt (mean 21 May), and *Heliomeris multiflora* (*Asteraceae*), one of the last species to flower (mean 12 August). Flowers were counted every other day in 18 2x2 m plots spread over about a km, and snowpack depth was measured daily throughout the winter at a central site.

Dates of first flowering were highly variable, ranging from 5 April to 19 June in individual plots for *Claytonia*, and 9 July to 7 September for *Heliomeris*. Snowmelt dates were also highly variable, ranging from 23 April to 19 June (even more variable if measured across individual plots). Even as early as 1 January, snowpack depth has some predictive value for flowering date for *Claytonia* (r^2=0.120; p=0.04). Estimates for *Claytonia* flowering improve as time goes on, with the highest correlation coefficients occurring based on snowpack depth on 1 May (r^2=0.675; p=0.001), but declining after that until the last sample date, 22 May (by which time flowering has begun in some years). For the late-flowering *Heliomeris*, the correlation coefficients for the relationship between snowpack depth and flowering date are not as high, ranging from close to 0 in January to r^2=0.236 (p=0.002) on 8 May. These differences between species reflect the fact that *Claytonia* has large flower buds well developed long before the snow melts, facilitating a quick response to snowmelt, while *Heliomeris* only emerges from the ground a few weeks after snowmelt and then forms buds. Because the sequence of flowering for the 120 species we follow is not very variable among years, it seems that we can make predictions with some confidence as early as five months ahead of the flowering of *Claytonia* and other early-flowering species, and as early as 1 March for the later-flowering *Heliomeris* (r^2=0.102, p=0.04), with most species falling between these extremes in terms of our ability to forecast flowering dates based on snowpack depth.

Keywords: flowering phenology, Rocky Mountains, snowpack, snowmelt, forecasting

Impacts of large-scale drought and deluge on ecosystem productivity and phenology in Southeastern Australia

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Globally, 2000-2009 ranked as the ten warmest years over a 130-year (1880-2009) climate record. In Australia, the Millennium Drought from 2001 until 2009 was the worst drought on record since 1900 for Southeastern Australia (SEA), with broad impacts on economy, environment and society. The drought period ended dramatically, with a large-scale La Niña associated flooding period spanning 2010-12. The decadal scale hydroclimatic variations from 2000 to present in SEA thus provided a unique opportunity to investigate how terrestrial ecosystems were affected by recent climatic extremes and intensification of the water cycle under altered hydro-climatic conditions. In this study, we examined the impact of early 21st-century drought and wet cycles on vegetation phenology and productivity over SEA (141-154° E, 29-39° S) using 14 years of Moderate Resolution Imaging Spectroradiometer (MODIS) Enhanced Vegetation Index (EVI) and Standardised Precipitation-Evapotranspiration drought Index (SPEI). This study was focused on SEA ecosystems due to their national significances in primary production, floodplains/wetlands, and biodiversity.

The SPEI showed that SEA experienced dramatic drought and wet cycles during 2000-2014, and 2002-03 (El Niño) and 2010-11 (La Niña) were the most extreme drought and wet years since 1950. Results showed high spatial and temporal variability in vegetation phenology and productivity over SEA. Annual integrated EVI (iEVI, surrogate of vegetation productivity) showed negative anomalies of >1.5 standard deviations over most SEA in 2002-03 drought year, associated with no detectable phenological cycle over most vegetation groups due to significantly reduced vegetation activity (near-flat seasonal profiles of EVI). In contrast to biomes at the Northern Hemisphere mid- and high-latitude that generally have recurrent phenology, the high-variability in vegetation phenology across wet to dry years over SEA highlighted the extreme climatic variability, and showed different plant strategies in response to drought of Australian ecosystems. Sensitivity of iEVI to drought severity (SPEI) varied 3-fold among vegetation groups. Vegetation productivity of shrublands, tussock grasslands, Eucalypt open woodlands, and Callitris forests/woodlands showed higher sensitivity to SPEI, followed by Eucalypt woodlands/open forests. Acacia open woodlands/shrublands and Eucalypt tall open forests showed relatively small sensitivity to SPEI. By plotting sensitivity to drought severity against mean annual precipitation (MAP) among vegetation groups, we found that humid ecosystems (MAP>800 mm) showed relatively small sensitivity to drought. Unexpectedly, the highest sensitivity to drought severity was not found at arid ecosystems (MAP<300 mm), but rather found at semi-arid ecosystems (300<MAP<800 mm). This unique finding is interesting and may suggest that semi-arid ecosystems will be more vulnerable to future climatic extremes and may experience loss of ecosystem resilience under mega-drought conditions. Amplification of hydrological cycle as a consequence of global warming is predicted to increase climate variability with more frequent drought events. There is a compelling need to better predict how Australia ecosystems will be impacted by future mega-drought, advances made here provided critical observational evidence to support more sound predictions.

Keywords: climatic variability, El Niño-Southern Oscillation, drought, phenology, ecosystem resilience, remote sensing

Climatic drivers of fruiting phenology: a quantitative review throughout the Neotropics

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Climatic drivers of plant reproductive phenology are well studied in Northern temperate regions, where temperature and photoperiod play a major role boosting flowering RICHARDSON et al. (2013). However, these drivers are much less well understood across the tropics, where shifts in temperature or day length throughout the year are comparatively modest REICH (1995). The relatively constant environmental conditions in the tropics suggest the hypothesis that reproduction in tropical plants is more uniformly distributed over the annual cycle. Although this hypothesis was initially supported by pioneer studies SMYTHE (1970); SNOW (1965); FRANKIE et al. (1974), patterns of tropical reproductive seasonality remain unresolved. Here, we aim to disentangle the environmental drivers that control the degree of seasonality of fruiting phenology in the Neotropics across a wide continental-scale environmental gradient. We focused on fruiting because of its key role in determining the availability of resources for animal frugivores and other ecosystem functions such as seed dispersal effectiveness. We performed a comprehensive systematic review of published and unpublished studies on fruit phenology carried out across the Neotropics, and collated data from 110 study sites covering different vegetation types and rainfall regimes. Using the number of fruiting species per month as a response variable, we applied circular statistics (6-8) to calculate proxies of fruiting season length (circular standard deviation), central tendency of fruiting (angular mean) and fruiting seasonality (r vector). General Least Square models and circular-circular correlations explored the relationship between climatic variables (i.e. thermic amplitude, precipitation, extra-terrestrial solar radiation and evapotranspiration) and fruiting. Demarcated and statistically significant seasonality could be detected in 45 % of study sites, although in most cases fruiting seasons were relatively long, lasting at least six months each year. The best environmental predictors of the fruiting season length were thermic amplitude, seasonality of rainfall and the difference in day length between the shortest and the longest day of the year. There was a mean lag of ~3 months between the timing of fruiting and the main environmental drivers. In conclusion, although fruiting season was generally long, almost half of all Neotropical study sites were subjected to some degree of fruiting seasonality. Timing and length of fruiting seasons were correlated with environmental drivers; more extreme climatic conditions in terms of temperature and rainfall tended to exhibit shorter fruiting seasons. Despite widespread belief in relatively constant conditions in the tropics, our results highlight the role of climatic drivers in the timing and seasonality of fruit production, highlighting a future research agenda under mounting climate-change scenarios.

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Keywords: climatic variability, America, rainfall, temperature, frugivore, circular statistics

Late spring frost risk in a warming world

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The questions how risks of late spring frosts have been altered in the past and will change under future warming are discussed controversially in the current literature. Damage by late spring frosts is an inherent risk for deciduous trees since maximizing their growing season shifts leaf unfolding and/or flowering dates to earlier dates when late spring frosts can still occur. In this time, winter frost acclimation is gradually lost and the fresh new leaves are especially vulnerable to freezing.

Climate warming in temperate regions has been shown to lengthen the growing season, both at the spring and autumn side, and shorten the winter season. Spring phenology, e.g. bud burst and leafing, is mainly triggered by forcing temperatures, whereas winter chilling and too are far lesser degree photoperiodic requirements prevent too early plant development.

In this paper, the interplay of mean warming of mean and minimum temperature as well as altered temperature variability on spring phenology and associated late spring frost risk is studied for past and simulated for future conditions. Based on this analysis, we aim at explaining systematically (regional, temporal, trait specific) the existing controversies in late spring frost risk assessment.

Keywords: modelling, frost risk, phenological trends, climate trends

Interannual variation in the response of tree phenology to experimental warming at the boreal-temperate ecotone in North America

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The timing of phenological events influences growing season length, plant-plant interactions, plant-insect interactions, human health and much more. Alterations to plant phenology associated with climate change have been observed globally, most commonly through analysis of long-term observational datasets e.g. SPARKS and CAREY (1995); BRADLEY et al. (1999); MENZEL et al. (2006); PRIMACK et al. (2009). However, there remains considerable uncertainty about the magnitude of change as well as limitations to inferences from both observation and experimental work WOLKOVICH et al. (2012). Here, we present results that show not only strong effects of warming on spring and fall leafing phenology but also significant interannual variation in those effects. Our research took place in the Boreal Forest Warming at an Ecotone in Danger (B4WarmED) experiment RICH et al. (2015) located at two forested sites in Minnesota, USA. The experimental design is a 2 (site) x 2 (habitat) x 3 (treatment) factorial, with six replicates (total of 72, 7.1 m^2 circular plots). Treatments include three levels of simultaneous plant and soil warming (ambient, +1.7 °C, +3.4 °C). Warming is achieved using infrared heat lamps and soil heating cables. Treatments approximate warming anticipated during the next 75-100 years and enable assessment of non-linear responses to warming. Seedlings of 11 common boreal and temperate tree species were planted in 2008 into plots in open and closed canopy habitats. We measured tree seedling phenology twice weekly during five growing seasons (2009-2013). In general, warming caused earlier leaf out in spring for all species and later leaf senescence in fall for seasonally deciduous species extending the photosynthetic growing season for all species by ≈10 and ≈20 days on average for +1.7 °C and +3.4 °C warming, respectively. For deciduous species, the contribution to growing season length of fall versus spring phenology was similar. We also saw strong interannual variation in the effect size of warming. For example, in *Populus tremuloides* the mean advance of budburst with +3.4 °C warming ranged from 2 days in 2013 to 18 days in 2012. Stronger effects of warming were seen in early compared to late springs. Differences among species in timing of budburst were also greater in early compared to late springs suggesting that climate change could increase asynchrony of leafing in forested communities. Results may stem from differences among species in the relative importance of temperature versus daylength as cues for budburst as well as changes between early and late spring in the relative dominance of these cues. More data on plant phenological responses at the population and community level as well as elucidation of species-specific environmental cues for phenology will further our understanding of the causes of phenological shifts and their consequences for ecological processes now and in the future.

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Keywords: climate change, experimental warming, interannual variation, community phenology

Root and shoot phenology may not respond to warming in the same way

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Climate change is increasing temperatures and extending the growing season for many organisms. Shifts in phenology have been widely reported in response to global warming and have strong effects on ecosystem processes and greenhouse gas emissions. It is well understood that warming generally advances aboveground phenology, but patterns of root growth and the influence of temperature on roots are unclear. Most terrestrial biosphere models assume that root and shoot growth occur at the same time and are influenced by warming in the same way, but recent studies suggest that this may not be the case. Testing this assumption is particularly important in the Arctic where over 70 % of plant biomass can be belowground and warming is happening faster than in other ecosystems. In 2013 and 2014 we examined the timing of root growth in the Arctic in plots that had been warmed or unwarmed for 10 years. We found that peak root growth occurred about one month earlier than leaf growth, suggesting that spring root phenology is not controlled by carbon produced during spring photosynthesis. If roots are not controlled by photosynthate early in the season in this ecosystem, earlier spring leaf growth with warming may not cause earlier root growth. In support of this, we found that warming increased spring leaf cover but did not significantly affect root phenology. Root growth was not significantly correlated with soil temperature, and instead root growth was negatively correlated with leaf cover and positively correlated with soil moisture. These results suggest that aboveground phenology, one of the most widely measured aspects of climate change, may not represent whole-plant phenology and may be a poor indicator of the timing of whole-plant carbon fluxes. Additionally, model assumptions that root and shoot growth occur at the same time may need to be revised.

Keywords: climate change, root phenology, whole-plant phenology, experimental warming

Modelling anomalies in the land surface phenology of Europe using inter-annual variations in climatic drivers

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Vegetation phenological events, such as the timing of leaf onset or leaf senescence, vary between years depending on climatic conditions. Temperature is one of the key parameters to regulate vegetation phenological events in high latitude regions such as Europe. Thus, changes in air temperature will lead to changes in the timing of the phenological events. In addition, other drivers such as photoperiod or precipitation can regulate phenology in the northern and southern European regions, respectively. There is unanimity that an advance of spring has occurred in the last few decades as a consequence of warming trends across the globe. This means that leaf onset starts earlier resulting in an extension in the length of the growing season. On the other hand, our knowledge about the climatic drivers of autumn phenophases is more limited and there is a lack of general consensus about the extent to which climate can affect senescence. Hence, under the scenario of future climate change, there is a need to better understand the climatic drivers controlling phenology, especially for the end of the growing season (autumn).

This study presents anomalies in the land surface phenology (LSP) variables - onset of greenness (OG) and end of senescence (EOS) - estimated for the European forest during the last decade, and identifies the main climatological drivers which control these anomalies. Multi-temporal Medium Resolution Imaging Spectrometer (MERIS) Terrestrial Chlorophyll Index (MTCI) data at 1 km spatial resolution were utilized to derive the key phenological metrics (OG and EOS) for a 9-year time-series dataset from 2003 to 2011. The anomalies in the phenology for a given year were defined as the difference with the longer-term mean, normalized by the standard deviation across years. Daily grids of surface temperature/precipitation and short wave radiation as a proxy of photoperiod were obtained from the European Climatic Assessment Dataset and the satellite sensors MSG/Meteosat, respectively. A multivariate non-parametric regression method (Random Forest) was applied to model the phenology anomalies using different climatic measurements: monthly average values of temperature (max, min and avg.), precipitation and short wave radiation; trimestral cumulated values such as growing degree days, chilling requirements, among others; or the date of specific events such as the first freeze or the last freeze. All these values were computed using either 30 or 90 day moving windows, moving backward from the phenological event date.

