10th World Dendro Conference Program

June 10th -15th, 2018
Thimphu, Bhutan

Keynote Presentations

Monday June 11th 8:30- 9:15, Auditorium

From Sacred to Scientific: Bhutan's Shifting Worldviews and Nature Conservation

Presented by: **Dr. Karma Phuntsho**
Founder and President
The Loden Foundation, Thimphu, Bhutan
http://loden.org/

9:15- 10:00, Auditorium

Walkabout Dendro: progress, perspectives and Challenges from Downunder

Presented by: **Dr. Kathy Allen**
Dept. Ecosystems and Forest Sciences
University of Melbourne
Melbourne, Australia

In the past decade and a half, Australian efforts have firmly established the place of Australian dendrochronology in the scientific world. Although Tasmania may long have been the only part of Australia known for producing 'useful' robust ring width chronologies, the geographical scope as well as the breadth of the discipline has been steadily pushed forward beyond this 'safe' frontier. Although dendroclimatology still remains a dominant focus within the broader discipline, considerable emphasis on dendroecology, forest dynamics, and its applications has rapidly emerged. Some of this focus has resulted in dendrochronology taking centre stage in controversial conservation debates. In this talk, I will reflect on recent developments and work in the region. I will discuss future directions for dendrochronological research, and how we might make more of much maligned 'weeds' like eucalyptus.

Tuesday, June 12th 10th 8:30- 9:15, Auditorium

The Role of Dendrochronology in the 21st Century: Lessons Learned from Water Managers

Presented by: **Dr. Connie Woodhouse**
School of Geography and Development
University of Arizona
Tucson, Arizona, USA

While the international community of dendrochronologists speaks many different languages, we share a common language related to the practice of dendrochronology. We are fortunate that this practice, which takes a variety of forms, is highly complementary to studies in a number of different fields, including paleoclimatology, ecology, and archaeology to name just a few. Because of this, dendrochronologists make good partners in collaborative, multidisciplinary research projects. We are also fortunate that much of the general public is familiar with tree rings, and intuitively can recognize how patterns of rings widths record past environmental variability. This common basis of understanding provides a starting point for interactions and engagements beyond the science world. Tree rings have real-world applications in resource management, and a common understanding of tree rings has facilitated my engagement with water resource managers over the past several decades. Through collaborations, I have co-produced information from tree rings that has proven to be useful to resource management, but I have learned many lessons from my collaborators along the way. The focus of this talk is on some of the lessons I have learned about approaches to collaborative research, as well as the broader role of dendrochronology in the world today.

9:15- 10:00, Auditorium

What we nearly missed – an overview of recent dendrochronological research in China

Presented by: **Dr. Hans Linderholm**
Gothenburg University Laboratory for Dendrochronology (GULD)
University of Gothenburg
Gothenburg, Sweden

Wednesday, June 13th 18:00, Lugar Theater (downtown)

Into the Inferno

Presented by: **Dr. Clive Oppenheimer**
Department of Geography
University of Cambridge
Cambridge, UK

Clive will introduce a special screening of *INTO THE INFERNO*, a feature-length film about volcanoes and the communities that live on them, that he made with renowned filmmaker Werner Herzog. The screening will be preceded by a short introduction and followed by an audience Q&A. The New York Times described the film as "a metaphysical exploration of the wonders and terrors of nature as well as the fragility and comedy of human life, complete with beautiful cinematography [and] haunting music".

Thursday June 14th 9:00- 9:45, Auditorium

Dendrochronology: The Future is the Past

Presented by: **Dr. Edward R. Cook**
Director: Tree-Ring Lab, LDEO
Columbia University
Palisades, New York, USA

The title of my plenary talk is both self-evident and metaphorical. Dendrochronology is above all a science of the *Past* as recorded in the annual radial growth patterns of tree rings and the wood properties contained within them. For the most part, none of these patterns arise from planned experiments. Rather, tree rings are a record of unsupervised changes in radial growth and wood properties due to changes in the operational growth environment of the trees as they age. Remarkably, these unsupervised changes produce unique patterns of variability over time that can be matched from tree to tree when exposed to the same or similar environmental history of growth limiting factors. This is the phenomenon of crossdating, which makes dendrochronology practically unique in geochronology for its dating precision, and in turn a science of unparalleled versatility. All of this is appreciated by those attending the 10th World Dendro Conference in Thimphu, Bhutan. So, how does the *Past* inform the *Future* here? Tree rings cannot be used to predict the future, although some have tried to do so. Rather, the *Past* scientific accomplishments of dendrochronology are what will propel it into the *Future*. This is encapsulated in something Albert Einstein said: “If we knew what we were doing, it wouldn’t be called research.” What this means is that there is still much to learn about tree rings: how to process them, how to extract information from them, and how to interpret that information. So, there are still many uncertainties in dendrochronology at all stages of analysis and interpretation, but that is good. These uncertainties should be embraced, not criticized as some would do, because they give us reason to continue our scientific research in dendrochronology and along the way make interesting discoveries, even some highly relevant to today’s global environmental change problems. It also means that we must learn from past researchers in dendrochronology, “standing on the shoulders of giants” as Isaac Newton so aptly put it. This means we must be students of the science for as long as we are active in tree-ring research and never be satisfied with the scientific status quo. Advances in the science will come from understanding *Past* accomplishments, especially their limitations, and this will propel the science of dendrochronology and us into the *Future*.

Friday June 15th 9:00- 9:45, Auditorium

The role of climate in forest response to rising CO2: Insights from tree-ring carbon isotopes

(Florence Hawley Presentation)

Presented by: Dr. Soumaya Belmecheri
Laboratory of Tree-ring Research
University of Arizona
Tucson AZ, USA

The terrestrial biosphere has been responding to rising atmospheric carbon dioxide concentration (ca), through increased plant photosynthesis and reduced stomatal conductance. The resulting enhancement in gross primary production contributes to the strengthening of the land carbon sink, which currently sequesters 30% of total anthropogenic ca emissions. Elevated ca leads to an increase in CO2 concentration within the leaf (ci), and plants adjust their stomatal conductance towards a proportional ratio of ca and ci (i.e. constant ci/ca), resulting in an increase of water use efficiency (WUE- ratio of carbon gain per unit of water loss). Under elevated ca, the increase in WUE has been widely observed in laboratory and ecosystem experiments and in tree-ring records in response to rising ca since 1850 CE. These observations are consistent with recent atmospheric evidence of greater photosynthetic carbon isotopic discrimination by the terrestrial biosphere, however, they contradict analysis of above-canopy CO2 and water vapor fluxes, which showed a larger increase in WUE over the past 20-years requiring trees to close their stomata to preserve a constant ci. While observational, proxy-based measurements and process-based models support a WUE enhancement with rising ca, the magnitude and underlying mechanisms of plant physiological responses to elevated ca remain highly uncertain. The implication of CO2 effect on forests WUE, global evapotranspiration, and continental runoff should therefore be regarded with caution. These findings have significant implications in predicting future terrestrial C sink and thus require exploring whether these responses represent a short-term acclimation or long-term response of plant functional traits to environmental changes. Analyses of tree ring stable C isotope ratios (13C) since the onset of the industrial period allow examination of ci-regulation in response to rising ca, including the role of climate in modulating leaf-gas exchange strategies. Data suggest that WUE is still recently increasing in most species but that the rate of increase is less than expected and may have reached a plateau in the recent decades. This evidence demonstrates that a broadly conserved suite of functional traits allows woody plants to adapt their leaf gas exchange to elevated CO2.

14:45-15:15, Auditorium

Keith Briffa: a commemoration of his contributions to dendrochronology and paleoclimatology

Presented by: Timothy J. Osborn
Climatic Research Unit
University of East Anglia Norwich, UK

Keith R. Briffa (1952-2017) was one of the most influential palaeoclimatologists of the last thirty years. His primary research interests lay in late Holocene climate change with a geographical emphasis on northern Eurasia. His greatest impact was in the field of dendroclimatology, a field that he helped to shape. His contributions have been seminal to the development of sound methods for tree-ring analysis and in their proper application to allow the interpretation of climate variability from tree rings. This led to the development of

many important records that allow us to understand natural climate variability on timescales from years to millennia and to set recent climatic trends in their historical context.
This presentation will survey some of Keith's most significant contributions and their enduring impact. These include (1) the assessment of chronology quality, (2) the separation of climatic and age-related signals via tree-ring standardisation, (3) the development of long chronologies of tree-growth parameters from key sites, and (4) the interpretation of tree-ring data to yield insights into past climatic variability at large spatial scales. These scientific achievements will be complemented with insights into Keith's spirit, his enthusiasm for dendrochronology and his enduring support for the development of dendroclimatology communities in many regions of the world. There will be the opportunity for others to contribute their memories of Keith and their view of his legacy for dendrochronology.

Session Abstracts:

Dendroclimatology

Session Chairs:

Dr. Valerie Trouet, LTRR, University of Arizona, Tucson, Arizona, USA
Dr. Rob Wilson; School of Earth & Environmental Sciences, St. Andrews University, St. Andrews, Scotland

Ongoing and projected future climatic change at global and regional scale raises questions about anthropogenic forcing of the climate system and the amplitude of its response. To improve our understanding of the climate system's sensitivity and its natural variability, a longer time frame than instrumental data alone can offer is required. Moreover, knowledge of pre-industrial climate conditions is important to distinguish between anthropogenic and natural (e.g., volcanic, internal) drivers of climate variability. Proxy climate records have therefore been developed to reconstruct past climate at a wide range of spatial and temporal scales. Tree-ring records are often the most prevalent and reliable proxies over the recent past and their annual resolution is necessary to study extreme events in past climate. The ology session(s) welcomes papers that use tree-ring data to study any aspects of past climate and its influence on human systems and ecosystems.

Monday June 11th 10:30-12:30
Presentations DC1-8
(Breakout Room 1)

DC-1 Paleoclimate reconstructions of the northeastern United States using Atlantic white cedar tree-rings (Jessie Pearl, Kevin Anchukaitis, Neil Pederson, and Jeffrey Donnelly)

Presented by: Jessie Pearl

High-resolution paleoclimate records are essential for improving detection and attribution of internal and forced climate system responses. The densely populated northeastern United States is at high risk from increasing temperatures, droughts, and extreme precipitation events. The region has limited annual and seasonal-scale proxy climate records beyond the instrumental record. Atlantic white cedar, a wetland conifer found within 200km of the Atlantic coastline of the United States, is a promising new temperature proxy that can fill in these data gaps. However, certain cedar sites contain multivariate climate signals in their rings. Here, we present a dense network of Atlantic white cedar tree ring chronologies across the northeastern United States and show how site selection is extremely important for paleoclimate reconstructions. Ring width variability reflects winter through summer temperatures at inland and 'hydrologically stable' sites in the northernmost section of the species' range. Ombrotrophic sites along the coast of the Northeast contain hydrologic signals embedded in their rings, and correlate with growing season precipitation. We demonstrate skilful climate reconstructions for the last several centuries and the potential to use sub-fossil samples to extend these records over the entire Common Era. This comprehensive understanding of the species' climate sensitivity and geologic environment leads to a tree-ring network that provides the long-term context at multi-decadal and centennial time scales for the large-scale ocean-atmospheric processes that influence the climate of the region.