Our study offers new insights into the modelling of LSP, recognising non-linear patterns between phenology and environmental drivers within a multivariate non-linear space. The findings of our study show that land surface phenology anomalies are highly correlated with extreme climatic events. The correlation coefficients (pseudo-R^2) were equal to 0.81 and 0.62, and the relative errors were 0.1 and 0.2, for spring and autumn, respectively. The main drivers in the spring anomalies were temperature and photoperiod, whereas the autumn anomalies were driven mainly by the date of the first freeze and cumulated values of chilling temperatures.

Keywords: modelling, anomalies, land surface phenology, climate variability, MERIS

Assessing spring phenological change at continental to global scales

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The general value of phenological research for understanding Earth systems interactions and facilitating global change studies has now been accepted. 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 station latitude. SI models process weather data into a form mimicking the spring growth of many plants that are not water limited, and are responsive to temperature increases. This paper summarizes recent work using longer and denser station data since 1900 across the continental USA, which has shown: 1) the SI onset of spring growing earlier since the late 1950s, including a dramatic shift in the mid-1980s; 2) regional differences in the Southeast USA; 3) 2012, the earliest year on record; 4) 2013, among the latest years on record; and 5) spatial aspects of the inter-annual variability of spring`s onset. Finally, the latest results from on-going work will be presented that uses gridded air temperature data and SI to assess changes in the spring phenological responses around the globe in both the past and the future at the century time-scale.

Keywords: global change, spring indices, phenological trends, modelling

Trends for budburst and flowering of woody plants in Norway as related to climate change

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The dates of phenophases occurrence for a number of series of tree species, provenances and cultivars in southern Norway were analysed. For all of them there was a change towards earlier phenophases (negative linear trends). On an average the phenophases occurred seven days earlier during this period. The analysis are based on observations carried out at the international phenological garden (IPG) at Fana (western Norway), and on fruit trees at the Norwegian University of Life Sciences (Ås, southeastern Norway) Ås (starting 1947), whereas no series at the IPG garden goes further back than 1964.

The phenophases are mostly budburst, start of flowering, petal fall, and also start of growth for the spruce. All of these are spring phenophases, whose mean dates of occurrence vary from the first days of May to the first days of June. The dates of occurrence of the phenophases correlate with nearby seasonal temperature series. For most of the series, the highest negative correlations were found using mean temperatures for the seasons March-May and April-May.

The trees of *Larix decidua*, *Betula pubescens*, *Fagus sylvatica* 'Har' and *Populus tremula* grown in the IPG garden at Fana during the period 1971-2005, showed steeper trends towards earlier phenophases than at other Norwegian IPG gardens. Similar analysis has also been performed for fruit phenophases at Ås, but the trends in this region did not differ significantly between cultivars and species.

Keywords: phenophases, temperature, trends, significance, budburst, woody plants, cultivars, flowering, climate change

Biogeographical regions and their flowering phenological patterns across Europe

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Phenological changes of plant species determined by complex interactions of environmental factors are in the focus of recent climate impact research. Nevertheless, there is a lack of studies on the comparison of biogeographical regions in Europe in terms of plant responses to climate. We examined the characteristics of the flowering phenology of six wild plant species (*Convallaria majalis*, *Robinia pseudoacacia*, *Sambucus nigra*, *Syringa vulgaris*, *Taraxacum officinale*, *Tilia cordata*) along a north-south transect in Central-Eastern Europe. Data from twelve countries (Finland, Estonia, Latvia, Lithuania, Poland, Slovakia, Hungary, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Macedonia) over the period 1970-2010 were investigated. Various biogeographic regions of Europe were compared to identify the spatio-temporal patterns in their phenophase response to climate change. Statistical models based on robust linear regression were used to determine the factors most influential in driving changes at the beginning of flowering dates across Europe. We found that some characteristics of the data series (e.g. quantiles, skewness) can provide better understanding of the influence of the predictor variables (such as temperature or precipitation). Our results demonstrate significant advancements in plant flowering onsets within the Continental and Alpine biogeographical regions, while less pronounced responses were detected at the Pannonian and Mediterranean regions during the last 40 years.

Keywords: biogeographical regions, flowering phenology, trend, robust methods

Impact of snow and temperature on alpine plant phenology in the Alps

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In alpine environments, the growing season is severely constrained by low temperature, snow and frosts. In such environment, the timing of vegetation onset in spring is critical for survival, growth, reproductive success and competitive abilities. Assessing the effect of climate change on alpine plant phenology requires a good understanding of the direct or indirect impact of the snow cover (snow depth and duration) and air temperature.

Here we analyze the climatic data from 74 automatic snow and meteorological stations that contain almost 20 years of data in alpine terrain ranging from 1600 to 3000 m asl in the Swiss Alps. The network gives a unique opportunity to analyze snow and climate effects on timing and growth of alpine vegetation because the ultrasonic sensor mounted in each weather station also detects plant growth in summer (e.g. the beginning of the growing season, maximum plant height).

Our analysis of trends over time indicates that the timing of snowmelt and the beginning of plant growth were tightly linked over the past 20 years. We also detected trends towards earlier maximum plant height, highly correlated with above-ground biomass.

Combining data from meteorological stations with phenology data gave us novel insights in phenological changes in alpine terrain over time and mechanisms influencing plant phenology in the context of climate change.

Keywords: alpine plants, climate change, growing season, phenology, snow depth, snow melt, vegetation onset

2.2 Poster Presentations

Climatic warming in the higher latitudes of Europe between 1951 and 2012 - the case of Murmansk Region

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Some climatic changes in the northern hemisphere and particularly in Europe are evident in the last three decades SCHWARTZ et al. (2006); STAINFORTH et al. (2013). The most pronounced expression of such trends is an earlier and a longer growing season. However, anomalies in the timing of the thermal growing season in Fennoscandia have been observed only recently KARLSEN et al. (2007); BLINOVA and CHMIELEWSKI (2008). Murmansk Region (66-70° N) is situated in the Atlantic-Arctic climatic zone of the temperate belt, and climatically the region is very heterogeneous. Two latitudinal vegetation zones can be distinguished: tundra and taiga. Gridded data of daily mean air temperatures from the E-OBS dataset (version 9.0) at 0.25° resolution were used for this analysis. The traditional biogeographic provinces of Murmansk Region are used to differentiate climatic influences regionally. The orographic regions from the provinces Lim and Lt which correspond to the highest mountains of the whole Murmansk Region were treated in this study as a separate unit Lapponia tulomensis/Lapponia Imandrae montes (Lt/Lim-mts). The average annual temperature in Murmansk Region has been -0.32 °C in the reference period 1981-2010 with extreme years of -3.3 °C and 1.4 °C. The actual length of the growing season reached 120 days on average, onset on 30 May and ending on 27 September. Since 2000 there has been a tendency to earlier onset and mainly to later end of the growing season. Shifts in the timing of the growing season and its mean prolongation by 18.5 days/62a are demonstrated for Murmansk Region (1951-2012). In this period the onset of the growing season advanced by 7.1 days/62a while the end was extended by 11.4 days/62a. The actual shifts in the timing of the growing season were more pronounced in colder (oceanic north-eastern & central mountainous) parts. The delay in the end of the growing season is similar to the entire Fennoscandian pattern but it has not been detected in the rest of Europe. Recent climatic trends could influence the retreat of the tundra zone and changes in the forest line. Losses of tundra biodiversity and enrichment of the northern taiga by southern species could be expected from present climatic trends.

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Keywords: climate change, warming, growing season, Murmansk Region, biogeographic provinces, tundra zone, north taiga zone

Using cloud computing to study trends and patterns in the Extended Spring Indices

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The Extended Spring Indices (Si-x) models SCHWARTZ et al. (2013) are a suite of regression-based models that predict the general timing of spring first leaf and of first bloom based on indicator plant species lilac and honeysuckle (genera *Syringa* and *Lonicera*). These models use daily maximum and minimum temperatures to calculate accumulated degree hours and estimate to the number of "high energy" synoptic weather warm weather events since January 1st each year.

Previous studies based on the Si-x models e.g. AULT et al. (2013) have been developed using point data, i.e. values from single weather stations or coarse grid cells. However, it is now possible to obtain maximum and minimum daily temperature grids at high spatial resolution. This allows SI-x model calculation at continental scales. For instance, DAYMET provides long term records (1980 to the present) of daily gridded weather products for the contiguous United States, Mexico and parts of Canada at a 1 x 1 km resolution. Running the SI-x models for DAYMET poses, however, a significant computational challenge because regular desktop machines are not prepared to deal with such large amount of data.

In recent years, cloud computing has become an operational and affordable solution to process large amounts of data. In this study we report on our efforts to calculate the SI-x models using DAYMET and a specialized cloud computing platform, namely Google Earth Engine, which also allows the analysis of the results.

The calculation of SI-x as a continuous product reveals high spatial resolution patterns formed by the temperature regimes and day length of each location. It also allows examination of the relative importance of the different regressors used in the SI-x models and to map phenological changes, trends and dynamics at a continental scale.

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Keywords: cloud computing, phenological trends, spring indices, time series

Changes of dry matter, biomass and relative growth rate with different phenological stages of corn under Mediterranean conditions

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Crop growth period and the length of the phenological stages on plant are directly affected by climate conditions. Therefore, seasonal climate fluctuations such as maximum and minimum daily temperature changing and precipitation rates are important for quantity of annual corn production in Mediterranean area. This study was carried out to determination of dry matter, biomass, relative growth rate (RGR) values in eleven phenological stages (V4, V8, V12, V16, VT, R1, R2, R3, R4 and R5) of corn during the period 2005-2007 in Aydın location, which is characteristically Mediterranean weather condition in Turkey. Additionally, calculated growing degree days (GDD) throughout the phenological stages, per ear weight, plant and ear height (cm), shriveled remnants of kernels (ineffective pollination) on upward of ear (cm) were measured. The data of the study is average of 31G98 and 32K61 corn hybrids value.

It seems that a significantly differences amongst the years which the field study establishment. All properties, except per ear weight, were significantly effected by years. Maximum dry matter and biomass values on the phenological stages were measured in 2005. Maximum per ear weight, plant and ear height values were also obtained from the first year of the experiment. However, maximum shriveled remnants of kernels (ineffective pollination) on upward of ear value were obtained from 2007. It is suggested that three parameters should be used for yield estimating and determination of biomass and dry matter values among phenological stages of corn. These parameters are: (i) calculating GDD values, (ii) rainfall amounts of the years and (iii) determining the number of days when daily temperature rises above 37.5 °C during growth in stages of corn.

Keywords: *zea mays* L., growing degree day (GDD), plant height, per ear weight

Foliar phenology as a sensitive indicator to climate change: a case study to investigate its applicability to the Mediterranean Area

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Leaf phenology is shifting in response to global warming YONGSHUO and FU et al. (2014). While changes in phenological spring events due to global warming have been widely documented, changes in autumn phenology, and therefore in growing season length, are less studied and poorly understood VITASSE et al. (2009).

European phenological records indicate that leaf unfolding has advanced an average of 2-3 days per decade for the last five decades PEÑUELAS and FILELLA (2001); PEÑUELAS et al. (2002); MENZEL et al. (2006); GORDO and SANZ (2009) and that leaf senescence or fall has been delayed by 1-2.5 days per decade MENZEL and FABIAN (1999); PEÑUELAS et al. (2002); MATSUMOTO et al. (2003); GORDO and SANZ (2009). Changes in the dates of leaf senescence and fall in the phenological records, however, are slower, more heterogeneous and less consistent than those for leaf unfolding PEÑUELAS et al. (2002); MENZEL et al. (2006). This alteration affects surface albedo, ecosystem carbon balance and evapotranspiration, forest productivity, the timing of the transitions between active and dormant stages.

In a previous study JOLLY et al. (2005) the use of a generalized bioclimatic index (growing season index, GSI), based on photoperiod, vapour pressure deficit and minimum temperature, was used to asses autumn canopy foliar dynamics in different ecosystems. This study investigates the use of this index at four Mediterranean (central of Italy) meteorological stations with long time series datasets (1955-2013) set on different climatic area. A preliminary analysis shows that photoperiod is the most important factor affecting GSI. The index shows little interannual variations for all the stations, except the one located in the mountains. This station is characterized by a colder climate than the others and for this reason minimum temperature becomes more important than photoperiod affecting GSI interannual variability. Our results suggest that further investigations on the definition of the growing season index are needed in order to apply it to the assessment of autumn canopy foliar dynamics in a Mediterranean.

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Keywords: agroclimatic indices, growing season, temperature trends

Floristic diversity and reproductive seasonal patterns in a tropical altitudinal gradient

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Climate is a major factor in determining plant community composition and plant phenology VAN SCHAIK (1986). Here we use six sites along an altitudinal gradient to study how changes in climate may affect plant community composition and phenology. These sites are located in the poorly studied, but species rich vegetation, the rupestrian grasslands (campos rupestres) in SW Brazil from 970 m to 1300 m asl. Rupestrian grasslands are characterized by poor, quartzitic or sandy soils with a mosaic of vegetation created by large substrate heterogeneity GIULIETTI et al. (1987). In July 2012 we started a long term project to observe the diversity and reproductive phenology of these plant communities. In each site we sampled all angiosperms in thirteen plots along a 250 m transect which have been observed monthly for flowering and fruiting phenology. Environmental data were collected by a weather station at each site. We addressed 3 questions: 1) how large is the species turnover along the altitudinal gradient? 2) how does the seasonality of flowering and fruiting phenology change along the altitudinal gradient?; and 3) are phenological changes along the gradient produced by species turnover or environmental conditions? We observed decreasing temperature and increasing precipitation with increasing altitude, as well as a decrease in species richness and an increase in the number of individuals per species. Flowering and fruiting were continuous throughout the year for all areas during the period of study. Nevertheless, most areas showed peaks of flowering and fruiting in the driest season or in the transition from wet to dry season. For two areas along the gradient we found a strong negative correlation between the percentage of flowering and fruiting individuals and temperature and precipitation. We expect that the long-term study will reveal more important information on the dynamics of this highly diverse ecosystem.

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Keywords: altitudinal gradient, mountain grasslands, climatic change, reproductive phenology

Northern treelines as bioclimatic indicators

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The alpine and arctic treelines are results of long-term processes involving adaptation to a cold climate with environmental stress, and with low soil temperatures and nutrient uptake rates. Global warming and changed land use as a result of changes in global economy and agricultural policy may interfere with the treeline changes. The global warming is expected to enhance tree growth and seed reproduction, thereby increasing treeline altitudes and latitudes. Expansion of the forested area as a result of reduced logging and grazing would also reduce the albedo and enhance global warming in treeline areas. Feedback effects caused by increased soil temperatures and related output of greenhouse gases is expected to further increase global warming and treeline advance. On the other hand, local disturbance factors like increased risks of insect outbreaks, windthrow, grazing, anthropogenic disturbance and paludification would reduce or interfere with these changes, or even lead to a retreat of treelines. These limitations should be taken into account when evaluating treelines as climatic indicators.