DC-2 Long-term trends in European tree growth over the past 1000 years – an interspecies comparison (Andrea Seim, Willy Tegel, Ulf Büntgen, Paul J Krusic, Wolfgang Beck, Matthias Bollinger, Karl-Uwe Heussner, Franz Herzig, Jutta Hofmann, Raymond Kontic, Tomáš Kyncl, Alexander Land, Mechthild Neyses-Eiden, Sabine Remmele, Andreas Rzepecki, Georgios Skiadaresis, Felix Walder, Thorsten Westphal, and Hans-Peter Kahle)

Presented by: Andrea Seim

Hydroclimate variability is a crucial element in the ongoing assessment of past and future climate change. Potential forcing factors, the amplitude and frequency of long-term (i.e. multi-decadal to centennial) growth trends of precipitation sensitive tree-ring records from low elevation sites, which are essential to reconstruct the full range of hydroclimate variability, are merely studied and not yet fully understood.

The study presents the first large-scale multi-species comparison of long-term growth trends across Europe, spanning the last millennium. Tree-ring measurements from precipitation sensitive tree species in Central Europe for oak (*Quercus* spp.), beech (*Fagus sylvatica*), fir (*Abies alba*), pine (*Pinus sylvestris*) and spruce (*Picea abies*) have been collected from historical and archaeological timbers, and linked to the present with material from living trees to produce well-replicated species chronologies. Those species-specific chronologies show

similarly supra-regional tree growth fluctuations. Furthermore, first comparisons between the different species yielded significantly correlations of the growth trends in the high and low-frequency domains. New findings gained in the study of climate forced, low-frequency trends in tree growth and their underlying causes will improve climate reconstructions, model simulations and the quantification of long-term changes in the carbon cycle at continental to global scale.

DC-3 Climate influence on radial increment of native and alien oaks in Poland (Agnieszka Bronisz)

Presented by: Agnieszka Bronisz

Genus oak (*Quercus* sp.) consists of many individual species of different morphology, biology and ecology. In Poland two native (pedunculate and sessile) and one alien (red) oaks are important from the ecological and economical point of view. Climate influences the tree growth process in great measure. Pace and intensity of tree-ring formation is shaped by different weather elements such as temperature, precipitation or moisture availability. The aim of this research is to compare annual growth rates and climate-growth relationships of two native and one no native oaks. To reach the goal, only dominant, healthy and undamaged trees were sampled from the 34 sample plots from western Poland (16-20 trees per sample plot). One increment core per tree was taken using a Pressler borer. Elaborated tree-ring width series were cross-dated visually using standard dendrochronological techniques. To pronounce climate-related high-frequency signal and to minimize long-term age-dependent trend, each tree ring width series was standardized in the two-staged detrending process using the negative exponential curve and the linear regression function. DendroClim2002 software was used to investigate the influence of climate on the growth of analysed oaks. Climate data used in the study originates from the CRUTS 3.1 set. Significance of analysed relationships was assessed at the 0.05 level. Achieved results shows significant positive effect of precipitation in July of the previous year of ring formation and in June and July of the year of ring development.

DC-4 Silver fir response to changing climatic conditions from inside and outside distribution range in Poland (Karol Bronisz)

Presented by: Karol Bronisz

Tree species growing in temperate climate zone form new layers of wood year by year. Size of the annual diameter increment depends on many factors, among which the most important are: age, tree's condition and meteorological factors (mainly the temperature and precipitation). The spatial distribution of tree species is the result of arrangement to climate factors connected with geographical localization and height. These factors limit possibility of the tree growth in the different regions of world. Growth of trees that occur out of their natural distribution range is limited mainly by arrangement to meteorological factors.
Silver fir (*Abies alba* Mill.) is one of the most important forest-forming species in Poland, especially in mountains and uplands. It grows mainly in a southern and central part of Poland and achieves northern border of its natural range in Europe.
The basis of the analyses were increment cores sampled from four study sites located inside and outside the natural distribution range of silver fir (20 sample plots, 16-20 dominant

trees per plot). Individual series were cross-dated visually with the CDendro (www.cybis.se) software. Dendrochronological analyses including interactive detrending (negative exponential curve and the linear regression function), chronology building, and the calculation of standard descriptive statistics were created using dendrochronology program library in R (dplR). CLIMTREG software was used to investigate the influence of climate on the growth of silver fir. Climate data used in the study originates from the CRUTS 3.1 set.
The main purpose of this study is to compare tree-rings sequences of silver fir growing inside and outside the distribution range and investigate their response to climate conditions. Silver firs from inside and outside the range show different response to thermal conditions. Obtained dependencies in the nearest future may change the natural range of silver fir.

DC-5 Stable isotopes reveal climate signal hidden in tree rings of endemic Balkan pines (Tom Levanič, Jernej Jevšenak, and Polona Hafner)

Presented by: Tom Levanič

The climate of Mediterranean, including Balkan peninsula is highly subjected to increasing greenhouse gases concentrations and their effect on climate. In this region of limited water resources, reliable climate predictions on seasonal to decadal timescales are essential in developing effective strategies for mitigating environmental and socioeconomic impacts of climate change. The increase in temperature and decrease in precipitation, as forecast by climate change scenarios for the Eastern Mediterranean region, pose one of the main challenges for the sustainable management of natural resources in countries of the Adriatic and Aegean regions (IPCC, 2007; Matyas, 2010). Long reconstructions of past climatic conditions are critical to explore longer interaction between the local climate and largescale oceanic and atmospheric changes over the centuries, since the instrumental data are not long enough to be able to detect them in the long-term changes in climate. Balkan peninsula is known of its relict tree species due to the late glacial refugia and some more or less untouched forest sites (Bennett et al., 1991; Médail & Diadema, 2009; Willis, 1994). Two Balkan tree species, *Pinus heldreichii* and *Pinus peuce*, are particularly interesting for dendroclimatology because they can get very old and grow on extreme sites
There have been a limited number of studies focused on growth and development of chronologies of *P. heldreichii* and *P. peuce*. Most of these studies comes from the Pirin Mountains in Southwestern Bulgaria. With a help of *P. heldreichii* tree-ring chronologies, Vasileva and Panayotov (2016) successfully dated fire events. Panayotov et al. (2010) analysed climate signal in tree-ring chronologies of *Pinus peuce* and *Pinus heldreichii* and concluded that climate signal exists, but is weak. From the same region, Trouet et al. (2012) presented a summer temperature reconstruction (1768 – 2008) based on maximum latewood density (MXD) measurements. Other studies include the analysis of climate-growth relationship of *P. heldreichii* on Kosovo (Bojaxhi & Toromani, 2016; Bojaxhi & Toromani, 2017), in Albania (Seim et al., 2012; Seim et al., 2010) and in Greece (Klippel et al., 2017). Based on the fact that several studies report good potential of PIPE and PIHE for developing long chronologies from living trees, and warn that climatic signal is relatively weak in tree rings of *P. heldreichii* (Klippel et al., 2017), and particularly in *P. peuce* (Panayotov & Yurukov, 2007) we decided to 1) study climate signal and 2) potential for long climate reconstructions in tree-ring widths and in stable carbon isotopes ratios in rings at the northern edge of species distribution in eastern part of Montenegro between 1720 and 1860 m a.s.l.
Results show that, despite high and temporally consistent EPS values and good agreement

among sampled trees, climate signal in tree ring widths is weak in *P. heldreichii* (weak significant response to temperature and no response to precipitation) and non-existent in *P. peuce*. However, stable carbon isotope ratio in tree rings turns out to be a completely different story. Both studied species have a very similar climate response which allows us to merge isotope chronologies into a single composite chronology for *P. heldreichii* and *P. peuce*. Composite chronology has a strong signal related to average monthly temperature in July and August and monthly hours of sunshine duration in August with r> 0.6 and r< -0.6 for single months, respectively. In case of sunshine duration, climate signal was enhanced when July and August values were merged into a single variable (r = -0.70). Temporal stability of temperature, precipitation and sunshine hours signal is consistent. Spatial extent of the composite carbon isotope chronology extends over a very large region including Montenegro, Albania, parts of Bosnia and Herzegovina, southern Serbia and Macedonia.

DC-6 Variability in growth-climate relationship between juveniles and adult trees in treeline (Achyut Tiwari, Zhou Zhe-Kun, and Fan Ze-Xin)

Presented by: Achyut Tiwari

The response of altitudinal treelines is considered reliable indicators of rapidly changing climate on tree growth and forest dynamics. Demographic response including stand age structure and regeneration potential of tree species in treeline ecotone indicate treeline dynamics, and tree ring records of these forests show the growth limiting climatic processes. To find out the variability in growth-climate response between juveniles and adult trees, we analysed different tree species (*Abies spectabilis, Betula utilis, Abies georgei* and *Larix potaninii*) in trans-Himalayan zone, Nepal and Hengduan mountain, China. We reconstructed the age structure of tree by counting the yearly formed rings in cross-section of stem, and also by terminal buds count for seedlings and saplings. For the adult trees, limiting climatic factors for tree growth were identified by most closely linked periods of low and high growth in alpine treelines. For juveniles the growth-climate response was explored by the correlation between tree establishment and climatic factors. The growth response of adult trees showed that treeline is moisture sensitive in trans-Himalayan zone, Nepal and is temperature sensitive in Hengduan zone, China. However juvenile trees of *A. spectabilis* and *B. utilis* treeline in Nepal showed positive correlation with temperature, similarly the negative correlation between tree establishment and climatic factors were observed for juvenile trees of *A. georgei* (Tianbao Mt.) and *L. potaninii* treeline (Xiangcheng) in China. From our study we concluded that the growth-climate response of adult trees and younger trees are not the same; in the upper treeline the juveniles are more favoured by temperature and the adults by moisture. Closer examination of belowground environment (soil temperature and moisture), separately to juveniles and adults, as well of biotic interactions are highly important for making accurate prediction on growth-climate response in upper treelines.