Keywords: treelines, temperature, land use, seed reproduction, feedbacks, human interactions, local disturbance factors

Flowering and fruiting of neotropical myrtaceae

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Myrtaceae is the eighth largest plant family in the world and one of the most important in Neotropics, especially in the Atlantic forest MORI et al. (1983); OLIVEIRA-FILHO and FONTES (2000). This family contributes with the floristic structure by high number of species and individuals and with the maintenance of ecological interactions because produces flowers visited by insects and fruits dispersed for a wide assemblage of vertebrates GRESSLER et al. (2006); STAGGEMEIER (2008). We monthly observed the flowering and fruiting patterns for 73 species in three Atlantic forest sites in south-eastern Brazil during 30 up to 70-months. Despite of floristic differences between areas (less than 30 % of species shared) phenological patterns regarding the number of reproducing species and individuals were similar. Our results showed that flowering was significantly seasonal even in an unseasonal forest. Flowers were always available but the flowering peak in all forests was between December and February. Climate explained 38 % to 6 7% of flowering and day length was the most important predictor. Since bloom during the longest days (>12 h) is a shared pattern for all sites, we suggest shifts in day-length play a major role in shaping Myrtaceae flowering patterns at a broad geographical scale. Contrasting with seasonal flowering, the fruiting was continuous with at least 10 % of species fruiting each month. Fruit production was not strongly predicted by climate (R^2adj: 0.19 to 0.35) although there is a tendency to find more fruits in the less rainy season when days are short and cold (May to August). More species fruiting during the driest and coldest days, suggesting an advantage perhaps related to decreased predation rates at this time of year MORELLATO et al. (2000). The high predictability of Myrteae fruiting time along the years and the continuous fruit production in all forests, strongly support the suggestion of a robust coevolution link between Myrteae and seed disperser' animals mediated by phenological strategies. The success of dispersal, crucial for the persistence of fleshy-fruited populations, strongly depends on correspondence between fruiting maturation, the presence and abundance of frugivores and on favourable abiotic conditions for germination. Therefore, fruiting time for each species may be related to a wide variety of environmental stimuli, placing reproductive activity at the most advantageous time of the year.

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Keywords: climate, day length, flowering, fruiting, Myrteae

Mapping the main spatio-temporal patterns of spring onset over Europe

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The study of interannual variation in phenological patterns is relevant for understanding the impact of global change on our planet. Till now, this kind of studies has been done by clustering of spring onset information from phenological models or remote sensing data. Such a clustering identifies regions have similar phenology or phenoclusters. In this contribution we present a novel analysis of phenological patterns based on co-clustering. This method allows the simultaneous analysis of spatial and temporal phenological patterns present in the data.

The analysis is illustrated using the Extended Spring Indices (SI-x), which characterize spring onset by predicting the first leaf dates (FLD) for key plant species from daily maximum and minimum temperatures and latitudinal information (as a proxy for day length). The FLD values were calculated from the European E-OBS temperature dataset, which provides weather data for the period 1950 to 2011 at a spatial resolution of 0.25 degrees After that, the FLD values were clustered using the Bregman block average co-clustering algorithm WU et al. (2015) and the resulting co-clusters were grouped using k-means to identify the main spatio-temporal patterns present in the data.

Results show that there are five main FLD spatio-temporal patterns over Europe. These patterns were named according to their relative spring onset timings as “very late”, “late”, “early”, “very early” and “abnormal”. The first years of the period under study exhibit very late FLD values especially in northern Russia, Scandinavian countries, Iceland and few areas of Western Europe (e.g. the Alps). In recent years, warmer springs (early FLD values) are common particularly in most of the Iberian Peninsula, northern France and Ireland. Results also show that western Turkey had the most intricate temporal patterns as this area belongs to several distinct patterns. This study has also found anomalous FLD values (e.g. Iceland) that might indicate quality issues in the E-OBS temperature datasets.

These results offer a novel view of the long term phenological patterns that exists in Europe and of their temporal dynamics. Thus, we conclude that co-clustering is a promising method to map phenological patterns over large areas.

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Keywords: spatio-temporal patterns, co-clustering, Europe, spring indices

3 Match or mismatch in phenology

3.1 Oral Presentations

Dynamic changes in a keystone resource modulates heterogeneous responses to climate change in a wild bird population

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Over recent decades there has been huge interest in climate-induced changes in plant and animal reproductive phenology. Research increasingly suggests that while some species and populations are successfully tracking the shifting peak in their food source, others are not, leading to disruption of the synchrony between different trophic levels. Despite this growing body of literature, few studies consider the spatial scale with which animals interact with their environment, instead focusing on population-wide processes. Oak trees (*Quercus* spp.) represent a keystone species in many deciduous forests; not only do they support entire ecological communities but the timing of their spring leaf budburst influences the reproductive phenology and performance of a diverse range of organisms. Great tits (*Parus major*) are a classic example, primarily feeding their young on caterpillars of the winter moth (*Operophtera brumata*), which in turn feed on newly-emerged oak leaves. Long-term study of this system in the UK has demonstrated that both winter moth and great tits have tracked the advancement of spring, with female great tits adjusting timing of egg-laying between years, thus avoiding phenological mismatch. However, studies to date have largely been done at the population-level and thus mask more fine-scale heterogeneity, both in individual's phenotypes and the environments they experience. Here we use 54 years' data on great tit breeding phenology from an intensively-studied population near Oxford, UK, to explore fine-scale spatial variation in the rate at which tits adjust timing of breeding in relation to changing climates. Using data for 436 fixed breeding locations (nestboxes) within our 385 ha study woodland, we demonstrate marked spatial heterogeneity in the rate of advancement of timing of egg laying over time. To quantify changes in resources over time we scored the amount of canopy dieback of each mature oak tree within our study site (N=5748), and found that local oak tree health was a strong predictor of spatial variation in the rate of advancement in laying. Birds nesting in boxes in areas with substantial oak dieback advanced their laying at a significantly slower rate than those in areas with more healthy oaks. Given that oak abundance is a key indicator of territory quality in tits, this study suggests that chronic oak dieback can act to reduce habitat quality and constrain individuals' ability to track advancing springs. To our knowledge this is the first study to demonstrate how fine-scale spatial variation in the health of a keystone species can influence how higher trophic levels track environmental change.

Keywords: phenological trends, reproductive timing, trophic mismatch, heterogeneity, great tit, wild population, habitat quality

Match or mismatch: A test with 7 butterfly species, over 300 host and nectar plants and 58 years of phenological observation

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Possible phenological mismatch with climate change is of growing concern, since many species rely on specific biotic interactions. Several recent publications show that different species and especially species from different trophic levels show distinct temperature sensitivities. This raises the question if a synchronous timing of phenological phases can still be expected with warming temperatures. The availability of food plants, fruits, or pollinators needs to be in time, since otherwise survival or reproduction are at risk. Yet, an assessment of possible match or mismatch is difficult, since data on the timing of phenological onsets for species of different trophic levels is scarce. Here, we present analysis from a single-site, long term dataset, and assess how butterfly and corresponding host/nectar plant phenology respond to temperature. We ask if these responses might lead to phenological mismatch with climate change.

First sighting dates of the seven butterfly species were recorded at one single site in South Germany (1957-2013). The relevant host and nectar plants of each of the butterfly species were extracted from LepiDat. For over 90 % of these, spring emergence dates of host plants and/or flowering dates of nectar plants are available for the same period and site. Climate data for the same period was taken from a climate station in 5 km distance.

Overall, the overwintering strategy of the butterfly species plays an important role, and species that overwinter as imago on average appear earlier (average DOY 86-99) than species overwintering in pupae or larvae stage (average DOY 108-147). We assessed which temperature value (minimum, maximum, mean), and which time period explains most of the variance in butterfly sighting dates. For early butterflies, these explain 25-42 % of the variance, while for later butterflies values were higher (R2 0.45-0.48). Overall, maximum temperatures are better predictors than mean or minimum temperatures, and a two month period seems to be most appropriate for analysis. The temperature responses show considerable differences between species (2.5-5.5 days/°C).

First butterfly sighting shows a close relation to the start of flowering of nectar plants, however, the "safety lag" is usually rather small (often only some days). Moreover, at first butterfly sighting dates, usually only few of the nectar plants are already in blossom, and the maximum diversity of flowers is reached considerably later. This means that mismatches can easily occur with diverging shifts of flowering dates. For larvae, however, green fresh leaves are already available from most of the host plants when needed. Thus, shifts in leaf emergence dates are less likely to cause phenological mismatch.

These two types of possible mismatch are analysed with regression techniques, and temperature responses of butterfly species are compared to those of the individual host and nectar plants. Furthermore, a more detailed analysis of outlier years is performed. In total, the analysis allows to estimate species-specific exposure to mismatch with climate change.

Keywords: butterfly, nectar plant, host plant, long-term observation, mismatch, climate change

The spatial scale of selection on phenology in a wild bird population

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Studies of the phenology of breeding behaviour in birds have been influential in two key areas in ecology and evolutionary biology. First, in understanding how natural selection acts on variation within populations, and second as well-studied example of phenotypic change driven by environmental change. However, the majority of studies of avian reproductive phenology have not considered the spatial scale at which phenotypes should be defined and at which selection acts. Here, we use data from a 54-year study of the breeding phenology of the great tit (*Parus major*), involving >10 000 breeding observations, coupled with study of the phenology of herbivorous insects and trees, on which these birds depend for successful reproduction, to show that a consideration of spatial scale leads to a quite different understanding of the way that phenology varies between individuals. We show, first, that the timing of reproductive decisions in great tits (egg-laying, hatching of young) is best predicted by very local phenology of oak trees, a keystone resource for herbivorous insects in deciduous forests. We then separate variation in phenology into that occurring within, and that occurring between, locations used in repeated years by breeding birds. We show that natural selection is stabilising on variation within spatial locations, implying that there is a site-specific optimum timing at very small spatial scales. As a consequence, previous analyses that have combined data across locations, have confounded variation operating at multiple levels. A new, spatially-explicit, focus on phenology is needed to better understand how variation arises and is maintained within populations as they respond to changing climates.

Keywords: evolution, selection, spatial variation

Experimental manipulation of spring temperature to alter breeding phenology in a population of wild blue tits (*Cyanistes caeruleus*)

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Species in seasonal environments often need to match the peak energetic demand of reproduction with peak resource availability to maximise reproductive success. Annual variability in the timing of resource peaks means that many consumers must exhibit plasticity in their reproductive phenology to maintain optimal timing. Current climate change is adding directional change to these annually shifting resource peaks. It is not yet known whether existing plasticity is sufficient to cope with the novel environments that arise from this change or whether species will reach the limits of their flexibility. Therefore it is important to assess how climatic changes will impact the ability of seasonally breeding species to match resource peaks. In order to achieve this it is helpful to identify the cues used by the species to predict optimum timing and to determine the limits on their ability to behave plastically in response to such cues. Gaining understanding of either of these elements is challenging because explicitly testing the influence of temperature fluctuations in the wild can be problematic. This has been attempted for some bird species, where nest box temperatures have been manipulated in order to alter breeding behaviour. However there have been very few manipulations focusing specifically on lay date. In this study we extend on from previous work by conducting a more extensive test of how nest box temperature can alter lay date in a population of blue tits (*Cyanistes caeruleus*). The blue tit population in Wytham woods, UK, was chosen as the study system for this experiment because their phenology has been studied in detail since 2001, with population level analyses showing strong correlations between lay date and spring temperatures.

However, in order to identify the exact cues females use to predict optimal first-egg date it is necessary to test different cues experimentally at the individual level. For this experiment, we manipulate pre-laying temperature experienced by females by heating and cooling nest boxes prior to laying. During this period females visit the nest box intermittently during the day and roost there at night. As a result our manipulation of in-nest temperature will alter how the female's perceived night time and day time temperatures. This experiment will allow us to test whether in-nest box temperature acts as a cue for optimal laying time. It will also allow us to begin to look at the limits of plasticity in laying date, by assessing how females respond to temperature treatments that are likely outside of what they would usually experience in the wild. Both of these outputs are a first step towards gaining the information we need to predict the future of the population. Predicting the future of phenology under climate change is important because optimal reproductive timing plays a role in the reproductive success of this species. A failure to match peak chick food demand with the peak of their caterpillar prey can cause high nestling mortality.

Keywords: experimental manipulation, phenological trends, matching – mismatching

Using citizen science to quantify spatial variation in ecological mismatch in woodlands

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Phenological data has long been collected by what we now call citizen scientists. Their records have been fundamental in developing our current understanding of the effects of global climate change on phenology PARMESAN and YOHE (2003). As the field advances existing citizen science schemes are often inadequate for addressing some of our most pressing questions. For instance, a major cause of concern under climate change is that interacting species may become mismatched DURANT et al. (2007); THACKERAY et al. (2010); IPCC (5th Report). The vast majority of insights into mismatch have been obtained through intensive long term single site projects, perhaps the most prominent being of oak, winter moth and great tit populations VISSER et al. (2006). Citizen science has thus far contributed little to our understanding of the frequency or severity of mismatch (with the exception of THACKERAY et al. 2010). This is in part a legacy of most schemes following a particular group such as birds and overlooking species interactions.

New citizen science projects designed to focus on mismatch can address this shortcoming and in 2014 we launched the UK-wide Track a Tree scheme (www.trackatree.org.uk). Track a Tree records individual trees and their understorey species to examine the interaction between canopy shading and flowering herbs in UK woodlands. Track a Tree was designed to answer the following questions: (i) Does the order of phenology in woodland trees and flowering plants vary across space? (ii) How plastic is the phenological response of individual trees within and between species? To address these questions volunteer recorders monitor the phenology of individual woodland trees and their associated ground flora throughout spring. Our approach is already providing information on the phenological response of species that make up some important UK habitats; in 2014 over 130 woodland sites were monitored, representing over 250 trees and 2000 phenological observations. Building on this I will present results from the first two years of Track a Tree and outline how further work could explore interacting species at different trophic levels.