DC-7 Climate-growth relationships investigated through tree-ring measurements based on Pinus koraiensis trees from the Russian Far East (North-East Asia) (Olga Ukhvatkina, Alexander Omelko, Anna Vozmishcheva, Alexander Zhmerenetsky, and Tatyana Petrenko)

Presented by: Olga Ukhvatkina

Despite this, there are very few studies of Russian Far East climate (e.g., Willes et al., 2014; Jacoby et al., 2004; Shan et al., 2015); moreover, there is an absence of dendrochronological studies for the continental part of Russian Far East. Meanwhile, most of species present in northeastern China, the Korean peninsula and Japan grow in this region. In addition, the distribution areas of these trees often end in the south of the Russian Far East, which increases the climatic sensitivity of plants. Additionally, some parts of the forests in the Russian Far Eastern have not been subjected to human activity for the last 2000-4000 years. This makes it possible to forests extend the studied timespan. In addition, the southern territory of the Russian Far East is sensitive to global climatic changes as it is under the influence of cold air flow from northeastern Asia during the winter and summer monsoons. All of the factors listed above create favorable conditions for dendroclimatic studies.

Mixed forests with Korean pine (*Pinus koraeinsis* Siebold et Zucc.) are the main vegetation type in the study area, and they form an altitudinal belt up to 800 m above sea level. This area is the northeastern limit of the range of Korean pine-broadleaved forests, which are also found in northeastern China (the central part of the range), on the Korean peninsula, and in Japan. The Sikhote-Alin mountain range is one of the few places where significant areas of old-growth Korean pine-broadleaved forest remain. The *Pinus koraiensis* – one of the most long-lived tree species in the north-east Asia forest which has undecayable woods. These allowed us to find preserved wood samples and investigated important climate-growth relationships more than 450 years. In this we present first results of our dendroclimatic research. The climate

The territory of Russian Far East is characterized by a monsoon climate which is determined by the interaction of the Pacific Ocean and the Siberian anticyclone. So, the radial growth of Korean pine in the study region is mainly limited by the pre-growth autumn-winter season temperatures and spring – early summer precipitations.

Using the tree-ring width of *Pinus koraiensis*, the mean minimum temperature of the previous August-December has been reconstructed for the southern part of Sikhote-Alin Mountain Range, northeastern Asia, Russia, for the past 486 years. We successfully reconstructed April – June precipitation for the southern – middle of Sikhote-Alin Mountain Range for the past 300 years. These datasets are the first climate reconstructions for this region, and for the first time for northeast Asia, we present a reconstruction with a length exceeding 486 years. Undoubtedly, the results of our research are important for studying the climatic processes that have occurred in the study region and in all of northeastern Asia and for situating them within the scope of global climatic change.

DC-8 The role of disturbance in northern hemisphere tree-ring based chronologies and climate reconstructions (Miloš Rydval, Jesper Björklund, Neil Pederson, Jonathan Schurman, Daniel Druckenbrod, Kristina Seftigen, and Miroslav Svoboda)

Presented by: Miloš Rydval

Due to their inherent ability to provide annual resolution and widespread terrestrial availability, tree-rings are a particularly important proxy archive containing paleoclimatic information spanning centennial to millennial timescales. However, there is also recognition that the presence of disturbance trends (e.g. due to fire, windstorms, insect outbreaks, logging) in tree-ring width (RW) series can violate uniformitarian assumptions and potentially complicate the development of climatically sensitive tree-ring chronologies (e.g. Briffa et al., 1996; Gunnarson et al., 2012; Rydval et al., 2015). If the interpretation of mid- to low-frequency climatic trends from tree-ring chronologies were impacted by disturbance signatures in some datasets, this could have significant implications for understanding paleoclimatic conditions in some regions. Therefore, understanding the possible role of disturbance-related biases in climatic reconstructions is of vital importance to gaining insight into the robustness and reliability of such records, particularly in regions where chronologies of alternative parameters such as maximum latewood density (MXD) or blue intensity (BI) are currently sparse or absent. With its unique ability to remove disturbance trends without loss of low frequency information, the Curve Intervention Detection (CID) method (Druckenbrod et al., 2013; Rydval et al., 2015) was used to identify and correct for disturbance trends in over 4000 northern hemispheric RW chronologies published in the International Tree-Ring Data Bank. The mid- to low-frequency trends and climate sensitivity of RCS-detrended chronologies was assessed before and after CID correction against gridded instrumental temperature, precipitation and drought (PDSI) datasets. Although some chronologies displayed little to no signs of synchronised disturbance, others contained disturbance signatures which were temporally concentrated and affected the overall chronology trends. Despite some limitations, climatically sensitive CID-corrected chronologies generally displayed better agreement with the primary climatic variable. In instances where CID correction resulted in chronology 'improvement', correlations with the primary climatic driver increased on average by r = 0.05 over the 20th century. For a subset of locations for which MXD or BI data were also available, these alternative parameter chronologies, which are typically less susceptible to disturbance, were used to evaluate the properties of CID-corrected RW chronologies in pre-instrumental timeperiods. The findings of the CID analysis indicate that non-climatic disturbance trends could affect interpretation of paleoclimatic conditions on local to regional scales, warranting further detailed investigation. The application of CID also raises the prospect of utilizing chronologies from sub-optimal (i.e. more disturbance-affected) locations for future dendroclimatic research.

Monday June 11th 14:00-15:30
Presentations DC9-14
(Breakout Room 1)

DC-9 Ensemble reconstructions of Northern Hemisphere summer temperatures during the Common Era (Kevin J Anchukaitis, Rob Wilson, Sébastien Guillet, Markus Stoffel, Jan Esper, Christophe Corona, Lea Schneider, David Frank, and the NTREND Consortium Members)

Presented by: Kevin J Anchukaitis

The Earth's climate history is a combination of forced changes, feedbacks, and internal climate system variability. Long-term paleoclimate reconstructions provide unique insights into the characteristics and causes of past temperature variability, allow fingerprinting of the contribution from radiative forcing agents, and provide out-of-sample tests for climate models. Recent advances in our understanding of the sources of uncertainty and bias in tree-ring reconstruction have resulted in improved estimates of past temperatures that capture the spatiotemporal signature of volcanic eruptions, reveal regional and continental-scale difference in past climate histories, and preserve low frequency variability in hemisphere temperature fluctuations. Substantial differences remain, however, between reconstructions and models in their frequency spectra, the degree of Medieval and Little Ice Age temperature change, and the magnitude of post-volcanic cooling. Here, we take an ensemble approach to hemisphere and continental-scale summer temperature reconstructions in order to identify the range of uncertainty and sensitivity to proxy selection and reconstruction parameters. We use an expanded network of Northern Hemisphere temperature-sensitive tree-ring chronologies as potential predictors and our ensemble samples across a range of potential proxy subsets, calibration and validation periods, instrumental targets, and reconstruction methods. We quantify the range of possible reconstructions associated with different ensemble 'flavours'' and compare the magnitude of uncertainty associated with each parameter and predictor choice. Finally, we compare our ensemble reconstructions against last millennium general circulation model simulations in order to evaluate the contribution of reconstruction uncertainty and sensitivity to extant differences between models and paleoclimate estimates of past temperatures.

DC-10 Late 20th century divergence in maximum latewood density: 20 years on (Thomas M. Melvin and Timothy J. Osborn)

Presented by: Timothy J. Osborn

It is 20 years since we reported in Nature (Briffa et al., 1998, “Reduced sensitivity of recent tree growth to temperature at high northern latitudes”) a widespread divergence between instrumental summer temperatures and maximum latewood density (MXD) chronologies averaged over hundreds of high latitude or high elevation sites across the Northern Hemisphere. We revisit this work, review subsequent literature and its influence on the field, and report new analysis. An improved identification of divergence will be presented. A number of divergence explanations are explored: aliasing, passing climate thresholds, changes in seasonal sensitivity and multiple climatic influences including light limitations. These are explored by comparison across multiple variables within the Schweingruber network, inter-variable interactions and relationships with instrumental data and with other, long MXD records.

DC-11 Summer hydroclimate and temperature co-variability across Europe since 850 CE (Fredrik Charpentier Ljungqvist, Andrea Seim, Paul J. Krusic, Jesús Fidel González-Rouco, Johannes P. Werner, Edward R. Cook, Eduardo Zorita, Jürg Luterbacher, Elena Xoplaki, Georgia Destouni, Elena García Bustamante, Camilo Andrés Melo Aguilar, Kristina Seftigen, Jianglin Wang, Mary H. Gagen, Dominik Fleitmann, Olga Solomina, Jan Esper, and Ulf Büntgen)

Presented by: Fredrik Charpentier Ljungqvist

Global warming presents a major threat to agriculture and society in Europe via the increased risk of droughts. However, climate model simulations do not show consistent projections of hydroclimatic changes under global warming on regional scales, and there is increasing evidence of a timescale-dependent, temperature–hydroclimate relationship. As the period of instrumental data is too short – even in Europe – to assess low-frequency changes in the temperature–hydroclimate relationship we need to turn to palaeoclimate proxy data for the answer. We present the first large-scale comparison of temperature–hydroclimate growing season co-variability patterns for Europe using: (1) gridded instrumental data for the periods 1901–2003 and 1766–1900, (2) tree-ring based temperature and hydroclimate gridded reconstructions for the period 850–2003, and 3) two high-resolution climate model simulations for Europe, CCSM4 and MPI-ESM-P, for the period 850–2003. By a number of different analysis we conclude: (a) the co-variability between summer temperature and hydroclimate in Europe depends both on region and time-scale and has to some degree been changing over time, (b) the correlation between temperature and hydroclimate becomes stronger, and more positive, at lower frequencies in reconstructions, but not to the same extent in the models, (c) simulations show a stronger negative temperature–hydroclimate relationship than that found in instrumental data, whereas reconstructions also show a positive relationship, and (d) cross-spectral analyses reveal partly similar cycles in temperature–hydroclimate co-variability despite different correlation patterns.

DC-12 Strip-bark morphology and radial growth trends of ancient Pinus sibirica trees in Mongolia: Considerations for dendroclimatic reconstructions (Caroline Leland, Edward R. Cook, Laia Andreu-Hayles, Neil Pederson, Amy Hessl, Kevin Anchukaitis, Oyunsanaa Byambasuren, Baatarbileg Nachin, Nicole Davi, Rosanne D'Arrigo, Kevin Griffin, Daniel A. Bishop, and Mukund Palat Rao)

Presented by: Caroline Leland

Some ancient trees exhibit strip-bark morphology in which a portion of the cambium, the active layer of growth in the stem, dies in response to environmental stress. Partial cambial dieback has been linked to several different ecological and physiological factors, but the causes of dieback vary depending on site conditions. Further, the implications of such morphology on radial growth trends and its importance for tree-ring-based climate reconstructions remain unclear. We investigate the timing and potential environmental drivers of cambial dieback in *Pinus sibirica* trees from a xeric site in central Mongolia, and compare growth patterns of strip and whole-bark (full cambium) trees over the past 500 years. Cambial dieback occurred primarily on the southern side of trees, and was most common

during the cold and dry 19th century. These unfavourable climatic conditions, combined with high exposure to solar radiation, suggested by the orientation of strip bark, might be responsible for cambial dieback. Increasing ring-width trends are gradual in most strip-bark trees, and do not immediately follow dieback dates detected for individual stems. However, a mean ring-width chronology of all strip-bark trees abruptly increases and significantly exceeds ring widths of coeval whole-bark trees in the early 20th century. After standardizing strip and whole-bark series to remove allometric trends, the differences in recent growth trends persist. Before using strip-bark trees for climate reconstruction, we suggest comparing strip and whole-bark ring-width trends in order to determine if there are potential morphology-related growth trends. We extend this study by analysing stable isotopes in tree rings to evaluate whether there are physiological differences between strip-bark and whole-bark trees.

DC-13 Natural drivers of spring northern tropical belt movements over the past 800 years (Raquel Alfaro-Sánchez, Hanh Nguyen H., Stefan Klesse, Amy Hudson, Soumaya Belmecheri, Nesibe Köse, Henry F Diaz, Russell K Monson, Ricardo Villalba, and Valerie Trouet)

Presented by: Raquel Alfaro-Sánchez

Movements in the position of the northern edge of the tropical belt have strong hydroclimatic implications in many Northern Hemisphere (NH) regions. The tropical belt has shown a widening trend since the late 1970s, which is primarily attributed to anthropogenic forcings. Yet, the influence of natural climate variability is also acknowledged and the relative importance of prospective drivers is incompletely understood. Tree-ring data from five NH mid-latitude regions were used to reconstruct interannual spring NH tropical belt boundary movements over the past 800 years (1203-2003 CE). The results showed that southern-most (northern-most) tropical belt positions occurred during positive (negative) El Niño Southern Oscillation and Pacific North American phases and that the tropical belt contracted significantly following strong volcanic eruptions. The longest period of persistent tropical belt expansion occurred in the late 16th century, at the crux of the Little Ice Age. It was likely associated with multidecadal La Niña-like conditions and can be linked to synchronous societal crises in North America, Turkey, and China that were exacerbated by severe regional droughts during out of the past 500 years. These results thus warn for potential socio-economic consequences of future tropical expansions, which could be modulated by natural modes of climate variability and by potential natural or artificial stratospheric aerosol injections.

DC-14 The potential to assess the influence of summer Jet stream variability on East Asian climate in a paleoclimate context (Hans W Linderholm, Peng Zhang, Deliang Chen, Keyan Fang, and Jee-Hoon Jeong)

Presented by: Hans W Linderholm

Jet streams (JS) are fast and relatively narrow air currents thousands of kilometres long found near the tropopause. There are several jet streams, but globally they are usually classified into the subtropical and the polar front JS. The positions of the JS are important because synoptic scale disturbances usually form in the regions of maximum and minimum JS wind speed, and propagate eastward along tracks that follow the Jet axis. During zonal JS conditions, weather-systems move quickly which results in changeable weather, but during meridional conditions, persistent weather types, i.e. blockings, occur. Recently, there has been a focus on how climate change may affect JS characteristics and the potential impacts of these, including extreme events. Within the JETCLIM project, we here focus on the westerly JS during summer (JJA) in East Asia. The JS displays a seasonal march from south (winter) to north (summer) in average JS position. However, other JS characteristics, including waviness, intensity and shape, are needed to further understand JS behaviour and its relation to surface climate. Observational data (1951-2010) shows interannual variations in various JS indices during summer, where these variations have regionally been associated with surface climate anomalies. To set the observed changes in JS characteristics in a long-term context, we assess the potential for utilising tree-ring data to infer past JS characteristics. Preliminary results show that data from an Asian tree-ring network can be used to infer past summer JS characteristics back in time, on short and long timescales.

Tuesday June 12th 10:30-12:30
Presentations DC15-22
(Breakout Room 1)

DC-15 Tree-ring based drought (scPDSI) reconstruction for the Lidder valley, Kashmir, Northwest Himalaya (Uttam Pandey, and Santosh K. Shah)

Presented by: Uttam Pandey

To reconstruct past drought variability, tree-ring study was carried out in the Lidder valley, Kashmir, Northwest Himalaya. Twenty-one tree-ring chronologies were prepared using four conifer taxa i.e., *Abies pindrow, Cedrus deodara, Pinus wallichiana* and *Picea smithiana*. These tree-ring chronologies range from 138 years (1877-2014 C.E.) to 499 years (1515-2013 C.E.). The principal component analysis among the tree-ring chronologies was carried out for 1877-2013 C.E., in which principal component 1 (PC1) explains highest variance (51%). The PC1 was correlated with monthly regional self-calibrated Palmer Drought Severity Index (scPDSI). Significant positive correlation was observed for previous year August through July of current year. The highest positive correlation was for the months of January to July of current year. The January-July scPDSI was reconstructed using nested principal component regression approach and the reconstruction was extended from 1515 to 2012 C.E. The reconstruction explains 25.7% of total variance in the instrumental period. The dry periods

observed in the reconstruction are 1713-1755, 1771-1811, 1824-1889, 1907-1948 and 1952-1976. The reconstruction was assessed for dry and wet period based on classification used for PDSI. In addition, the reconstruction was compared with tree-ring based drought and precipitation reconstruction from the Kashmir valley and with Oxygen isotope records from the Karakorum to understand its local and regional coherence.

DC-16 Towards a drought atlas for western Australia – the 'WADA' (Alison O'Donnell, Ed Cook, Jonathan Palmer, Chris Turney, and Pauline Grierson)

Presented by: Alison O'Donnell

The ability to identify spatial patterns of past climatic variability in much of the Southern Hemisphere is constrained by the sparse distribution of proxy records. For example, only two multi-century tree-ring records have been developed for mainland Australia. While broad-scale teleconnections have enabled the development of the eastern Australian and New Zealand Drought Atlas ("ANZDA"; Palmer et al. 2015 ERL) using proxies that are remote from the eastern Australian mainland, it is unclear if this approach can be extended to western Australia. Here, we assess the potential to develop a drought atlas for western Australia using the same proxy records as those used to develop the ANZDA. These records include the two continental tree-ring records from western Australia and 175 records that are in the Australasian region but remote form western Australia – 174 tree-ring records from Tasmania (SE Australia), New Zealand and Indonesia and a coral record from Queensland (NE Australia).
The two western Australian tree-ring records allow robust reconstructions of past hydroclimatic variability over spatially broad areas (i.e., > 3° x 3°) of semi-arid northwest and southwest Australia. These reconstructions reveal synchronous periods of drought and wet conditions between northwest and southwest Australia as well as a generally anti-phase relationship with hydroclimate in southeast Australia over the last two centuries. The inclusion of the 175 remote proxy records did not improve the reconstruction potential over western Australia, suggesting the need to develop new local proxy records to better understand spatial variability of past hydroclimate across western Australia. Importantly, given the spatially broad climate signal evident in the existing local records, we suggest that only a few new records from key locations in western Australia are needed to enable the development of a robust drought atlas for the region.

DC-17 Summer Precipitation in the United Kingdom during the last 1000 years derived from oxygen isotopes in oak tree-rings (N.J. Loader, G.H.F. Young, D. McCarroll, D. Davies, D. Miles, and C. Bronk Ramsey)

Presented by: Neil J. Loader

United Kingdom (UK) summers dominated by anti-cyclonic circulation patterns are characterised by clear skies, warm temperatures, low precipitation totals, low air humidity and more enriched oxygen isotope ratios (δ18O) in precipitation. Such conditions usually result in relatively more positive (enriched) oxygen isotope ratios in tree leaf sugars and

ultimately in the tree-ring cellulose formed in that year, the converse being true in cooler, wet summers dominated by westerly air flow and cyclonic conditions. There should therefore be a strong link between tree-ring δ18O and the amount of summer precipitation. Stable oxygen isotope ratios from the latewood cellulose of oak trees sampled across the central southern UK produce a mean δ18O chronology covering the last 1000 years that correlates strongly and significantly with summer precipitation. The isotope-based rainfall signal is stronger and more stable over time than reconstructions based upon oak ring widths. Our reconstruction is explored in relation to UK precipitation variability and periods of "mega-drought". The existence of long, well-replicated oak tree-ring chronologies across the British Isles mean that it should now be possible to reconstruct summer precipitation over many centuries and potentially millennia.

DC-18 The Western Cordilleran Snow Atlas: 2000 years of snowpack history for the western United States (Bethany L Coulthard, Kevin J Anchukaitis, Gregory T Pederson, Jay Alder, Steven Hostetler, and Edward Cook)

Presented by: Bethany L Coulthard

Mountain snowpacks provide essential water supply for human populations and ecosystems in the western United States. Warmer temperatures and changing precipitation patterns will increasingly alter the quantity, extent, and persistence of snow in coming decades, yet snowpack observations are limited and sparse, and forecasts contain considerable uncertainty especially at local scales. Here we provide novel perspectives on the variability of the western United States snowpack system over the Common Era using a new tree ring-based Western Cordilleran Snow Atlas. The atlas is based on a curated and snow-sensitive network of over 1000 tree-ring chronologies combined with a 4x4 km PRISM-based modeled April 1 snow water equivalent dataset. We present a full space-time characterization of snow and associated water resource fluctuations over the past 2000 years, including roles of internal and forced variability, and comparisons against existing observations, model simulations, and proxy records.

DC-19 Hydroclimate variability in Northern Europe over the last millennium - insights from a climate model-proxy data comparison (Kristina Seftigen, Hugues Goosse, Francois Klein, and Deliang Chen)

Presented by: Kristina Seftigen

The integration of climate proxy information with General Circulation Model (GCM) results offers considerable potential for deriving greater understanding of the mechanisms underlying climate variability, as well as unique opportunities for out-of-sample evaluations of model performance. In this study, we combine insights from a new tree-ring hydroclimate reconstruction from Scandinavia with projections from a suite of forced transient simulations of the last millennium and historical intervals from the CMIP5 and PMIP3 archives. Model simulations and proxy reconstruction data are found to broadly agree on the modes of atmospheric variability that produces droughts and pluvials in the region. Despite these

dynamical similarities, large differences between simulated and reconstructed hydroclimate time series remain. We find that the GCM simulated multidecadal/longer hydroclimate variability is systematically smaller than the proxy based estimates, whereas the dominance of GCM simulated high-frequency components of variability is not reflected in the proxy record. Furthermore, the paleoclimate evidence indicates in-phase coherencies between regional hydroclimate and temperature on decadal time-scales, i.e. sustained wet periods have often been concurrent with warm periods and vice versa. The CMIP5/PMIP3 archive suggests, on the other hand, out-of-phase coherencies between the two variables in the last millennium. The lack of adequate understanding of mechanisms linking temperature and moisture supply on longer time scales has serious implications for attribution and prediction of regional hydroclimate changes. Our findings stress the need for further paleoclimate-data model inter-comparison efforts to expand our understanding of the dynamics of hydroclimate variability and change, to enhance our ability to evaluate climate models, and to provide a more comprehensive view of future drought and pluvial risks.