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Keywords: phenological mismatch, citizen science

3.2 Poster Presentations

Climate change impacts on wild boar in Bavaria mediated by abiotic and biotic phenological changes

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Globally, populations of wild boar (*Sus scofra* L.) are increasing dramatically indicated both by expanding ranges to previously not occupied areas and hunting bags higher than ever recorded. It has been hypothesized that this development is due to land use / land cover changes, a.o. related to maize cultivation area and renewable energy production from agricultural biomass, and recent climate change. The latter factor is strongly linked to abiotic and biotic phenological changes in terms of shorter snowy and less cold winter season as well as a longer vegetative growing season and more frequent mast years of oak and beech. In this paper we evaluate regionally resolved hunting bags of wild boars in Bavaria from 1961-2014 and their respective trends. As potential drivers, we use different parameters from climate and phenological data of the German Meteorological Service for the same period, data on maize cultivation area and yields as well as information on seed production in forests. Understanding and modelling of the population dynamics of wild animals related to climate change and phenology is of paramount importance for adaption in wild boar management.

Keywords: modelling, phenological trends, animal biometeorology

4 Remote sensing and phenology

4.1 Oral Presentations

Growing seasons detected by digital cameras along five seasonal vegetation in the tropics

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Leaf flushing and senescence are important events in plant life cycles, exerting temporal control over the structure and function of the plant community LIETH (1974). Phenological observations in several sites at once is challenging in the tropics, given the complex and highly diverse vegetation types. Recently, the use of digital cameras to successfully monitor phenology in tropical ecosystems has been demonstrated ALBERTON et al. (2014). Near-surface remote phenology using digital cameras allows the monitoring and comparison of phenological patterns across different sites and vegetation types. In the present work, we quantified green color changes and defined the growing season among five different seasonal Brazilian ecosystems: caatinga (semi-arid shrubland, Pernambuco State), cerrado campo sujo (savanna grassland, São Paulo State), campo rupestre (mountain grassland, Minas Gerais State), and two areas of cerrado sensu stricto (closed savanna, São Paulo State), capturing a gradient of water deficit. For each site, we selected a Region of Interest (ROI) representing the community and extracted RGB channel values, calculating the RGB chromatic coordinates index (RGBcc) RICHARDSON et al. (2009); ALBERTON et al. (2014). We processed around 170,000 images, acquired between 2013 and 2014. We use the 90th Gcc percentile of all daytime images (taken from 6:00 a.m. to 6:00 p.m.) to represent the daily community value.

Preliminary results showed that caatinga and the grasslands (campo sujo and campo rupestre) had highest green values, with amplitudes of 0.34 Gcc to 0.38 Gcc, while cerrado vegetation sites had 0.34 Gcc to 0.35 Gcc. Caatinga vegetation had the shortest growing season, lasting less than two months. Cerrado sensu stricto sites were more similar, having their greenness peak at the same period (September and October). In comparison, the Cerrado campo sujo had a different period for the peak of the growing season (November and December), despite being located at the same latitude. The campo rupestre grassland had the most contrasting pattern, with the growing peak occurring during the months of January and February. The initial approach presented here is important to support the investigation of phenology environmental drivers and the effect of climatic variations, as well as better understanding phenological variations across different types of tropical ecosystems.

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Keywords: digital cameras, leafing, remote phenology, seasonality

Phenological monitoring of alpine grassland based on innovative biophysical remote sensing products adapted to alpine areas

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Phenological monitoring in mountains is especially challenging as factors such as elevation, solar radiation, snow cover, and soil moisture affect vegetation phenology on a small scale. Remote sensing data are a valuable source for monitoring land surface phenology (LSP) and related ecosystem processes, since they provide repetitive and spatially explicit information even for remote areas. However, the retrieval of phenological and biophysical parameters from remotely sensed data is a challenging task, especially when dealing with mountain environments such as the Alps. Already available products such the MODIS Vegetation Phenology, Snow Cover, and Leaf Area Index (LAI) products may present limitations in mountain areas due to the heterogeneous landscape and topography. In fact, the extreme topographic variability and the patchy land-cover and ecosystem structures require specific algorithms to be developed. This is achieved in this study using 250 m spatial resolution active and passive remote sensing imagery to derive LSP metrics together with time series of biophysical parameters, namely snow cover, LAI, and soil moisture, for alpine grasslands covering the whole Alpine Arc (43°- 48° N / 5°- 15° E) and the years 2002 - 2014.

The approaches are specifically developed to take into account the peculiarity of the mountain areas in order to obtain more accurate remotely sensed products. 4-day composites of the 250 m resolution MODIS daily surface reflectance product (MOD/MYD09), which omit pixels of poor observation and geolocation quality, are the basis to derive NDVI time series. These are in turn used to model LSP metrics, namely start of season and length of season, using the TIMESAT software JÖNSSON and EKLUNDH (2002). Additionally, LAI time series are derived from the surface reflectances using a radiation transfer model tuned on the spectral characteristics of mountain grasslands PASOLLI et al. (2011a). Yearly grassland productivity measures are derived from these time series.

For the detection of snow covered area (SCA) also the red and near infrared bands of the MODIS surface reflectance product are used NOTARNICOLA et al. (2013). Additionally, the cloud cover information from the MOD/MYD10A1 product is considered. The SCA is used in a next step to derive the snow cover duration. Soil moisture maps are derived from high resolution Advanced Synthetic Aperture Radar (ASAR) Wide Swath images together with the MODIS NDVI, correcting for the presence of vegetation. The algorithm for soil moisture retrieval is based on an advanced machine learning regression approach, the support vector regression technique PASOLLI et al. (2011b).

Having these long time series of tailored products over mountain areas allows better understating of key processes that influence vegetation phenology. They can be used to correct the NDVI time series for residual noise, as well as the LSP layers for site specific conditions. The influence of topographic and biophysical features can further be quantified using multivariate regression analysis.

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Keywords: remote sensing, land surface phenology, time series, leaf area index, soil moisture, snow cover

Revealing the influence of drought on spring vegetation phenology

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The phenological cycles of vegetation green-up (i.e. onset of growth) and brown-down (i.e. senescence) are ubiquitous, but are complex and show large variability across space and time. Phenology is sensitive to climate and this study clarifies how changing climate may alter the spatial and temporal characteristics of phenology. Satellite remote sensing offers a unique vantage point from which to observe phenological cycles across large regions and enables tracking events such as the start, end, and duration of the growing season REED et al. (1994).

In the western USA, herbivore species such as elk, moose, and deer depend on the availability of herbaceous plants and deciduous shrubs for forage. These vegetation types are most nutritious for herbivores during spring, so characterizing early spring phenology may provide crucial information towards understanding how shifts in climate could affect herbivore behavior and health CHRISTIANSON et al. (2013); MIDDLETON et al. (2013). This study builds upon prior research to answer whether 1) drought conditions advance the beginning of spring green-up and 2) drought conditions accelerate the rate or speed of green-up.

To characterize spring phenology and drought relationships, we investigated multiple phenological measures calculated from Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery at 250 m spatial resolution across Wyoming, USA. Phenological metrics calculated from source normalized difference vegetation index (NDVI) included the start of season time (SOST), time of maximum change (MCT), green-up window (GUW: days from SOST to peak NDVI), and early spring window (ESW: days from the SOST to the MCT).

Evidence showed that drought conditions advanced the start of spring, although the best measure for the beginning of spring (SOST or MCT) varied by land cover type. The SOST correlated positively, strongly, and significantly with many drought indicators (e.g., Standardized Precipitation Index, Palmer Drought Index) for evergreen forest. For grasslands and shrublands found at lower elevations, however, the MCT provided a stronger indicator of advancing spring during drought than SOST. Evidence for any acceleration of spring green-up was not so clear. In fact, in forests the GUW and the ESW were longer (indicating deceleration of green-up) in drought years. For grasslands and shrublands, results were geographically variable. The GUW was either not significantly correlated or was longer under drought conditions depending on location. However, the ESW showed acceleration especially across the northern third of the state. Further analysis is needed to investigate whether the ESW and the MCT show similar results in phenology studies elsewhere. It is possible that the phenological signal of vegetation in the more arid areas was too subtle to detect a significant response to drought conditions.

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Keywords: remote sensing, climate, drought, spring, normalized difference vegetation index, herbivore

Crop suitability monitoring with 100 m PROBA-V data

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This study has been realised within the framework of a PhD targeting to advance agricultural monitoring with improved yield estimations using SPOT VEGETATION type remotely sensed data. For the first research question, the aim was to improve dry matter productivity (DMP) for C3 and C4 plants by adding a water stress factor. Additionally, the relation between the actual crop yield and DMP was studied. One of the limitations was the lack of crop specific maps which leads to the second research question on 'crop suitability monitoring'.

ZHANG et al. (2003) argues that simple methods from remote sensing have proven to monitor the phenological metrics (max, min, amplitude, onset dates). These methods take advantage of the fact that vegetation phenology tends to follow relatively well-defined temporal patterns (ZHANG et al. 2003). Furthermore, using temporal characteristics of satellite images can largely improve the accuracy of cropland classification, because of the distinct crop phenology compared to other land use and land cover types THENKABAIL and WU (2012). The objective of this work is to create a methodological approach based on the spectral and temporal characteristics of PROBA-V images such as characterising each study crop using phenology metrics to improve the estimation of annual crop yields.

The PROBA-V satellite was launched on 6th May 2013, and was designed to bridge the gap in spaceborne vegetation measurements between SPOT-VGT (March 1998 - May 2014) and the upcoming Sentinel-3 satellites scheduled for launch in 2015/2016. PROBA-V has products in four spectral bands: BLUE (centred at 0.463 μm), RED (0.655 μm), NIR (0.845 μm), and SWIR (1.600 μm) with a spatial resolution ranging from 1 km to 300 m. Due to the construction of the sensor, the central camera can provide a 100 m data product with a 5 to 8 days revisiting time. Although the 100 m data product is still in test phase, a methodology for crop suitability monitoring is going to be developed. The multi-spectral composites, NDVI (Normalised Difference Vegetation Index) (NIR_RED/NIR+RED) and NDII (Normalised Difference Infrared Index) (NIR-SWIR/NIR+SWIR) profiles will be used in addition to secondary data such as digital elevation data, precipitation, temperature, soil types and administrative boundaries to improve the accuracy of crop yield estimations.

The methodology is evaluated on several FP7 SIGMA test sites for the 2014-2015 period. Reference data in the form of vector GIS with boundaries and cover type of agricultural fields are available through the SIGMA site partners.

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Keywords: PROBA-V, phenology, crop, SIGMA

Opportunities to assess grassland biodiversity using digital repeat photography

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Grasslands show a variable degree of biodiversity essentially due to climate and management practices. In turn, grassland biodiversity translates into spatial variability of species distribution, and these species are likely characterized by a different phenology. We hypothesize that by quantifying the spatial variability of grassland phenology we could obtain indices that correlate to ecosystem biodiversity.

Digital repeat photography is a widespread tool used to track the seasonal development of vegetation greenness, not only integrated over a portion of the scene, but potentially also at the level of each pixel. While the first approach is well established and widely used, the pixel based approach has been so far poorly explored.

Taking advantage of a new tool to process digital images of a vegetation canopy (the R package phenopix), we extracted pixel-based greenness indices and relevant phenological dates in grassland sites characterized by different degrees of biodiversity, with a spatial resolution on the order of 10-20 cm.

The investigated grasslands show a high small-scale spatial variability in phenological dates. For example, the beginning of the growing season can vary by more than one month in a 40 m^2 area of a subalpine grassland in the European Alps. Even more surprisingly, the growing season length can vary between 70 and 140 days, i.e. by more than two months at the same site.

We will further show how the spatial variability of (i) phenological dates and (ii) the shape of the seasonal trajectories correlate to biodiversity indices. We will also illustrate how the strength of the relationships changes across sites and what factors are likely to control it.

Taken together, our results show that pixel-based analysis of digital images of the vegetation cover can be linked to biodiversity in grassland ecosystems, therefore representing a new and promising tool for future application.

Keywords: phenocameras, phenopix, proximal sensing, R software, spatial variability

Phenologies in cool earthlight: How passive microwave time series can reveal land surface phenologies and more

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Cool earthlight, the emissions of microwaves from the land surface, offers a complementary perspective on the seasonal dynamics of the vegetated land surface to the conventional approach that relies on reflected sunlight. Conventional vegetation indices, such as the Normalized Difference Vegetation Index (NDVI) and the Enhanced Vegetation Index (EVI), are built from reflectance in the visible and near infrared bands and these indices track the absorption of photosynthetically active radiation. In contrast, Vegetation Optical Depth (VOD) is a frequency-dependent estimate of microwave flux emitted from the soil that is attenuated by the water content of the vegetation canopy. Multi-frequency microwave radiometer data can also be used to retrieve surface air temperature (ta), volumetric surface soil moisture (vsm), fraction of open water (fw), and precipitable water vapor (pwv), only when the surface is not frozen. Here we explore land surface phenologies and land surface seasonalities in croplands and mixtures of croplands and natural vegetation in Russia, Kazakhstan, Ukraine, Ethiopia, and Brazil with a recently constructed suite of land variable constructed using brightness temperatures from three microwave radiometers: Aqua/AMSR-E, FengYun3B/MWRI, and GCOM-W/AMSR2. The entire time series covers the period from June 2002 through December 2014 and includes day and night acquisitions. The coarse spatial resolution is offset by the higher frequency of acquisitions. Our prior work has shown the efficacy of the Convex Quadratic (CxQ) model to capture the seasonality of thermal time using growing degree-days (GDD) and conventional vegetation indices. Here we demonstrate how VOD, GDD, ta, vsm, fw, and pwv behave as a function of both accumulated GDD (AGDD) and day of year. We highlight seasonal development of day/night differences in these variables. Using AGDD as the independent variable, the CxQ model works well at higher latitudes, but other environmental drivers are better suited to capture land surface dynamics in the tropics.

Keywords: remote sensing, land surface phenology

Remote sensing based mapping of the growing season in alpine parts of Norway and on the High Arctic Archipelago of Svalbard

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The main aim is to use satellite data to map the growing season, both in the Norwegian mountain range and on the High Arctic archipelago Svalbard, interpreted from field observations. These Arctic and alpine areas, is characterized by scattered vegetation cover and huge differences in plant species composition and in the length of the growing season between ridges and snow-beds. This as a result of local topography, hydrology, and winter snow depth, which could lead to 3-6 weeks earlier onset of flowering on a ridge compared with a snow-bed a few meters away. In addition, the season is short and it is often frequent cloud cover. Hence, remote sensing based mapping of the growing season in the arctic-alpine zone is a challenging task.