DC-20 What can we learn from using daily climate data for growth-climate response analyses? (Ryszard J. Kaczka, Karolina Janecka, Barbara Spyt, and Aleksander Hulist)

Presented by: Ryszard J. Kaczka

Growth-climate response analyses are the core element of all dendroclimatic investigations. The identification of climatic factors influencing tree growth and determining the dominant factor is likely the most common test performed by dendroclimatologists. The comparison between averaged monthly climate data and tree-ring chronologies remains a standard methodological convention. Nevertheless, monthly divisions (averages and sums) of climate data poorly reflect a phenological calendar and cycle of tree growth. The Vaganov–Shashkin model (Shashkin and Vaganov 1993) and CLIMTREG software (Beck et al. 2013) provide frameworks to integrate climate data of higher temporal resolutions, however, result in complex models.

Here we present a straightforward approach of applying daily climate data in a standard statistical approach to compute growth-climate responses. The bootstrap Pearson's correlation is calculated for climate data of all possible periods (i.e., from one to 365 (or 366) days of the year (DOY)). This trial was performed using data from a temperature sensitive subalpine Norway spruce stand in the Tatra Mts., Poland (Büntgen et al. 2007, Kaczka et al. 2016). Eleven parameters of annual tree rings were employed: i) ring width: total (TRW), early- (EWW) and latewood width (LWW), ii) blue intensity: early- (EBI), latewood (LBI) and delta blue intensity (dBI), iv) wood density: early- (EWD), latewood (LWD), maximum (MXD) and minimum density (MID), and v) cell wall thickness (CWT). Ring width (TRW, EWW, LWW) and blue intensity (EBI, LBI, dBI) parameters were measured from digital images of the wood surface with software CooRecorder, Cybis. Wood density (EWD, LWD, MID, MXD) and CWT parameters were measured with the SilviScan, CSIRO. All eleven parameters were measured from the same set of cores and standard chronologies were built with ARSTAN software using cross-dated measurements from 23 trees. Climate correlations were calculated with DendroCorr software (Hulist et al. 2016) employing instrumental daily data of temperature (1927-2011 CE) from a meteorological station located 2.6 km from the sampling site and at the same elevation (1520 m a.s.l.). Comparisons between the monthly- and daily-based climate-growth responses indicated different temporal periods when the highest correlation values were calculated. In case of TRW climate-growth relationships employing monthly data revealed the highest correlation for the June-July period (r=0.54),

whereas using daily data a shorter period most strongly linked to tree growth variability (165-196 DOY, r=0.68). In this period (~165-196 DOY) most of the current-year tree-ring cells are produced by the cambium, providing a clear link between our findings and the physiology of Norway spruce in this region. This physiological-climate relationship is further supported by a strong correlation between EWW and temperature over a similar interval (162-198 DOY, r=0.68), while LWW was related to the temperature over a longer interval (165-302 DOY, r=0.45). The results from correlation analysis between MXD and LBI and daily climate data were similar (r=0.72 and r=0.68, respectively) over the intervals of 110-249 DOY and 97-249 DOY, respectively. Using monthly climate data, MXD and LBI correlation analysis indicated the strongest climate relationship over the April-September period (92-274 DOY). The EWD, MID, and EBI correlated with much shorter periods in the spring season and produced lower correlation values for both monthly and daily climate datasets. The parameters related to latewood density (MXD, LWD, LBI), dBI and CWT were mostly driven by longer periods of temperature data spanning the spring, summer and early autumn (April-September = 64-278 DOY). These findings indicate that parameters representing latewood density are good proxies of growing season temperature reinforcing its usefulness in climate reconstructions.

DC-21 Novel high-resolution climate datasets for the Himalayan Kingdom of Bhutan (Stephen Stewart, Kunzang Choden, Melissa Fedrigo, Stephen Roxburgh, Rodney Keenan, and Craig Nitschke)

Presented by: Stephen Stewart

Large deviations between global climatological datasets, such as the WorldClim and CRU CL 2.0 products, and local weather station observations exist across the Himalayan Kingdom of Bhutan. Biases and error associated with gridded climate data may be problematic for predicting the effects of climate on species distributions and tree growth. The robustness of paleoclimate reconstructions may also be confounded by the use of existing global datasets. To overcome these limitations, we developed high resolution temperature, precipitation and vapour pressure datasets for Bhutan. The interpolated surfaces were developed using a combination of pre-existing and novel spline based methods, which include the use of thermal remote sensing data and local topographic indices for improving temperature interpolation performance. The new climate datasets show distinct differences from the WorldClim and CRU CL 2.0 datasets, and the precipitation surfaces better describe the heavy rainfall experienced in the southern foothills while retaining the effect of orography throughout the central valleys and ranges. The development of vapour pressure surfaces also allows for the calculation of ecologically important variables such as vapour pressure deficit for the region. The datasets presented in this paper should facilitate dendrochronological research in Bhutan.

DC-22 Effect of drought on cork growth along the production cycle (Carla Leite, Vanda Oliveira, and Helena Pereira)

Presented by: Carla Leite

Cork oak is a species that grows in the western Mediterranean region for which the most recent climatic scenarios predict, among others, higher temperatures and reduced

precipitation than usual values. Cork is the outerbark of the cork oak, and has a considerable economic importance for the Portuguese forest and industry due to its specific set of properties, that largely justify the interest as a raw material for multiple usages, from cork stoppers to insulating materials.
This paper presents the results of a dendroclimatological study of the effect of higher temperatures and lower precipitation levels than the long term mean, in different moments of the cork production cycle, namely in the beginning, middle or end of the cycle. The results obtained with this trial can contribute for the sustainability of the all cork sector in a climate change context as forest producers might use them to adapt their managing procedures in a mitigating strategy for the impact of the forthcoming climatic changes.

Tuesday June 12th 14:00-15:15
Presentations DC23-27
(Breakout Room 1)

DC-23 Dendroclimatic evaluation of Cedrus deoadara growing in northeast India (N. Dhirendra Singh, and Ghanashyam Singh Ksh)

Presented by: N. Dhirendra Singh

Tree-ring research in India was initiated with the application in the field of forestry research, growth rate determination, wood productivity and quality. Various studies have been made to find out the dendroclimatic potential of different trees growing in the Indian peninsular and Western Himalayan region. Many of the studies show the relationship between climate and annual growth ring formation in trees of Kashmir region. A considerable number of studies focus on the reconstruction of the pre-monsoon temperature based using tree-ring width indices of *Cedrus deodara* and *Pinus wallichiana* which revealed century scale negative temperature anomalies. The present study deals with the study on the climate growth relationship of *Cedrus deodara* growing in North East India. It was revealed from the analysis that the growth of the tree was influenced by the temperature factor rather than rainfall. Temperature of May to August influenced the growth of the tree.

DC-24 Centennial tree-ring records over north Kashmir, India in the context of recent climate change (Naveen Gandhi, and H. P. Borgaonkar)

Presented by: Naveen Gandhi

Tree-rings are known as excellent proxies for developing millennia long climate records. Such records are useful in understanding climate variability before instrumental era and to assess the effects of the recent global climate change. Tree-ring based studies are limited over the Himalayan region, particularly from the Jammu and Kashmir, INDIA. In the present study, over 100 of tree-ring samples of *Cedrus deodara* and *Abies pindrow* from four different forest sites of north Kashmir are analyzed. The tree-ring chronology from Dangiari spans around 400 years. The tree-ring index chronologies (time span 210-325 years) from Kaleban, Kanzalwan and Mawar sites show a higher growth rate after 1900 A.D. Such rise in the tree growth is limited to recent years in case of chronology from Dangiari. Meteorological data of the Srinagar station which is comparatively closer to the tree-ring sites have been used in

response function analyses to understand the tree growth-climate relationship. The analyses clearly indicate a significant negative (positive) response of summer temperature (precipitation) over the tree growth. Higher temperature results in an increase in the rate of evaporation of available soil moisture received from the small amount of precipitation during summer. As this season coincides with the later part of active growth period of the trees, a loss of soil moisture due to extensive heating likely to affects the tree growth. Therefore, though the higher temperature accelerates the photosynthesis, significant soil moisture deficiency occurs at higher temperatures due to high rate of evaporation and evapotranspiration. More than average precipitation during the season is very useful in maintaining the minimum requirement of moisture and is found to be conducive for the tree growth.

DC-25 Warming-induced response on Tree Growth: A Dendroclimatic Analysis of Teak (Tectona grandis L.F.) from tropical forest of India (Hemant Borgaonkar)

Presented by: Hemant Borgaonkar

Monsoon precipitation (June–September) plays a pivotal role in the agricultural productivity of the South East Asia. Studies have shown significant changes in the frequency and amount of monsoonal precipitation since last three decades as consequences of global warming and other factors. This justifies projection of future climate through various models. Sensitivity of these models largely depends on the precise estimation of some climatic parameters (temperature, rainfall, etc.) in the past especially beyond the period of instrumental observations. Regional dendroclimatic research since last few decades has exhibited that quantitative reconstruction of aforementioned parameters is possible for more than three centuries by studying tree rings with annual resolution. In this paper, four tree-ring width index chronologies of Teak (*Tectona grandis* L.F.) from tropical forest of India are presented. Significant positive relationship of tree-ring chronologies with all India monsoon rainfall (AIMR) and corresponding Southern Oscillation Index (SOI) and Palmer Drought Severity Index (PDSI) indicates the importance of moisture in tree growth-climate relationship. Analysis also reveals the significance of an extended monsoon in the form of a dependence on the climate in the latter part of the summer monsoon and the months following (i.e., September, October and November). It appears that an extension of growing conditions beyond the end of the monsoon period is the most important climatic aspect for producing positive annual growth in teak by extending the trees ability to utilize soil moisture for a longer period of time and keeping leaves longer into the winter before the annual drought sets in. Systematic warming in the region since the 1940s appears to be responsible for a strengthening of an inverse relationship with September - November maximum temperature that is consistent with warming scenarios. Results also indicate the time dependent nature of the relationship to maximum temperature for the late and post-monsoon season, starting around 1940 for September and at about 1950 for the month of October. The importance of temperature for the month of November, however, shows no time-dependence at all, possibly indicating a gradual shifting in the timing of the onset of the dry season since the 1940s.

DC-26 Climate growth analysis of Siberian pine (Pinus sibirica) in Altai Mountains, northwestern China (Sher Shah, Yu Jian, Liu Qijing, Shi Jingning, Adnan Ahmad, and Abdul Manan)

Presented by: Sher Shah

Dendrochronology generally works under the assumptions that A1:J50-growth relationship is age-independent, once growth trends and/or disturbance pulses have been accounted for. However, many studies show that the tree structure and physiology changes with the age causing the climate-growth signals to waver over time. Using chronology statistics and climate growth analysis using (dplR) and (treeclim) package of the R software. The chronology shows highly significant relation to the last year July temperature and showing significant negative relation to the December temperature. There are no significant relations found with the maximum temperature (Tmax) in the other months. The significant negative relations found in the last year October precipitation, a highly significant relation in the May precipitation and very highly significant relation in the current March precipitation. The ring's width showing no significant relations to the June July precipitation of the last and current year and no as such relation to temperature as well. Only December temperature showing the significant relation among 200 years long chronology of the Siberian pine. On the base of our results, we can't say that that June July temperature and precipitation and Dec, Jan temperature has a significant effect on the ring widths of the Siberian pine. The results of this study show that Siberian pine trees are less sensitive to the temperature and precipitation. As the Siberian pine life is 800 years long and the chronology length is up to 200 years showing that these are young trees. Another reason is that this tree survives in extreme cold temperature and cold wind exposure of the continental climate. This species requires more extensive research because of the limited research done on the climate-growth studies of this species. Paleo-climate reconstruction studies need to conduct for this species in future.

DC-27 How does the last half century compare to the last millennium? Examining new temperature reconstructions for southeastern Australia (Kathryn Allen, Ed Cook, Brendan Buckley, Rob Evans, Michael Grose, and Patrick Baker)

Presented by: Kathryn Allen

Robust annually resolved temperature reconstructions in the Southern Hemisphere (SH) are rare compared with the Northern Hemisphere. We have developed two nested 979-year mean temperature records for Tasmania over the Austral summer (December – February) based solely on Tasmanian tree-rings. The first model is based on all potential tree-ring predictors available (unrestricted reconstruction), and the second constrained to use records only from *Lagarostrobos franklinii*, a species particularly sensitive to summer temperatures (restricted reconstruction). Our reconstructions depend on a mixture of ring widths and wood properties such as density, tracheid radial diameter and cell wall thickness. Both reconstructions explain between ~50 and 66% of the variance for each nest, although the restricted reconstruction exhibits superior verification statistics. Both reconstructions show strong positive relationships with temperatures over southeastern Australia and moderate negative relationships with temperatures in the coastal northeast of the continent. We find that the periods centred on 1300, 1320 and 1500 CE were as warm as the most recent

period, but that the elevated temperatures since ~1950 - shown as a step-change in our reconstruction - have persisted longer than any of the three earlier periods and are due to a lack of cool summers. A comparison with projections for the region illustrates that by 2100 CE mean summer temperatures will substantially exceed reconstructed median temperatures over the past millennium. The strength of our SH reconstruction and their spatial signature also highlights the importance of high quality sub-regional reconstructions where multiple large-scale ocean-atmosphere processes drive climate over a region.

Wednesday June 13th 10:30-11:15
Presentations DC28-30
(Breakout Room 1)

DC-28 Tierra del Fuego revisited: new dendroclimatic reconstructions based on recently updated tree-ring network from the southernmost forests of the world (Vladimir Matskovsky, and Fidel A. Roig)

Presented by: Vladimir Matskovsky

For the last decades, many areas of southern South America have experienced climatic and ecological changes that are driven by global and hemispheric-scale ocean-atmosphere interactions. In order to place these recent changes in a long-term context, and to make them more predictable, we need to explore proxy climate archives extending behind the relatively short instrumental climate records. Tierra del Fuego Island is the southernmost woodland region of the World and is placed close to the Antarctic Peninsula and the Circum-Polar Current, the oceanic factor that controls most of the climate around the Southern Hemisphere. This makes proxy tree-ring data from Tierra del Fuego to be a valuable source of palaeoclimatic information on regional and hemispheric scale.
The main objective of this study is to identify long-term climate variability and its extremes in Tierra del Fuego from a tree-ring chronology network covering the insular territory. For this purpose, the climatic response of tree ring network consisting of 39 sites of *Nothofagus pumilio* that was developed in 1980-s, 1990-s and 2000-s was reanalysed. According to the results the best responding chronologies were updated in the season of 2017/18. In total 13 chronologies were updated up to the ring of 2016 (growing season 2016/17). The updated network covers the period of AD 1648-2016.
The results of reanalysis of the updated network showed that it has the best skill in reconstructing climatic parameters of the end of the growing season (February) that depend on maximum and especially minimum temperature (diurnal temperature range, cloudiness, frost day frequency). Also it is important to filter out the persistent 7yrs nonclimatic cycle from tree ring chronologies. Several reconstructions covering last 2-3 centuries are presented and discussed.

DC-29 June air temperature reconstruction based on tree-ring width of spruce in the Solovki Island (1676-2012) (Ekaterina A. Dolgova, Olga N. Solomina, Vladimir V. Matskovsky, and Elena A. Cherenkova)

Presented by: Ekaterina A. Dolgova

Tree-ring collections from the northern part of European Russia were mostly collected in the 1970s and 1980s and were never updated since that time. In this study we present the results of the spatio-temporal analysis of the climatic signal of spruce (*Picea abies* (L.) Karst and *Picea obovata* Lebed.) growing in the Solovki Islands in different ecological conditions. Solovki is one of the most promising region from the point of view of dendrochronology: the archipelago is located in the vicinity of the northern tree limit, is reach in the spruce of old age and wooden architectural monuments dating back to 12th century when the Solovetsky monastery was established.

As a result more than 140 tree-ring width series were successfully cross-dated and used for developing 12 local chronologies. All local chronologies were compared with temperature and precipitation records. All local chronologies showed statistically significant common sensitivity to June air temperature variation. Pearson's coefficients of correlation vary from 0.26 to 0.56 ($p<0.05$). Final composite spruce tree-ring width chronology covers the period 1626-2012 ss. and consists of 134 samples. EPS value exceeds the threshold value 0.85 after 1676 when at least 6 samples are present in the chronology.

The bootstrapped response climate analysis revealed a positive relation of spruce growth to June-July air temperatures of the current year and a negative one to temperature in February. There is also a positive response of spruce growth to July precipitation of the current year. June air temperature is the most distinct climatic parameter controlling spruce growth which is reflected in both static and moving response function analysis. Computed moving correlation between the spruce chronology and the climatic factors shows that only the correlation with June temperature is stable over time. The relation is weaker in the beginning of the instrumental records ($R= 0.3 - 0.4$, $p<0.05$) but it is getting stronger since 1920s ($R = 0.5\text{-}0.6$, $p < 0.05$). July air temperature signal disappears in the beginning and in the end of the instrumental period.

Statistically significant and temporally stable relation between the composite ring width spruce chronology and June air temperature allowed to reconstruct this parameter back in time. For the reconstruction the composite chronology was scaled against June air temperatures. Comparison between predicted and actual June temperatures revealed a good agreement over the period 1901-2012. Positive values of RE and CE statistics indicate predictive skills of the applied model. This finding allowed to reconstruct the June air temperature using spruce tree-ring width chronology since 1676. According to smoothed by 30-year spline reconstruction the cold anomalies date back to 1676–1680, 1761-1823, 1836-1899, 1935-1952, and 1960–1979, and the warmings occurred in 1681-1760, 1824-1835, 1900-1934, 1953-1959, and 1980–2012. The coolest reconstructed June air temperature occurred in 1836 and was 2.9 ^{0}C cooler than the reference period (1901-2012). Other strong cold anomalies in June were identified in 1976 (–2.4 ^{0}C), 1982 (–2.4 ^{0}C), 1820 (–2.4 ^{0}C), 1790 (–2.3 ^{0}C), 1817 (–2.2 ^{0}C), 1879 (–2.1 ^{0}C), and 1810 (–2.1 ^{0}C). According to the reconstruction the warmest June temperature occurred in 1685 (+3.0 ^{0}C).

The comparison of June temperature reconstruction with the dates of major climatically effective explosive volcanic eruptions (Sigl et al. 2015) showed that many reconstructed coldest years, such as 1836, 1982, 1817, 1810, 1661 and 1674 CE occurred after major tropical volcanic eruptions (Briffa et al. 1998; Sigl et al. 2015) or followed within several years (1-2 years). The coldest June temperature anomaly in the reconstruction occurred in 1836 CE after the eruption of Cosiguina (Nicaragua) in June 1835. This research is funded by the Russian Scientific Foundation № 17-77-20123.

DC-30 Three century long pre-monsoon temperature reconstruction from central Nepal based on tree rings analysis (Sugam Aryal, Narayan Prasad Gaire, Prabina Rana, Deepak Kumar Kharal, Basanta Sharma, Nawaraj Pokharel, and Jaishree Sijapati)

Presented by: Sugam Aryal

Nepal is witness of the rapidly happening climate change and its effects on diverse sectors including forest and biodiversity. However, response of biodiversity to climate change is being analysed based on station based short climatic data. However, to have long perspective on past climate change and impacts, we have to find alternative proxy climate source. Tree ring as proxy climatic source can fulfil the gaps in climatic data in Nepal Himalaya. A dendroclimatological study was carried out in Manang region with the aim to know the climatic response of the tree-growth and to reconstruct long climatic history in trans-Himalayan region of Nepal Himalaya using tree ring of *Tsuga dumosa* (Himalayan hemlock). We collected more than 40 tree core samples from Timang area of Manang. Treering data were prepared and analysed using commonly used dendroclimatic procedure. Standardization was carried out using signal free approach along negative exponential curve fitting and age-dependent spline. A 618 years long chronology was developed spanning from 1399 to 2017 C.E. The portion of chronology from 1702 to 2017 C.E. was found to be significantly replicated by 85% of the samples. This 316-years long portion of chronology was then used for further analysis. The growth-climate relationship showed that *Tsuga dumosa* was sensitive to the seasonal temperature. It showed negative response (r = 0.59) to the pre-monsoon (March-April) temperature and positive response (r= 0.38) to the monsoon (June-September) temperature. In case of rainfall, it showed positive response to the March (r= 0.31) rainfall and negative response to June (r= 0.27) and August (r= 0.34) rainfall. The response of chronology with pre-monsoon (February-April) season was considered to be statistically significant for climatic reconstruction. The simple linear regression model was prepared using mean temperature of March-April. Our growth-climate model was robust for climate reconstruction with positive value of RE (0.568) and CE (0.215). Finally, 316 years long pre-monsoon (March-April) temperature was reconstructed from 1702 to 2017 C.E. The reconstruction shows distinct warm and cool period. The average temperature of whole reconstructed period was 10.4oC. The trend of reconstructed pre-monsoon temperature appeared to be increasing from 1702 to 1725 C.E. which is followed by decreasing trend up to 1760 C.E. The trend goes up in 1780 C.E and again fell down to the least value during 1860s. Afterwards, the trends sharply went up in 1880 C.E. before rising up again in 1960s it experienced a depression in 1920 C.E.. In recent years the trend was decreasing with the beginning of 21st Century. This reconstruction will be helpful to understand the long climatic history of the central Himalaya.