To map the onset and end of the growing season we mainly use MODIS satellite data, both the MOD09A1 product (8-days, 500 m, 7-bands reflectance) and the MOD09Q1 product (8-days, 250 m, red and NIR reflectance) for the 2000 to 2014 period. Due to a short and intense period with greening-up and frequent cloud cover, all the cloud free data is needed, which requires reliable cloud masks. We used a combination of three cloud removing methods (State QA values, own algorithms, and manual removal). This worked well, but is time-consuming as it requires manual interpretation of cloud cover. Then we smooth the time-series data. In addition, we also apply Landsat 8 satellite data for parts of Svalbard. This sensor has 30 m pixel resolution, and on Svalbard almost daily data are obtained due to the location close to the North Pole. We also use this sensor to prepare for the forthcoming Sentinel-2 satellite sensor with both high spatial and temporal resolution.

During the seasons 2009-2010 we established serval phenological observation tracks both on Svalbard and in alpine parts of mainland Norway. These observation tracks are designed to detect the phenological variation at a scale that can be compared with MODIS data. The last two seasons these manual observations have partly been replaced by automatic cameras, and the monitoring adjusted to prepare for interpreting the high spatial and temporal resolution data from the Landsat 8 and Sentinel-2 sensors.

The onset of the growing season is mapped with a NDVI threshold method, which shows high correlation with field observations. The results shows large variation in onset of the growing season between years, but with no significant trend in the 2000-2014 period. For mapping the end of the growing season a combination of different methods have to be used, depending on the land cover type, but this work is not completed. The work is mainly funded by the Norwegian Ministry of Climate and Environment.

Keywords: arctic, alpine, phenological network, remote sensing, MODIS, Landsat 8

Deriving phenological layers for Germany from remote sensing data: spatio-temporal analysis and validity

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Information on the timing of phenological events and their changes are critical parameters for quantifying the impact of climate alterations and are of major relevance for terrestrial ecosystem models. Spatially consistent phenological information can be derived from remote sensing based vegetation indices by calculating phenological metrics such as Start of Season (SOS), End of Season and Length of Season (LOS). Different approaches exist for the preprocessing of time series from medium resolution satellite data as well as for the derivation of phenological metrics, but these methods often lack any biophysical or ecological meaning and qualitative comparisons between different methods are rare.

This study aims at (1) deriving SOS as an indicator for the onset of spring, (2) comparing the phenological layers with phenological ground observations and the global MODIS "Land Surface Dynamics" product, and (3) developing value added phenological layers from the data in order to (4) characterize spatiotemporal variations.

To determine the optimal method for the deviation of phenological metrics, MODIS 16-day NDVI data ranging from 2001 to 2012 were analyzed. An experimental set-up consisting of different methods for time series preprocessing (handling data quality, smoothing methods and considering the actual date of acquisition) and derivation of SOS using local thresholds (20, 35 and 50 %) was established.

Statistical measures were used to define the best method by comparing the derived SOS values with phenological ground observations provided by the German Meteorological Service (DWD). A mean duration of the phenological season "spring" is taken from DWD data and ranges from 22nd of February (day of year (DOY) 53) until 30th of May (DOY 150). The optimal method is able to derive SOS within the average range of DOY 52 and DOY 154 for 93 % of all pixels. In comparison, the MOD12Q2 phenological dataset estimates the onset of spring with values ranging from DOY 48 to 133 as too soon.
Based on the SOS for each year, a mean onset of spring was calculated for being considered as an appraisal for mean phenological development in Germany. The layer shows good accordance with spatial patterns of topography. The vegetation of low mountain ranges and the pre-alpine foothills show a later onset of spring than the vegetation in basin landscapes. This can be seen as an indicator for temperature-driven vegetation development.

The deviations of the annual SOS layers from the mean SOS layer were used to characterize the inter-annual spatial differences in the onset of spring. They indicate the rate of plant development for the year under consideration compared to the average year. For example, in 2008 northern Germany is characterized by unusually early SOS dates in comparison with southern parts of the country. This was caused by regional differences in precipitation and air temperature during the months January, February and March.

It can be concluded that a profound processing of remotely sensed time series enables the derivation of spatial patterns that reflect meteorological and other site-specific effects on actually measurable phenological development of the vegetation such as the onset of spring.

Keywords: land surface phenology, MODIS, time series, phenological layers, spatio-temporal analysis

A comparison of ground-based observations and the sensitivity of satellite-derived land surface phenology to variation in spatial and temporal resolution

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Time-series of remote sensing data are an important and effective way to assess land surface phenology trends across spatial and temporal scales. However, the estimates of land surface phenology parameters, such as start of season and end of season, from satellite sensor data are affected by the uncertainties resulting from pixel resolution, temporal resolution, phenology extraction method and atmospheric contamination, among others. Relatively few studies have provided a complete evaluation of the effect of these uncertainties on estimated phenological parameters.

The purpose of this study was to evaluate the sensitivity of satellite-derived phenological parameters to choice of temporal (compositing period) and spatial resolution. MERIS MTCI data (Level 2) for 2005 to 2011 were acquired for the United Kingdom. These datasets were compiled into 4, 8, 10 and 16 day composites using the BEAM open-source toolbox and development platform at 250 m spatial resolution, and then resampled to 500 m, 1 km, 2 km, 4 km, and 8 km. The discrete Fourier transformation was applied to create smoothed time-series of MTCI across the UK and an inflection-based method was used to estimate the start of season (SOS) and end of season (EOS) for each temporal and spatial resolution.

The results highlighted the variation in the phenological parameters with variation in both spatial and temporal resolution, conditional upon land cover type. The variation in composite period highlighted that (with the exception of coniferous forest) the 16 day composite period predicted a later SOS, and (with the exception of arable land cover) 4 day composite period predicted a later EOS estimate. In addition, coarser spatial resolutions predicted a later EOS compared with finer spatial resolutions. Further comparison with ground phenological observation (such as data from Nature's Calendar UK) would be useful to quantify the magnitude of these uncertainties.

Keywords: phenology, remote sensing, sensitivity, ground observations

Detection of spatio-temporal variability of the timing of start and end of growing season by multidisciplinary in situ and satellite observations

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To evaluate the variability of spatio-temporal variability of ecosystem functioning and service under rapid meteorological and climate changes, accurate detection of spatio-temporal variability of plant phenology is one of important issues. Towards this aim, satellite remote-sensing is useful but, from the in situ ecological research viewpoint, this approach has not been tested and validated by ground-truthing. Here, (1) we have conducted global, long-term continuous and comprehensive phenological observation network: PEN (Phenological Eyes Network: http://www.pheno-eye.org), which mainly consists of time-lapse digital cameras, in various ecosystem sites; (2) we examined the year-to-year variability of the timing of leaf-flushing, -colouring, and -fall by analysing temporal variability of red, green, and blue digital numbers extracted form daily phenological images; (3) we detected the spatio-temporal variability in the timing of start (SGS) and end of growing season (EGS) in Japan, Alaska, and Siberia from 2003 to 2013 by analysing Terra/Aqua MODIS satellite-observed daily green-red vegetation index (GRVI) with a 500-m spatial resolution; and (4) we evaluate the relationship between year-to-year variability in the timing of satellite-observed SGS and EGS and in situ-observed plant phenology. We found that (1) satellite-observed SGS and EGS respectively detected the timing of beginning of leaf-flushing and that of peak of leaf-colouring in closed-canopy deciduous coniferous (larch) forests in Japan and Siberia and an opened-canopy evergreen coniferous (black spruce) forest in Alaska; (2) the timing of satellite-observed SGS and EGS was respectively earlier and later than that of in situ-observed leaf-flushing and -fall in a closed-canopy deciduous broad-leaved (oak and birch) forest, which is located in a steep mountainous region, in Japan; (3) the year-to-year variability in the timing of satellite-observed SGS and EGS showed characteristics along vertical and/or horizontal gradients in Japan, Alaska, and Siberia; and (4) however, satellite-observed SGS and EGS included uncertainties due to heterogeneity of vegetation, footprint, characteristics of plant phenology (especially in autumn phenology), and cloud contamination in satellite data.

Keywords: Phenological Eyes Network (PEN), satellite (MODIS), time-lapse camera, timing of start and end of growing season

Seasonality of boreal forest spectra

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Boreal forests exhibit strong seasonal dynamics in their reflectance spectra during their short, snow-free growing period. In the Eurasian boreal zone, connections between phenological events and seasonal reflectance courses have mainly been established for data from multispectral satellite sensors whereas studies based on seasonal time series of hyperspectral satellite images are nearly non-existent. As several new hyperspectral satellite missions are currently developed, an understanding of the seasonality of vegetation spectra at a higher spectral resolution is also critical. In this presentation, we report an analysis of the seasonality of boreal forest spectra from the end of snowmelt until the time of maximal leaf area. We apply a forest reflectance model (FRT) to estimate the seasonal contribution of understory vegetation to forest reflectance from a time series of EO-1 Hyperion images, and extend the analysis to a theoretical examination of the role of understory in a range of different satellite viewing angles. Our analysis is based on a detailed seasonal series of field measurements carried out at the Hyytiälä Forestry Field Station in Finland.

Keywords: leaf area index, boreal, Hyperion, reflectance modeling

Seeking greener pastures: exploring multi-scale phenology of Australian temperate grasslands

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Australian temperate grasslands occur in the south-east of the continent and represent a diverse range of communities, from high-value native complexes to exotic-dominated grazing lands. Improving the monitoring and management of these lands is critical for maintaining the security of Australia's meat and wool industries, as well as protecting the biodiversity of native grasslands from the threats associated with a changing climate.

Phenology has been used in northern hemisphere temperate ecosystems to demonstrate changes in vegetation quantity, species composition and disturbance. However, with a few exceptions, phenological methods have not been used to any great advantage in Australia. The temperate grasslands of south-eastern Australia have unique characteristics including a highly dynamic response to rainfall and the retention of standing litter throughout the year. As such these ecosystems require further scrutiny to determine phenological drivers and develop applicability of phenological methods at a landscape scale.

Our aims are to determine the drivers of phenological variability among temperate grassland types and to compare multi-scale phenological methods. We examined twelve grassland sites that are dominated by C3/C4 native or exotic species near Canberra, Australia. Vegetative phenology profiles were captured via satellite through MODIS NDVI products and at near-surface by hourly time-lapse RGB phenology cameras ('phenocams'). Phenocam images were converted to multi-region green chromatic coordinate values. Remotely-sensed data was validated with field-based sampling, including biomass clippings (live/dead and grass/forb fractions), fractional cover, pasture height and species-specific abundance/phenophase data.

We found multi-scale satellite and phenocam data to be in general agreement, though the higher temporal capacity of phenology cameras is able to capture more subtle changes in vegetation. C3/C4 species dominance was the primary contributor to phenological differences with C3 grasslands greening earlier (August/September), and senescing more rapidly in response to increased temperatures. C4 grasslands green-up later (October) and were less responsive to rainfall pulses. Biomass validation suggests that standing litter (both senescent vegetation and brown flower stems) confound remotely-sensed phenology profiles based on spectral indices by masking sensor- target -light dynamics. We also found non-desirable species (weeds) to significantly contribute to overall greenness, even in native grasslands.

We show that phenology-based methods are a useful addition as landscape-scale grassland monitoring and management tools. Potential applications in temperate Australia include the identification of remnant high-quality native grassland, tracking weed invasions and community changes over time, and determining productivity responses to different climatic conditions. Overall, phenocam data demonstrated several advantages over satellite-based phenology, despite certain challenges.

Keywords: grasslands, phenocams, C3/C4, remote sensing, ecology

VIIRS land surface phenology: from climate date record to real time monitoring

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Land surface phenology has been widely measured from annual time series of satellite observations at local and global scales. Particularly, land surface phenology detected from the Advanced Very High Resolution Radiometer (AVHRR) and the Moderate Resolution Imaging Spectroradiometer (MODIS) during last three decades characterizes the interannual variation in magnitude and timing of ecosystems globally and their responses to a changing and variable climate. Moving forward, the Visible Infrared Imaging Radiometer Suite (VIIRS) that was launched in October 2011 extends and improves upon the measurements initiated by AVHRR and MODIS. It provides a basis for continuing the development of global land surface phenology record after MODIS. While long-term phenological data inform investigations of land surface dynamics and climate change, the VIIRS data also provide the capability to monitor phenological development in real time. This capability is particularly important for assisting agriculture, natural resource management, and land surface modeling for numerical weather prediction systems. Here we introduce preliminary results of two phenology products from VIIRS data. First, an annual global phenology climate data record at a spatial resolution of 500 m is generated using daily two-band Enhanced Vegetation Index (EVI2) during a two-year period (the preceding half year, the given year, and the succeeding half year). This sequence enables us to trace complete growing seasons, particularly for the regions where they may span two calendar years. The temporal trajectory is reconstructed using a hybrid piecewise logistic model, after the effects of cloud cover and snow contamination have been explicitly removed. Second, we have established a system to monitor in real time and forecast in the short term phenological development based on daily VIIRS observations available with a one-day latency. The system integrates a climatological land surface phenology from long-term MODIS data and available VIIRS observations to simulate a set of potential temporal trajectories of greenness development at a given time and pixel. These trajectories are apply to identify spring green leaf development and autumn color foliage status in real time and to predict the occurrence of future phenological events. This system currently monitors vegetation development across the North America every three days and makes prediction to 10 days ahead.

Keywords: land surface phenology, daily VIIRS observations, long-term phenology, real time monitoring

4.2 Poster Presentations

Impacts of the EO-based representation of the vegetation dynamics on continuous basin scale hydrologic models

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This poster presents a sensitivity analysis on the impact of different modelling of vegetation dynamics in a continuous distributed hydrological model, the Continuum model SILVESTRO et al. (2013). It is shown that a more detailed representation of the seasonal and interannual dynamics of the evapotranspiration (ET), linked to the phenological cycle forced by EO-derived vegetation indices, can have a significant impact on the spatial and temporal redistribution of water volumes among the different terms of the mass water balance. This analysis was conducted to estimate whether substituting the classical static representation of vegetation with a spatial and temporal distribution pattern of canopy conductance can improve the accuracy in the estimation of runoff and infiltration throughout the year. Specifically temporal dynamics of ET is linked to the vegetation phenological state through the canopy conductance, computed using the Light Use Efficiency approach (MONTEITH, 1977), for model photosynthesis rate, coupled with Leuning empirical approach (LEUNING, 1995), for model stomatal conductance. In this first analysis, the temporal dynamics and the spatial variability of canopy conductance are introduced using satellite estimates of the Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), well performing index for detecting vegetation changes in semiarid environments. The 8-days average FAPAR, derived directly from the MODIS product MOD15A2 with a spatial resolution of 1 km^2, was inserted in the LUE formulation to compute the photosynthesis rate. The case study area is the Orba river, a small watershed (drainage area of 776 km^2) in Northwestern Italy, with a presence of typical Mediterranean natural vegetation (both tall and short) and agricultural fields. The partition of the water fluxes (ET, runoff and infiltration) throughout a year mainly shows that ET flux rate, averaged over the basin scale, is significantly decreased with dynamic vegetation representation during late spring-summer period, when the deficit of soil moisture affects the plant transpiration. This behaviour leads to a lower cumulative ET for the LUE-Leuning approach compared to a static representation of vegetation conductance, currently employed in several hydrological models.

Different behaviour is also found across vegetation types; non irrigated crops and short vegetation are more subjected to drought (e.g. short roots) compared to forests since a marked reduction in ET fluxes in late summer is noticed. Conversely, agricultural fields start to transpire at a maximum level earlier in spring while Broadleaved and Coniferous need a longer warm up period. These spatial variations are only detectable by including representation of the vegetation dynamics.

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Keywords: modelling, FAPAR, Mediterranean basin, light use efficiency

Forest phenology monitoring with digital cameras on board an unmanned aerial vehicle

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The monitoring of forest phenology in a cost-effective manner at a fine spatial scale over relatively larger areas remains a significant challenge. To address this issue, unmanned aerial vehicles (UAVs) appear as a potential new option for forest phenology monitoring. The aim of this research is to develop an approach which employs optical cameras attached on a fixed-wing UAV to monitor forest phenology during the 2015 growing season, in order to detect the seasonal changes of the canopy and to allow scaling-up of field observations to make comparisons with Moderate Resolution Imagine Spectroradiometer (MODIS) optical satellite data. The effects of heterogeneity (different trees species and agricultural land covers) on phenology studies using satellite images can then be investigated. Vegetation indices (VI) are calculated from calibrated near-infrared and visible wavelength UAV imagery generating a VI time series, with values fitted by logistic models. Then, a selected model will estimate the day of year corresponding to beginning and end of growing season (phenological metrics). The same phenological metrics will be estimated from MODIS imagery. UAV imagery (6 cm spatial resolution) is being acquired at weekly intervals over the spring 2015 growing season over mixed deciduous and conifer woodland at Hanging Leaves Wood, Morpeth, UK. Such spatial resolution has the potential to separate out and monitor phenology of individual trees but over significant areas compared to near-surface remote sensing sensors such as tower-based cameras. Concomitantly, visual assessment of trees phenology phases is being carried out at weekly intervals and also digital images (consumer-grade visible light cameras) of understory vegetation are being taken at the same frequency. This paper will present the first results of analysis of this extensive campaign data, to address the key research questions: Can low-cost cameras attached on an UAV acquire time series imagery suitable for forest phenology monitoring? Do UAVs provide a basis for validating satellite-derived land surface phenology products? Future work will deal with methods to scale-up information from ground to UAV and to satellite level taking into account the influence of different land covers and understory vegetation.

Keywords: visible-light camera, near infrared camera, high resolution imagery, mixed forest, phenometrics, validation

Linking non-destructive measurements to investigate temporal niche complementarity in a grassland biodiversity experiment

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The relationships between biodiversity (often defined as plant species richness), plant productivity and ecosystem functioning have emerged as a central issue in ecological and environmental sciences during the last two decades TILMAN et al. (2001). Within this context, the concept of niche complementarity is expected to play a key role for successful plant species coexistence. Niche complementarity refers to a mechanism by which plant species in high-diverse communities specialize in taking up resources from different places, during different times or in different forms, and thus jointly exploit the available resources more efficiently than in a monoculture or in low-diversity mixtures, resulting in higher productivity (biomass production), higher resilience against disturbances and higher ecosystem functioning in general LOREAU et al. (2002). Temporal niche complementarity, arising from phenological diversity, is expected to extend the growing season because it might distribute peak phases of vegetative development, and therefore resource requirements, more evenly throughout the season STEVENS and CARSONS (2001). Still, temporal niche complementarity has rarely been studied in a biodiversity-ecosystem functioning context.

Within the framework of the Jena Grassland Biodiversity Experiment in Germany, we continuously monitored phenological adaptions of 13 temperate grassland species distributed over 92 experimental plots characterized by a diversity gradient ranging from monocultures to eight-species mixtures for two consecutive years. We hypothesize that offsets in key phenophases allow high-diverse communities to exploit resources over an extended period of time (`time-filling`) and are therefore of significant importance for ecosystem functioning (e.g. transpiration, water-use-efficiency). By combining advanced non-destructive imaging techniques, including high-definition timelapse photography, visible/near infrared imaging spectroscopy, thermal infrared imaging and laser scanning, we were able to track inter- and intra-seasonal changes in above-ground plant phenology, plant growth and resource acquisition along a biodiversity gradient in high-temporal and -spatial resolutions for the first time in a grassland experiment. Ultimately, this will enable us to improve phenology models of ecosystem functioning in diverse grassland communities.

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Keywords: temporal niche complementarity, biodiversity, ecosystem functioning, time-lapse photography, imaging spectroscopy, thermal imaging

Interactions of seasonal sun angle and tropical savanna phenology observed and modelled using MODIS

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Seasonal variations in solar zenith angle (SZA) alter the time series of surface reflectances, but this effect on remote sensing phenology has not been adequately evaluated. The objective of this study is to better understand SZA variations on vegetation index responses and improve upon the interpretation of remote sensing observed vegetation dynamics across space and time. The sensitivity of two widely used vegetation indices (VIs), normalised difference vegetation index (NDVI) and enhanced vegetation index (EVI), to SZA were investigated at four northern Australian savanna sites. The sites ranged from mesic to xeric savannas over a latitudinal distance of ~1100 km (12° S - 22° S), and we analysed these under seasonal-varying local solar noon SZA and two fixed SZA of 30° and 45°. Surface reflectance time series data acquired at different SZA configurations, were normalised to fix sun-angle conditions using Bidirectional Reflectance Distribution Function (BRDF) parameters provided by the MODerate Resolution Imaging Spectroradiometer (MODIS) MCD43A1 product. The impacts of sun-angle influences on four phenological metrics, including the start, peak, end and length of greening season were evaluated.

Our results showed both NDVI and EVI to be very sensitive to SZA, with NDVI more sensitive to SZA compared to EVI. The different sun-angle configurations resulted in considerable differences in the shape and magnitude of phenological profiles. Cross-site analysis showed that the sensitivity of NDVI and EVI to SZA not only varied spatially across different savanna vegetation classes, but also varied temporally across different phenophases. The sensitivity of VIs to SZA was larger in the southern semi-arid Acacia woodland sites, and lower at the northern mesic Eucalyptus woodland sites. The sensitivity of VIs to SZA was also generally greater during the dry season than in the wet season. Thus, sun-induced influences became greater with sparser vegetation conditions, both spatially and seasonally. The sun-angle effect on NDVI and EVI time series resulted in considerable differences in the VI-derived phenological metrics. Comparisons of phenological metrics between derived with SZA normalised to 30° and SZA 45°, revealed significant differences and highlights the importance of the selection of SZA to normalise the sun-angle effect. Across our four latitudinal sites, the sun-angle effect caused 38 and 26 day differences in the length of greening season (LGS) derived from NDVI and EVI, respectively, with varied SZA at local solar noon as compared to LGS derived from NDVI or EVI with fixed SZA at 30°. As remote sensing of phenology is usually applied at regional and even global scales, with considerable variations in SZA, in both spatial and temporal domains, our results thus demonstrate the need and importance to correct the sun-angle effects on spectral vegetation indices prior to their use to derive phenological metrics.

Keywords: remote sensing, vegetation dynamics, BRDF, solar zenith angle, land surface phenology

Time-series of Landsat 8 data in mapping the onset of the growing season in Adventdalen valley, on the Arctic Archipelago Svalbard

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High Arctic areas are characterized by a short and intense growing season, and the region has among the highest excepted future temperature increase. The study area of Adventdalen valley is located close to the administration center Longyearbyen, at 78° 13` N, 15° 40` E on the Arctic Archipelago of Svalbard.

The main aim of this study is to use time-series of Landsat 8 data from 2014 in mapping the growing season in Adventdalen valley and the surroundings (about 20x30 km), interpreted from field observations.

Field observations of phenology have been established at eight sites in Adventdalen. The observations sites are designed to capture the spatial and temporal variation in onset and end of the growing season along a 13 km long transect. The observations are carried out weekly at eight sites, five on the valley floor and three on a mountain plateau. All sites are easily accessible by car. The observation sites on the valley floor represent large homogeneous areas of the main vegetation types, both in areas with early (ridges) and late (snow-beds) onset of the growing season. The onset of the growing season is defined as flowering catkins of Arctic Willow (*Salix polaris*), and the end of the season is defined by 50 % yellowing leaves of Arctic Willow. These definitions represent well the general greening and yellowing of the vegetation. In addition, seven automatic cameras are used for observation on graminids, not easily observed on by non-botanist, and to achieve better time resolution.

Due to the location close to the North Pole, all the paths 22-29 and 211-217, within row 3-4 and 240-241, on Landsat 8 data cover the study areas. Hence, data are obtained almost daily. However, data from the different paths are recorded at different times of the day and make the processing more complicated. Furthermore, the images have high cloud cover, often over snow and ice surfaces, which makes survey more of a challenge. On 82 images available from late May to September 2014, the mean of cloud cover is 53 %, 11 have covering more than of 80 %, 34 less than 50 % and only 6 lower than 15 %. In addition to the band 9 for the detection of cirrus clouds, and Quality Assessment (QA) values, own algorithms are used. The objective is to produce a daily cloud-free and calibrated time series of synthetic images that are calculated using a variety of techniques, and then to map both the onset and end of the growing season, interpreted from the field data.

Keywords: arctic, Svalbard, growing season, phenology, time-series, Landsat 8

5 Phenological modelling

5.1 Oral Presentations

Using phenology models to generate transnational baselines for Environmental Assessment Indicators

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Phenology models provide a great opportunity to create transnationally relevant baselines for phenology based Environmental Assessment Indicators. Properly used, baselines derived from phenology models according to an international standard would allow meaningful cross-border comparisons of quantitative estimates of phenological change.

Phenological change is the most obvious ecological effect of climate change. It affects fundamental ecosystem properties, processes and services. Quantitative estimates of phenological change are increasingly being used in environmental, ecological and climate change assessments, both at the international (e.g. IPCC WG2) and national levels (e.g. NCA, USA). Still, there is no way to express local-national estimates of phenological change in a way that make comparisons between countries meaningful: What does a 26-day shift to earlier *Populus tremuloides* blooming over the past century mean compared to 13 days earlier *Betula pendula* leaf-out in Finland between 1846 and 2005?

Species-specific and local estimates of phenological change may, of course, be interesting and relevant from many perspectives, but we believe there is a lot to gain from developing a transnationally meaningful baseline.

As a standardized baseline, we propose that we use phenology data (e.g. for green up) for the climatological standard periods (e.g. 1961-90). In the cases when national databases are not available for this particular period, phenology models that have been calibrated regionally from other data sources are used to estimate the phenology data for the standard period.

We propose that the prioritized standardized baseline relates to the biological growing season, so that phenological change can be expressed in relation to the length of the growing seasons. For example, *Betula pendula* leaf-out in the Swedish province of Uppland has advanced 5 % in relation to the length of the 1961-1990 growing season, which corresponds to 7 days earlier leaf-out.

Prioritizing the biological growing season, we believe is motivated by the fact that the growing season is highly relevant for all types of ecosystems as well as for carbon budget modelling. It follows that international comparisons will be most meaningful when they are based on species that are (nationally) dominant from a carbon exchange perspective. Still, transnational comparisons of other species and phase combinations can be done in the same way.

Keywords: modelling, environmental assessment indicators, networks, phenological trends, carbon modelling

Insight in the behaviour of phenological models under changed climate conditions

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In this study 6 phenological models, 2 simple forcing (F)-models and 1 chilling/forcing (CF)-model, each with and without daylength (DL)-term in the forcing approach, were optimised (2001-2010) and validated (2011-2015) on blossoming data of an experimental sweet cherry orchard at Berlin-Dahlem (cultivar 'Summit'). Parallel in 3 seasons (2011/12 - 2013/14) climate chamber experiments and metabolomic studies were done (GÖTZ et al. 2014), to determine the date of dormancy release and the chilling requirement (C^*) of 'Summit'. Thus, it was possible to validate the optimised C^* in both CF-models, which distinctly differed. Additionally, in the season 2013/14 we carried out an *in situ* climate change experiment (CCE) on 3 trees in the sweet cherry orchard, in order to validate the optimised phenological models for warmer climate conditions. Compared to the other 'Summit' trees in the orchard, these three trees begun to bloom one month earlier, which could be a scenario for much warmer climate conditions in Berlin-Dahlem. On the basis of our experimental work and targeted metabolomic studies we were able to show that the estimated chilling requirement was only realistic in the CF-model with DL-term. This physiologically proofed model had the best accuracy in our CCE (model error of only 1 day). Similarly good results have also been found for the pure F-models with DL-term, because of the relatively low chilling requirement of 'Summit'. However, all models without DL-term clearly failed and the predictive error of these models was more than 20 days. This shortcoming of phenological models is frequently observed for changed climate conditions and rightly criticised RICHARDSON et al. (2012).

From this study we can conclude that the use of the DL-term in CF-models allows a more precise estimation of C^*, mainly for cultivars with a relatively low chilling requirement, were the end of endodormancy and the beginning of ontogenetic development are separated by a long period of ecodormancy. Beside numerical and experimental approaches in phenological modelling, metabolomic studies offer a deeper insight into the initiation, maintenance and release of dormancy. We believe that in the future this approach can offer new ways in phenological modelling.

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RICHARDSON, A.D. et al. 2012: Terrestrial biosphere models need better representation of vegetation phenology: Results from the North American Carbon Program Site Synthesis, *Global Change Biol*. **18(2)**, 566-584.

Keywords: phenological models, model validation, sweet cherry, metobolomic studies, climate change experiment

Assessing prediction quality of several phenological process based models using various types of databases: A case study using *Vitis vinifera* data

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Modelling phenology has become a major issue in the context of impact studies on plants and crops. Accurate simulations are essential to correctly predict the timing of development in the future. In recent years several models have been developed and tested to simulate phenology for various species. Furthermore, the development of databases and networks of observations have been used to test models under a wide range of climate conditions.