Forest Inventories and the Study of Global Change

Session Chairs:

Dr. Margaret Evens; LTRR, University of Arizona, Tucson, Arizona, USA
Dr. Neil Pederson; Harvard Forest, Petersham, Mass., USA

Forests contribute to roughly 40% of the annual global carbon sink. Critical questions at this juncture of the Anthropocene regarding the terrestrial carbon sink are, 'What are the drivers of terrestrial carbon sequestration?' and 'How will these systems respond to global change?' Tree rings have the potential to determine not only the trends of the forest carbon sink in recent decades, but also the drivers of the variability of this sink from seasonal to centennial time scales. Quantifying the drivers and variability of the forest carbon sink from tree rings, however, is still in its infancy and sorting out the possibilities from the limitations of using tree rings is fundamental to the use of dendrochronology as a proxy for addressing the global carbon sink. As we have done throughout the history of dendrochronology, we depend on other measurements of forest growth, thus, for this session, we welcome any studies addressing the terrestrial carbon sink using tree-ring data alone or in combination with or comparison against satellite, forest inventory, or eddy-flux measures of forest growth. Further we welcome expansions of the traditional dendro toolbox that consider multiple drivers of tree growth simultaneously (sensu the linear aggregate model), that model absolute rather than only relative growth, that integrate tree-ring data into process-based models of tree growth or vegetation dynamics, that address the challenges of using long time series with a fading record of stand dynamics, and that link growth and mortality processes via tree-ring data.

Monday June 11th 10:30-12:30
Presentatons MI1-8
(Breakout Room 2)

FI-1. National Forest Inventory of Bhutan (Timothy G. Gregoire)

Presented by: Timothy G. Gregoire

A multi-stakeholder meeting was convened in January 2009 to present preliminary thoughts on the possibility of designing and implementing a National Forest Inventory for the nation of Bhutan. The idea was met with widespread acceptance and encouragement. This presentation will describe the planning and implementation of the NFI, which has now been completed.

FI-2. Improving predictions of forest succession with data assimilation (Michael Dietze, Andria Dawson, Istem Fer and Jason McLachlan)

Presented by: Ann Raiho

Ecological succession is an important aspect of terrestrial ecology to be able to predict and can be modelled using process based models of vegetation dynamics. As climate changes, competitive interactions between species will also shift, challenging the predictability of ecological succession. Tree ring data are able to capture changing dynamics between tree species and shed light on how ecological succession can change with changing climate. At Harvard Forest, one of the most well studied temperate forests, ecological succession has not followed the predicted course. Both theoretical models and surrounding modern forest inventory data would predict red maple (*Acer rubra*) dominance, but red oak (*Quercus rubra*) has come to dominate. It is unclear what is driving red oak dominance at Harvard Forest. Tree ring data collected at Harvard Forest capture competitive dynamics that may have led to red oak dominance over red maple, but without a process model for ecological succession, it is difficult to determine the mechanism that led to red oak outcompeting red maple. Data assimilation is a tool that can be used constrain process models with tree data to improve predictability of process models and tease apart ecological mechanisms behind changing forest succession. Here, we assimilate tree ring estimated species growth increment into a forest gap model that represents the important processes of ecological succession. We found that starting the model with the correct data-derived composition and biomass greatly improved our prediction. We also found that growth between red oak and red maple are much more negatively correlated than models or data alone would predict. Furthermore, these data assimilation tools have been built in a generalized framework and can be applied to a multitude of ecological problems that dendrochronologists wish to answer.

FI-3. Accounting for the ecological memory of tree-growth to interacting disturbances: the importance of quantifying persistent and cumulative effects (Andria Dawson, Malcolm Itter, Loic D' Orangeville, Daniel Kneeshaw, Louis Duchesne, and Andrew Finley)

Presented by: Andria Dawson

Interactions between disturbances such as drought and insect defoliation may dramatically alter forest function under novel climate and disturbance regimes. However, the effects of these disturbances remain poorly understood. Current understanding suggests that trees exhibit delayed, persistent, and cumulative growth responses to these disturbances, and that physiological feedbacks in tree responses to these disturbances exacerbate their impacts on tree growth. These hypotheses remain largely untested at the landscape scale.
To test these hypotheses, we developed a Bayesian hierarchical that quantifies the effects and interactions of drought and defoliation on radial tree growth, while explicitly accounting for ecological memory of tree growth to these disturbances. The model considered both vulnerability to the defoliator (host versus non-host) and tree size (dominant versus understory). The model was applied to extensive tree growth, weather, and defoliation survey data from western and eastern regions of the Canadian boreal forest characterized by contrasting tree compositions, climates, and insect defoliators.
Results revealed persistent, decadal-scale tree growth responses to past water and

defoliation stress that varied among regions. Tree growth responses to water and insect defoliation stress were found to last up to a decade. Tree growth was negatively related to both water deficit and insect defoliation (host trees only). However, interactions between water and defoliation stress did not exacerbate disturbance impacts on host tree growth even after accounting for persistent and cumulative effects. This result is consistent with earlier experiments; it suggests that feedbacks in host tree responses to drought and insect attack may be weaker than predicted for defoliator-dominated boreal forest systems.
This work advances (i) the methods used to quantify ecological memory and (ii) understanding of persistent and cumulative disturbance impacts on tree growth. Both of these advances are a step towards improving predictions of forest function in future environments.

FI-4. Old carbon in the rainforest understory: complementary evidence from inventories and growth-ring patterns (Bhely Angoboy, Tom De Mil, Wannes Hubau, Joris Van Acker, and Jan Van den Bulcke)

Presented by: Hans Beeckman

Not less than 400 Pg carbon is stored in wood globally. This is almost half of the total carbon stock in the world's forests where tropical forests represent a share of 55 %. These quantities justify research efforts on the carbon dynamics of tropical rainforests.
Key factors of carbon dynamics like tree recruitment, growth and mortality are classically quantified through subsequent inventories of intact forest plots. The level of system integration of this approach is the forest community. The question arises whether growth-ring studies of individual trees could provide complementary information on the carbon cycle. The strength of the community based approach is the high number of tree measurements which make it particularly appropriate for communities that consists of many different species and size classes. Typical constraints are lacking metadata on stand history, point of measurement issues and measurement precision. A growth-ring study relies on exactly dated wood and high precision of measurements, but does not capture the community dynamics of a dense moist tropical rainforest. We evaluated whether the strengths of both approaches could compensate for the weakness of the other in a context of research on carbon dynamics.
Given this setting, we explored whether tree ages inferred from forest surveys are substantially different from ages based on ring counts, we tested correction protocols for forest censuses using reference ages from ring studies and we studied the carbon uptake through a community approach and a dated wood approach.
We measured trees in a semi-deciduous rainforest in the western Congo Basin forest belt, both in 5 permanent sample plots of 1 ha (surveyed in 2009, 2016 and 2017) and along a phenological trail that originally consisted of 6315 trees (annual tree measurements from 1948-1957 were found back) and where we recently rediscovered 448 trees. In 2013 and 2014 we were able to take wood samples from 55 trees alongside the trail that showed traces of ingrown nails, originating from tree labelling in 1948. This offers unique opportunities for a cambial wounding experiment spanning 66 years.
Nail traces allowed exact dating of tree increments. Many trees showed patterns of growth rings, but very often these appear as anatomically indistinct or non-periodical. Only a limited number of individuals from a few species showed tree rings that are annual, but cross dating of these was not successful.

We estimated total tree age using the number of rings formed between 1948 and 2014. We compared this reference age with ages inferred from tree size and annual increment in the permanent sample plots (dividing final DBH by the annual DBH growth during the period 1948-2014). Tree age inferred from DBH growth produced fairly well age estimations for young trees, but for trees older than 200 years, ages are both under- and overestimated. Census data from the permanent sample plots made clear that DBH data from 5 % of the trees needed to be corrected, which is common when dealing with forest inventories. A correction protocol has been developed to avoid that trees showing a zero, a negative or a very small increment impact the general analysis. We identified a correction protocol that resulted in realistic tree ages.
Plot-level mean tree ages and mean carbon ages where significantly higher in the understory and the emergent trees, compared to intermediates classes. Understory trees grow slowly and non-periodically, but they store more than half of the stand-level aboveground carbon, they contribute more to net carbon uptake and they outlive most of the canopy trees. Understory trees maintain a stable carbon pool, while carbon in larger trees is subject to faster turnover.
The major role of growth-ring analysis in a context of analysis of carbon budgets of undisturbed forests is avoiding unrealistic tree ages in correction protocols of census data. When forests are disturbed, either logged or degraded by overuse, growth-ring studies need to be considered in analysis of past and ongoing carbon sequestration processes, but substantial dating efforts remain necessary.

FI-5. Ecological forecasting of future tree growth based on tree rings: a continental-scale analysis of Douglas-fir (Pseudotsuga menziesii) (Justin DeRose, and Margaret E.K. Evans)

Presented by: Stefan Klesse

The relationship between climate variation and tree growth encoded in annual growth rings has long been exploited by dendroclimatologists to reconstruct past climates. More recently, statistical climate-growth relationships are being used for ecological forecasting of future tree growth. Here we forecast future growth of one of North America's most important tree species, *Pseudotsuga menziesii* (Douglas-fir), using the largest tree-ring dataset compiled for this species to date, comprising >29,000 time series from >2,600 locations from the northern distribution limit in British Columbia to the southern edge in southern Mexico. Given this exceptionally large geographic distribution, spanning >30Â° of latitude, our analysis explicitly accounts for how climate sensitivities vary continuously across environmental gradients. We analysed climate-growth relationships using a generalized linear mixed effects (LME) model that simultaneously analyses the influences on tree growth of three groups of predictors: (1) tree size and age (circumventing the need for detrending of raw ring widths), (2) annually varying climate variables, and (3) 30-year climate normals. Our analysis included "representative" samples of increment cores collected within the national forest inventories (NFI) of Mexico and the U.S. Downscaled CMIP5 climate projections were used to forecast future growth under a warming climate.
Output from the LME model yields good model calibration/verification statistics throughout the range of Douglas-fir. The percent of year-to-year variance explained in regional chronologies during the 20th century varies from 40% in the Pacific Northwest to almost 80% in the southwestern United States. Patterns of absolute predicted radial growth increment match well that of independently assessed productivity estimates (i.e., site index)

of USFS Forest Inventory & Analysis program. While the results mirror previously reported projections of large-scale growth declines by the end of the 21st century, the projected growth declines are notably smaller, particularly when based solely on the representative NFI samples. We even identify regions where Douglas-fir growth might increase under projected climate change.
This work highlights the value of tree-ring data for ecological forecasting of future tree growth, the importance of using a representative and densely replicated tree-ring dataset and analyses that capture continuous variation in climate sensitivities.