In this study we studied the impact of various databases representing different temporal and spatial resolution on the accuracy of simulation of flowering and veraison for the grapevine (*Vitis vinifera* L.). We compared the results of calibration and cross-validation of several classic phenological models (Growing Degrees Days, Chuine, Sigmoid, Wang and Engel's model and Richardson) for two different varieties (Cabernet Franc and Merlot), at two different locations (Middle Loire Valley and Bordeaux vineyards). Three datasets are used: 1) Dataset1: a dataset from a network of temperature sensors at a fine scale (a few kilometres) where phenology was also observed at each of the locations of the temperature sensors (11 to 60 different points) at very; 2) Dataset2: an historical dataset (20 - 30 years) from a plot located in the same area as the network; and 3) Dataset3: a dataset obtained from other locations in France (Phenoclim database).

Initial results showed that the database used to calibrate different models could influence model parameters and the best model choice. The objective of this work is to help to improve the quantification of uncertainties of each model and to identify which type of database is best suited: to simulate spatial distribution of phenology in a specific area (i.e. vineyard); to predict phenological stages in an operational mode; and to quantify the impact of climate change on phenology.

Keywords: modelling, databases, grapevine

New insights into sweet cherry's dormancy

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Studies concerning chilling requirements of sweet cherry are of great importance to improve phenological models on the base of physiological processes in plants. Mainly the release of dormancy is still "a black box" in phenological modelling. From an economical point of view, sweet cherries are one of the most interesting fruits. However, the information about the relationship between dormancy, growth and development of flower buds under climatic conditions of the North Eastern Germany are scarce. We investigated changes in sweet cherry buds of 'Summit' with respect to plant hormone gibberellins (GAs), which effects particularly the induction of flowering, stimulation of stem elongation through enhanced cell division and growth. To our knowledge, presented results are the first report about sweet cherry dormancy under natural conditions in fruit tree orchards with a high temporal resolution between the dormant stage (October) and flower development (April). Cherry samples were analysed for GA content using highly effective liquid chromatography in combination with very sensitive mass spectrometric detection URBANOVÁ et al. (2013). Eighteen GAs were verifiably detected in the buds compared to 23 GAs found in *Arabidopsis thaliana*, 14 in oilseed rape (*Brassica napus*) and 12 in rice (*Oryza sativa*). We found 8, 7, 2 GAs and 1 GA in buds with a content (pg/mg DW) in a single digit, double digit, and partly three-digit and four-digit range, respectively. Between leaf fall (8 November) and break of dormancy (1 December) in 2011, the content of 10 GAs decreased, the levels of 5 GAs were observed unchanged and 3 GAs showed the increase in their levels. Further, it was observed that the biosynthesis of 13-hydroxylated GAs is predominant in cherry flower tissue compared to that of 13-non-hydroxylated one. Among bioactive forms of GAs (GA_1, GA_3, GA_4, GA_5, GA_6 and GA_7) the content of GA_1 and GA_3 decreased between leaf fall and break of dormancy (158 vs. 41 pg/mg DW and 595 vs. 11 pg/mg DW, resp.). It was the most probably due to reduced GA3-oxidase activity (GA3ox) and/or metabolic utilization. In this context, the activity of GA2-oxidase (GA2ox) responsible for regulation of the bioactive GAs levels through their deactivation, between leaf fall and break of dormancy was also reduced in the same manner (the level of GA_8 as a GA2ox product of GA_1 decreased from 7 to 3 pg/mg DW). Interestingly, the highest levels were found for GA_{51} (ca. 600 pg/mg DW), the member of 13-non-hydroxylated GAs being GA2ox product of GA_9 - precursor of bioactive GA_4, which content as well as content of GA_9 was found to be unchanged in the study period. At the beginning of ontogenetic development, GA_3 content is rising to 69 pg/mg DW (from 11 at break of dormancy) and remains almost unchanged (57 pg/mg DW) until tight cluster. The variances of the GAs are presented with respect to the phenological stages until first bloom. This approach should improve understanding the dormant stage and ontogenetic development much better than we do at present.

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Keywords: dormancy, sweet cherry, buds, phytohormones

A biology driven model for daily pollen allergy risk

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Pollen is one of the most important causes of allergic responses in respiratory tract. As the individual sanitation improves, allergic risk is increasing and is expected to continue in the future due to the climate change. The pollen concentration in the air is highly influenced by the weather conditions. Regression analysis and modeling between the airborne concentration and weather conditions were utilized to analyze and forecast the future pollen conditions. Traditionally, daily pollen concentration was estimated by regression models that describe the relationship between pollen concentration and weather conditions with some limitations in space and time.

To overcome the limit, an integrated modeling strategy scheme was developed. The new scheme represents the entire region based on the analysis of biological and physical processes in pollen production, release, dispersal, and removal. The maximum potential of airborne pollen is determined by fitting the daily observed pollen counts to the Weibull probability distribution function (PDF) for each weather element. Then daily pollen concentration is estimated by multiple regression models of the daily Weibull PDF values.

The new models estimated daily pollen risk better than the original statistical models because of the newly integrated biological response curves. Although the new models over-estimated seasonal mean concentration, they did not simulate all of the peak concentrations. It would be resolved by adding external variables such as allergenic plants area and previous year's weather conditions, which determine the amount and maturity of the pollen species.

Keywords: airborne pollen, pollen observation, PDF, pollen allergy risk forecasting

Separating plasticity from microevolution in frogs and birds

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Phenology varies among populations and over time largely due to the effects of phenotypic plasticity and microevolution and estimating the magnitude of each can help us predict the fates of populations under climate change CHEVIN et al. (2010); PHILLIMORE et al. (2010). However, the principal methods for distinguishing the contributions of plasticity and microevolution suffer from drawbacks in their application to vertebrates. For instance, in a geographic context reciprocal transplant experiments are commonly used, but logistical challenges mean that we know little about the local adaptation of groups other than plants. Equally, while there exist many long-term studies of wild vertebrates, robust evidence for microevolution of phenology in situ is absent MERILÄ (2012). As a consequence we have a poor evidence base on which to predict how important microevolution of phenology will be in determining the fate of vertebrate taxa but see GIENAPP et al. (2013); VEDDER and SHELDON (2013).

We will outline a method for separating the contributions of temperature-mediate local adaptation and plasticity from spatiotemporal phenological data collected by citizen scientists. We will first illustrate by application to the first spawning dates of UK common frogs PHILLIMORE et al. (2010). We will then apply an extension of this approach to tens of thousands of first egg dates of blue tits, great tits and pied flycatchers from the BTO nest record scheme. We will show how this method enables us to estimate parameters that have proven extremely challenging to quantify using alternative methods, namely the magnitude of temporal microevolution and the relationship between temperature and the optimum phenology. We suggest that large-scale spatiotemporal phenological have great untapped potential for estimating key evolutionary parameters.

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Keywords: plasticity, local adaptation, microevolution, cues

Budburst modelling in short rotation coppice willows, does modelling chilling matter?

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When to start growth is a key element for plant development. An early budburst can prolong the growing period but also increase the risk of (late) frost damage. Selecting genotypes with an early budburst could contribute to improve short rotation coppice (SRC) willow yield. However, the management of the plot, mainly coppicing, can affect budburst and complicates its modelling. According to SAVAGE and CAVENDER-BARES (2013) willow dormancy is divided in two parts: During endo-dormancy chilling units are accumulated and the tree cannot grow in spite of favourable conditions, followed by eco-dormancy characterised by the accumulation of forcing units. These processes are mainly driven by air temperature and most budburst models are only temperature dependant. Our aim was to investigate whether modelling the chilling part matters for willows and how one can account for the coppicing effect. Material & Methods: Identical experiments were carried out in the south-east of England (Rothamsted Research, RRES) and Wales (Institute of Biological Environmental and Rural Sciences, IBERS) using four SRC willow genotypes, planted in 2009. Plants were coppiced in January 2010, 2012 and 2014. Bud development was scored annually for six (RRES) and three years (IBERS) between mid-February and the end of March using a visual scale. The day of budburst was defined as the day when more than 50 % of the trees reached a score of 3 ("green foliage shows"). Different budburst models were implemented and calibrated with data collected at RRES via a Bayesian procedure FU et al. (2012) and validated with data from IBERS.

Results: Our analysis showed a better budburst prediction when models included the chilling process. However, this is at least partly due to a better budburst prediction during coppiced years, when budburst was delayed. Using models with forcing only, the date of initializing forcing has to be placed after the date of coppicing to dismiss the bias. When a coefficient of extinction is introduced to modify the accumulation of forcing units at coppicing, the best predictions are when the unit accumulation is reinitialized to 0. Comparing our genotype prediction, the worst predictions are usually observed for earlier genotypes.

These results show the complexity to deal with pioneer species which tend to have early budburst dates (between mid-February and mid-March), especially when affected by coppice management. Data are needed to compare budburst date for tree coppiced and non-coppiced in the same year. Metabolite, enzyme, and non-structural carbohydrate profiles should underpin our understanding of the switch between endo- and eco-dormancy.

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Keywords: bayesian calibration, coppicing effect, dormancy, salix species

Using satellite derived phenology to model leaf unfolding and autumnal colouring of PEP725 phenological records: A species controlled multivariate approach

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Vegetation phenological studies are usually carried out from two different perspectives: ground observed phenology (GP) and satellite-based phenology, commonly termed land surface phenology (LSP). Both observation methods should be complementary, and, notwithstanding the great challenges in comparing satellite sensor and ground observation, the benefits are twofold. First, GP records are necessary in some situations for supporting (or interpreting) satellite estimates and, second, LSP data are necessary in some situations to up-scale GP, BADECK et al. (2004); MENZEL (2002); WHITE et al. (2009).

The establishment of a spatio-temporal relationship between LSP and GP has been the subject of some studies without very promising results. This can be linked to many aspects/uncertainties of both satellite and ground observations: i) insufficient observations or spatial coverage; ii) the species monitored may or may not represent LSP (points vs. pixels); that is, a single point observation may not be representative of the overall pixel characteristics; iii) unknown measurement accuracy and errors in data entry; iv) different phenological phenomena measured; v) different temporal resolutions between ground observations and LSP (day vs. composite period). Additionally, the spatial relationship between LSP and GP might be non-linear. Therefore, the performance of linear regressors can be deficient. Thus, a strong spatial correspondence between LSP and GP is unlikely, especially when the species composition in the landscape is unknown.

A new methodology to relate LSP and GP is proposed through the application of Random Forest, a non-parametric method which allows for non-linear relationships between phenology variables and for the inclusion in the modelling process of categorical predictors - plant species in our case. The proposed method can recognise complex patterns between LSP and the phenology of multiple specific plant species, integrating them into a unique overall model, rather than generating multiple models for every species. Additionally it is data-driven, which means that there is no need to incorporate a previous knowledge about the species composition in the landscape. Our approach produced a strong spatio-temporal association of leaf unfolding (GP) and onset on greenness (LSP) and autumnal colouring (GP) and end of senescence (LSP) (pseudo R-squared equal to 0.70 and 0.71, respectively) and allowed for the prediction of GP with a root mean square error of 6 days (over 365 days). The analysis revealed a non-linear spatio-temporal relationship between LSP and GP and a strong dependence with plant species.

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Keywords: modelling, PEP725, land surface phenology, multivariate, non-parametric, random forest

Phenological modelling using volunteered observations and machine learning methods

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Phenological models predict the timing of recurrent biological events like the appearance of the first leaf in deciduous plant species. Since in many ecosystems these timings are driven by environmental conditions, phenology has become a popular indicator for climate change. In addition, having reliable and robust phenological models is important for several applications like nature conservation, ecology, agriculture and even public health (e.g. hay fever).

In this study we use volunteered phenological observations curated and/or collected by the USA National Phenological Network to develop several machine learning-based phenological models. In particular we use long term records of first leaf and first bloom for lilac and honeysuckle species. The required explanatory variables for these models (i.e. the regressors) were extracted from DAYMET, a high spatial resolution (1 km^2) daily gridded dataset of weather variables for the period 1980 to the present.

Different non-linear machine learning methods were tested, from classical ones based on artificial neural networks or decision trees to more recent ones like Gaussian process or Kernel-regression methods. For this we used a convenient regression toolbox LÁZARO-GREDILLA et al. (2013). All models were intercompared and evaluated according to several quantitative measures of accuracy (systematic and unsystematic RMSE and MAE), bias (ME) and goodness-of-fit (with the Pearson's correlation coefficient) and benchmarked against standard phenological models (e.g. based on linear regression).

Results indicate that non-linear methods are able to accurately capture the dynamics present in the volunteered phenological observations. Further work includes testing the top models using other plant species and the identification of robust (different environments) and meaningful (biologically) regressors as well as on the application of the top models at a continental scale and for the complete period covered by the DAYMET dataset.

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Keywords: modelling, machine learning, phenological volunteered observations

5.2 Poster Presentations

Forecasting the wild daffodil flowering for touristic purposes

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Donnerwetter.de GmbH

We are able to create valuable forecasts with the help of our phenological garden. For example, individual vegetation phases throughout the year can be calculated in Germany up to 2 months in advance.
Not far from our weather-park and phenological garden there is a rare natural spectacle to admire: Millions and millions of wild daffodils bloom here on the meadows of an integral nature reserve.

On the basis of the daffodils bloom, we show the application of our computer model. The daffodils bloom starts after a mild winter and spring course already in early March and ends during April. After a cold and snowy winter flowering begins in mid to late April and ends until in the middle of May.

With our special computer model we can create a forecast of the daffodils bloom already from mid/late January. The forecasts are then published on the Internet (www.weisserstein.info). The forecasts are also used to schedule festivities around the natural event.

Keywords: daffodils, bloom, modelling, flowering model, planning touristic festivities

6 Challenges, new approaches and progress in phenology

6.1 Oral Presentations

Phenology and Conservation

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Phenology has achieved a prominent position in the current scenario of global-change research owing to its capability to monitor and predict the timing of recurrent life cycle events IPCC (2014); MENZEL et al. (2006); SCHWARTZ (2013). However, the implications of phenology to conservation and management of resources remain underexplored. These include the synchronicity between flowering and pollinators and fruiting and seed disperser activity, the connectivity and gene flow through pollen and seeds across fragmented landscapes, and the forecasting of climate-change effects on species distribution and ecosystem processes. Here, we investigate how phenology, a multidisciplinary science encompassing biometeorology, ecology, and evolutionary biology WOLKOVICH and ETTINGER (2014), can be a key component for conservation biology. We focus on global change shifts in plant phenology, their consequences on species-rich plant-animal interactions in the tropics, and how conservation efforts can be enhanced in relation to plant resource organization. We identify the importance of ecological networks in understanding the effects of temporal changes and mismatches on the maintenance and conservation of mutualistic interactions. Moreover, we examine how phenology can contribute to evaluate and mitigate land-use change on ecological interactions, combined with other natural and anthropogenic disturbances such as fire. We also explore the problem of exotic and invasive species and the key management role of phenology. This is the first appraisal explicitly addressing how conservation biology can be informed by phenology studies.

Finally, we propose a set of measures to boost the contribution of phenology to conservation science. We indicate the value of monitoring, including the use of satellites and digital cameras, the key role of historical information (e.g. from herbaria, dendrochronology) to produce long-term time series for tropical systems. We advocate incorporating phenology into predictive models, integrating the evolutionary history of species, to identify more resilient and sensitive groups of species to future climate scenarios and understand how phenological mismatches can affect community dynamics over time, ecosystem services, and ecological restoration. The last approach concerns the relevance of phenology as a conservation education tool for citizen science.

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Keywords: conservation, preservation, phenology, resource management

Embedded plant phenology - Collecting and comparing phenological data with a national observation network and citizen science communities

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In spring 2015, the Swiss citizen science website OpenNature (www.OpenNature.ch) was launched. The website aims at raising awareness for science-based climate change impact knowledge through collecting scientifically sound phenology and seasonality observations and understanding environmental change. The project focuses on five thematic groups including plants, animals, mushrooms, landscapes, and climate extremes. Plant phenological data are collected on the same platform together with other seasonality indicators. This opens the opportunity for users and contributors to create a cross-topical diary of the seasons and a more complete documentation of a selected area. For example, snow cover duration and plant development can now be documented on a single platform optionally adding e.g. information on cloud cover duration. OpenNature.ch also includes a news section presenting new scientific findings and shares the results on social media network such as Facebook (www.facebook.com/OpenNature.ch).

OpenNature is one out of three initiatives to document plant phenology in Switzerland. Here we present the complementary approaches for collecting plant phenological observations. We show comparisons of data from three different projects that all build on the same protocols but address different audiences and use different webtools. Data are taken from the following networks: 1) The Swiss Phenological Network by MeteoSwiss collects observations since 1951. The national network provides historical network data from the climatological reference period 1981-2010. These data are provided by experienced long-term observers that are assigned to an observation station. 2) PhaenoNet by the GLOBE programme (phaeno.ethz.ch/globe, Global Learning and Observations to Benefit the Environment, www.globe-swiss.ch) collects plant phenological observations since 2011. This project focuses on pupils and students from first to twelfth grade, but is also open for citizen scientists. Observations are collected for single plant individuals at pre-defined sites with regular visits. 3) Plant phenological observations from OpenNature.ch are collected in random way where revisiting sites are optional. Observers are encouraged to revisit the same location.

This contribution assesses strengths and weaknesses of the collaborating projects. Future development will focus on sharing data with partner projects, on the development of a more flexible visualisation of results and implementing continued news feed with contributions from scientists. Financed by the Swiss National Science Foundation (SNF) science communication program AGORA 2012-2015, OpenNature.ch builds on existing observations programs and partnerships in Switzerland under the auspices of the Swiss Academy of Natural Sciences SCNAT.

Keywords: phenological network, citizen science, climate change impacts

Evolutionary responses in the phenology of *Myrtaceae* in the Atlantic forest

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Estimating phylogenetic signal (PS) in the phenological traits has direct conservation importance because clades with conservative phenology can demonstrate phenological sensitivity to global warming WILLIS et al. (2008) and can be lost affecting the persistence of communities. PS in plant phenology of an important Neotropical plant family was investigated. PVR (Phylogenetic eigenVector Regression) and PSR curves (Phylogenetic Signal Representation) DINIZ-FILHO and BINI et al. (2012); DINIZ-FILHO and RANGEL et al. (2012) were applied and results were compared with results obtained from K-statistic BLOMBERG et al. (2003). The PSR approach combines the sequential addition of phylogenetic vectors that represent orthogonal axes that explain shared evolutionary history among species and enables to identify whether phenological traits evolved slower or faster than patterns expected by distinct evolutionary models (e.g. Brownian motion, neutral model). A robust phenological dataset of flowering and fruiting times in *Myrtaceae* was assembled based on observations over 30-70 months of 57 species for three Atlantic forests in southeastern Brazil (PEIC: Parque Estadual da Ilha do Cardoso; PEI: Parque Estadual de Intervales; and PESM: Parque Estadual da Serra do Mar). PVR and PSR allowed identification of complex evolutionary patterns that otherwise would be hidden in global analyses such as the K-statistic. We found species of a clade corresponding to the now synonymized genus Gomidesia exhibited conservative flowering times at PEIC probably due to recent speciation rates associated with evolution in the warm and hot Atlantic forest. This clade has a narrower distribution than other *Myrtaceae* clades and is thought to be younger.

Other interesting result, PSR showed fruiting times at PEI to have diverged faster than expected by Brownian motion for the clades in the base of *Myrteae* phylogenetic tree. This pattern was explained by embryo shape, an important taxonomic character for this family. Species with myrtoid and eugenioid embryo shapes fruited first, in the early summer; these plants have hard and/or bony seed coats or protective, fused cotyledons. Species with myrcioid embryos on the other hand dispersed their seeds in the period with longest day-lengths and fruited in the peak of summer; these plants have well developed and usually foliaceous cotyledons. This latter pattern may indicate an advantageous strategy for these species can reach higher photosynthetic rates to maxime growth and development in this period. A large percentage of unexplained variance in fruiting time still remains to be understood. Investigation of the relationships between phenophases is crucial to understand complex phenological patterns in highly diverse tropical ecosystem.

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Keywords: flowering, fruiting, *Myrtaceae*, phylogenetic signal, phylogenetic signal, representation curves

Climate change and coexistence: The role of temporal variability in structuring future communities

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Predicting community shifts with climate change requires fundamental appreciation of the mechanisms that govern how communities assemble. Much work to date has focused on how warmer temperatures may affect individual species via their physiology, generally predicting advances in most species leafing and flowering with climate change. Yet efforts to predict cascading effects of climate change and phenological shifts on species and communities are much rarer. There have been no efforts, to our knowledge, to predict shifts based on coexistence theory. Here we extend a major model of coexistence - the storage effect which is a stochastic community assembly model - to predict how communities will respond to climate change. Additionally we examine how the presence of species that can phenologically-track the start of season impacts coexistence and community assembly.

We adapt the storage effect model to examine how a nonstationary environment where the start of season shifts earlier over time affects coexistence and we examine how outcomes vary with the ability of species to phenologically track the timing of major climate events. Our results suggest coexistence and the mechanisms underlying it may change with climate change. Additionally, the findings suggest that trade-offs established under a stationary climate that allow a diversity of phenological tracking strategies across species in a community may not hold under non-stationary environments to maintain the same diversity of species. Instead, nonstationary environments may lead to abundance increases in species that strongly track climate and thus may explain recent findings linking phenological tracking to performance.

Keywords: storage effect, phenological tracking, nonstationarity, coexistence, invaders, community assembly

Perception of photoperiod in individual buds of mature trees regulates leaf-out

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Experimental data on the perception of daylength and temperature in leaf-less (dormant) temperate zone trees are surprisingly scarce.

To investigate when and where these environmental signals are perceived, we carried out bagging experiments in which buds on branches of *Fagus sylvatica*, *Aesculus hippocastanum*, and *Picea abies* trees were exposed to natural light increase or kept at constant 8 h days from December until June. Parallel experiments used twig cuttings from the same trees, harvesting treated and control twigs seven times and then exposing them to 8 h or 16 h days in a greenhouse.

Under 8 h days, outdoor budburst in *Fagus* was delayed by 41 days; in *Aesculus*, by four days; in *Picea*, day length had no effect. Buds on nearby branches reacted autonomously, and leaf primordia only reacted to light cues in late dormancy after accumulating warm days. Experiments on bud scales with different wavelength spectra and high-resolution spectrometry indicate a phytochrome-mediated photoperiod control.

By demonstrating local photoperiodic control of buds, revealing the time when these signals are perceived, and showing the interplay between photoperiod and chilling, this study helps modelling the impact of climate warming on photo-sensitive species.

Keywords: dormancy, photoperiod control, bagging experiments

6.2 Poster Presentations

Worldwide pollen forecast

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Only for a small part of the world pollen information is recorded and internationally exchanged. An increasing demand for allergy related pollen information due to worldwide travelling can be found. Due to the lack of pollen data, an own data assimilation method was developed to predict the pollen concentration over the world. The first step during data assimilation is to look for any available information of pollen during the last 5 days for a grid point. In most cases no data can be obtained, so step two is to proof: Grows the relative plant on site? Step three is to calculate the phenological development of the plants via temperature sums. As a final step, the weather conditions will be analysed to forecast the amount of pollen in the air column for every grid point over the globe. Calibration of the forecast with real-time data from Germany and Hatay/Turkey to check the accuracy of the forecast.

Keywords: pollen, forecast, worldwide, allergies, data assimilation

Storing phenological data: a proposal of database especially suited for tropical vegetation

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Plant phenology studies are based on a workflow from field observations to data storage and analysis. This process involves many steps that are time consuming and error prone. A special feature of phenology studies refer to the use of temporal data, i.e., data continuously collected along a given period of time. Usually, those studies consider a large number of marked trees, which are visited at regular intervals in order to observe changes on phenophases MORELLATO et al. (2010). In summary, plant phenology studies deal with a large amount of complex data, especially in the tropics, where the species diversity is very high. An effective way to support these studies rely on the adoption of phenology information systems, however, just a few phenology database systems and scripts are available. Motivated by the benefits of a database and by the lack of appropriate systems, we introduce here a conceptual design and implementation of a database to store, manage, and manipulate phenological data, especially suited for tropical ecosystems. This database was constructed in the context of the e-phenology project and integrates ground-based plant phenology direct observations with near-surface remote phenology using images from digital cameras. It includes information of local environment and climate (e.g., phytosociology, temperature, precipitation, and PAR) and ecological plant characteristics (e.g., pollination or dispersal syndrome, flower and fruit colour, and leaf exchange strategy) at individual and species level. We validated the proposed database design through the implementation of a Web application, exemplified on two case studies based on previous studies CAMARGO et al. (2011); ALBERTON (2014) conducted in the context of the e-phenology project at our core cerrado study area. In the first case study, we analyse the relationship between on-the-ground observations of *Xylopia aromatica* individuals flowering in two different environments and climate variables, based on long-term series analysis. In the second case study, we analyse the consistency between leafing flush based on on-the-ground observations of *Aspidosperma tomentosum* and *Miconia rubiginosa* individuals and the correspondent vegetation image indices (% Green) of both species. We conclude that the proposed database is a powerful tool that can be widely used to manage complex temporal data sets, integrating legacy and live phenological information from diverse sources and temporal scales. The proposed database model was designed to consider phenology information from several study sites and, therefore, we expect to contribute to facilitate accesses as well as improve the future scientific research on tropical phenology.

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Keywords: phenology database design, digital images, remote phenology, image-based phenological indices, on-the-ground observations

Phylogenetic constraints and trait correlates of flowering phenology in the angiosperm flora of China

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Aim: The phylogenetic constraint hypothesis of flowering phenology states that closely related species flower on similar dates. We test this hypothesis for the Chinese angiosperm flora and assess additional effects of growth form, deciduousness, pollination mode, and fruit type. We further examine whether the phylogenetic conservatism of flowering phenology tends to increase from tropical towards temperate latitudes.

Location: China.

Methods: The midpoint of flowering time for 19,631 angiosperm species present in China was compiled. Phylogenetic signal for flowering time was evaluated for the whole country using Blomberg`s K value (adjusted for circular data). We then regressed the phylogenetic signal for 28 provinces as a function of their latitude. An analysis of variance for circular data was conducted to test the differences among growth forms. Watson-Williams tests for circular flowering data were used to compare flowering dates between deciduous and evergreen species, animal-pollinated and wind- pollinated species, fleshy- and non fleshy-fruits.

Results: The results support the phylogenetic constraints hypothesis. The phylogenetic signal at the whole country scale was lower than that at the provincial scale. Phylogenetic signal was also lower at lower latitudes than at higher latitudes. Flowering dates were associated with biological traits, but the correlations depended on growth form.

Main conclusions: Flowering phenology was constrained by phylogeny and so one should account for phylogeny when studying the underlying drivers of phenology. The strength of phylogenetic conservatism appears weaker at larger scales and becomes stronger towards temperate regions. Flowering phenology also varies predictably according to biological traits such as growth form. It remains to be tested whether a phylogenetic signal for other functional traits increases with latitude.

Keywords: Chinese flora, deciduousness, fruit type, growth form, phylogenetic conservatism, pollination type

Using publicly sourced, archival data to create a baseline phenological database for the West Virginia University Natural History Museum

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A major challenge phenology is establishing a reliable historical dataset with which to compare modern observations. Without a baseline, it is impossible to discover trends and patterns associated with climate change. This research demonstrates unique methods of recovering archival phenologic data in order to create a definite baseline dataset for the state of West Virginia, USA in cooperation with the West Virginia University Natural History Museum.

West Virginia is a heavily forested state in the Appalachian Mountains along the eastern United States. The state has an exceptional culture of hunting, fishing, and farming, which has resulted in a strong connection to the land. There has been little research on phenology in West Virginia and no central phenological database for the state exists. In order to create a long-term historical database, we are utilizing archival sources to uncover historical phenologic data. We are collecting information from diaries of nature-minded citizens, natural history observations found in local history centers, herbarium specimens, field station records, and field notes taken by nature clubs. This data is being used to analyze temporal patterns of bird migration, to evaluate the factors that affect full flowering in wildflowers, and to create a general database of phenological data across species.

We are using a variety of techniques to recover, collect, and organize this historical phenologic data. Outreach materials such as flyers, brochures, newspaper and magazine articles, an online blog, and social media are being used to reach citizens who are in possession of relevant data. To supplement these materials, we are giving presentations to nature clubs and organizations during meetings and conferences. This type of public outreach for data collection is unique in the field of phenology and an important resource in establishing a reliable baseline dataset for future climate change research and citizen science programs.

Keywords: phenological database, archival data

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