FI-6. Boreal forests of Eastern Canada: beneficial effects of climate warming on growth may be transitory (Loic D'Orangeville, Daniel Houle, Louis Duchesne, Yves Bergeron, Rich P. Phillips, and Daniel Kneeshaw)

Presented by: Loic D'Orangeville

Predicted increases in temperature and aridity across the boreal forest region have the potential to alter timber supply and carbon (C) sequestration. Given the high degree of inter- and intra-specific variation in climate sensitivity of boreal species to recent warming, there is an urgent need to develop species-specific predictive frameworks that account for local conditions. Here, we matched the growth of 270,000 trees across a 761,100 km² region with detailed site-level data to quantify the growth responses of the seven most common boreal tree species in Eastern Canada to changes in climate. Applying growth models to trees within the boreal region, we show that conifer growth is mostly limited by water scarcity in southern regions but constrained by excessive water in northern regions. In contrast, broadleaf tree growth is largely insensitive to climate. Our growth models indicate that in the absence of disturbance, forest productivity could increase by 8-11±3% with warming up to 2°C. Additional warming (3-4°C above ambient) could cancel this gain and lead to substantial declines reaching 12±3% under 5% reduced precipitation. Our results confirm the transitory nature of warming-induced growth benefits in the boreal forest and highlight the vulnerability of the ecosystem to excess warming and drying.

FI-7. Linking climate and [CO2] variability to forest productivity and growth using process-based models and dendrochronological data (Guillermo Gea-Izquierdo, Dario Martin-Benito, Fabio Gennaretti, and Joel Guiot)

Presented by: Guillermo Gea-Izquierdo

Forests will experience new environmental conditions with a warming climate and higher atmospheric [CO2] (ca), resulting in higher evaporative demands and water stress. Elevated ca, however, could help trees partially mitigate the negative effect of more constraining climatic conditions. New modeling efforts attempt to assess forest performance under these new environmental conditions. Models mimicking functional processes at the individual and stand scale need to address carbon source and carbon sink limitations, and doing this requires to account for a number of functional traits including leaf and cambial phenology, as well as assessing xylem hydraulics and their interaction with carbon assimilation. Carbon sink

limitations imposed by low temperatures and hydraulic constraints related to cell turgor are key to understand cambial activity. These functional processes need to be modelled by (non-linear) climatic responses with a sound biological basis. Yet, we are still far from fully understanding the mechanisms determining plant functioning and, among others, how tree growth responds to the interaction between moisture and CO2 availability. In order to get unbiased estimates of the different traits involved, models need to be calibrated with the appropriate data. Data such as eddy-covariance carbon flux estimations, continuous growth measurements, transpiration (sap-flow) and forest plot inventory data need to be combined to properly address carbon and water fluxes. Assimilating dendrochronological data in complex models contributes with its large spatio-temporal coverage, but we also need to acknowledge limitations of individual tree ring-width data to address stand dynamics of carbon and water. Here we discuss the development of a process-based model (MAIDEN), which includes stand-level carbon assimilation, carbon allocation and water fluxes. The model was tested to different types of data, including dendrochronological growth data at tree- and plot-level (stand-based) from biomass- and repeated measurement plots. Assessing the effect of disturbances and management and maintaining scales (i.e., avoiding unitless model projections) is key to provide unbiased estimates of carbon pools and water fluxes to project forest dynamics. The model is applied to different forest types and functional species and we present different applications of the diverse processes modelled. We discuss shortcomings of current modeling approaches including model overestimation of the effect of ca and discuss potential future directions to improve the representation of basic functional processes in tree performance under a changing environment.

FI-8. Age structure and disturbance history of an old-growth temperate rainforest in the Caucasus (Dario Martin-Benito, Neil Pederson, Mehmet Dogan, Nesibe Köse, Harald Bugmann, and Christof Bigler)

Presented by: Dario Martin-Benito

Temperate rainforests of the Caucasus are unique in their environmental conditions and species composition, which is mainly dominated by *Fagus orientalis* (oriental beech) with varying conifer components. Because their climate is warmer than central European forests they could serve as analogues to future forests in parts of Europe. Their stand and biomass dynamics, however, have received little attention in ecological research. We studied the structural changes and disturbances of an old-growth forest in the western Caucasus of Turkey between 1600-1900 m a.s.l. using dendroecological methods on five plots and over 250 trees distributed across all diameter classes. Although the forest is mainly composed of oriental beech, individuals of the less shade tolerant *Picea orientalis* (oriental spruce) are also present across the ca. 300 ha old growth forest. Both species showed a wide range of ages, up to >400 years. With these data, we explore the forest dynamics at the centennial scale and to analyse the roles of disturbance, competition, and climate in driving the structures and growth of these forests. Radial growth patterns showed that both species can withstand long periods of suppression with very low growth rates and access the canopy layer only after several release events. The extension and good conservation conditions of these forests make it unique and calls for their protection.

Dendroarchaeology

Session Chairs:

Dr. Gretel Boswijk; School of Environment, University of Auckland, Auckland, New Zealand
Dr. Marta Dominguez Delmas; University of Santiago de Compostela, Dept. Botony, Santiago, Chile
Dr. Kathy Allen; University of Melbourne, Melbourne, Australia

This session highlights current research in dendroarchaeology. Dendroarchaeology is a broad area of research, encompassing chronology development, dating, development of landscapes, and past human use of forest resources, including provenance, trade, and use and reuse of timber on land and sea. We encourage papers addressing any of these topic areas and which present new insights into past societies and human behaviour concerning wood use. Papers presenting new advances in dendroarchaeological methodologies or which are leading research in new regions are also welcomed.

Monday June 11th 14:00-14:45
Presentations DA-1,3
(Breakout Room 2)

DA-1 The first accurate and precise calendar dating of a New Zealand Māori Pā (Gretel Boswijk, Alan Hogg, Warren Gumbley, Fiona Petchy, John Southon, Atholl Anderson, Tom Roa, and Lloyd Donaldson)

Presented by: Gretel Boswijk

New Zealand's archaeological landscape is dominated by a class of fortified villages known as pā. Pā are found mainly in the horticulture districts of the North Island, and their appearance in the landscape is associated with socio-economic and political changes in Māori society. However, understanding of these places is limited by a lack of precision of radiocarbon dates within the context of New Zealand's short prehistory. This talk presents results from a pilot project combining tree-ring analysis and high resolution radiocarbon wiggle-match dating of preserved palisade posts from Otāhau Pā, Waikato, which provided the first accurate and precise calendar dating of a New Zealand Māori pā.

DA-2 The Jordaens Van Dyck Panel Paintings Project – first dendrochronological insights (Andrea Seim, Johannes Edvardsson, Aoife Daly, Pascale Fraiture, Rūtilė Pukienė, Willy Tegel, Ian Tyers, Tomasz Wazny, Justin Davies, and Joost Vander Auwera)

Presented by: Andrea Seim

The Jordaens Van Dyck Panel Paintings Project is an innovative multidisciplinary art historical initiative that is systematically studying the oil paintings on oak panels by Jacques Jordaens (1593-1678) and Sir Anthony Van Dyck (1599-1641). An ongoing dendrochronological survey of nearly 300 oil paintings, combined with the study of the Antwerp panel makers' and Guild brand marks on the reverse of the panels, new archival research and traditional art historical scholarship, aims at a better understanding of the lives and works of these artists and paintings on wood panels in the 17th century.

Here we present first results of non/micro-invasive dendrochronological analyses and the dating of 222 oak planks of 106 paintings. So far, 73% of the paintings were dated and the heartwood dating can be often pinpointed to a narrower period using Antwerp panel makers' and Guild brand marks. Moreover, most of the oak trees used for the planks of the wood panels originate from mostly two non-specific regions within the former Baltic region (Baltic 1 and Baltic 3 reference chronologies). Comparison of the tree-ring series between all planks further shows that some planks utilized for the different wood panels, and thus different paintings, were even taken from the same tree. This comprehensive art historical-dendrochronological approach provides new insight into the collaboration between the two famous Flemish painters and the temporal succession of the paintings that are now located in various museums around the world.

DA-3 Precise oxygen isotopic dating of tree-rings: Development and evaluation of a new dating tool in Science-based Archaeology. (N.J. Loader, C. Bronk Ramsey, D. Davies, D. Miles, D. McCarroll and G.H.F. Young)

Presented by: N.J. Loader

A new technique for precision dating in dendrochronology and Quaternary research is introduced. The technique is grounded in the statistically-robust matching of stable oxygen isotope ratios in tree-ring cellulose, and is capable of absolutely dating wooden artefacts with annual precision. This presentation describes the development of the master chronology and introduces the protocols for assigning a date. The method is evaluated through the application of the isotopic dating method to case studies where conventional approaches alone have been unable to provide dates. The wider scope and application of the technique is discussed in the context of the historic dating sector and with specific reference to the reporting of dates, the analysis of non-oak species and the combination of dating results to refine uncertainties in radiocarbon dating. Precision isotopic dating is applicable to samples previously considered "un-dateable" by conventional dendrochronology.

Wood Anatomy and Modeling Wood Formation

Session Chairs

Dr. Jesper Bjorklund, *WSL, Zurich, Switzerland*
Dr. Kevin Anchukaitis; *LTRR, University of Arizona, Tucson, Arizona, USA*

While the focus of dendrochronology has traditionally been on whole ring metrics, particularly annual ring width, new research avenues have increasingly focused on sub-annual and cellular characteristics. In particular, wood anatomical analyses permit a finer temporal scale understanding on the controls on ring formation, can reveal meteorological influences on xylogenesis, and link tree physiological processes to biological and environmental influences on growth and wood properties. Combined with statistical and mechanistic modeling of these processes and their outcomes, the wealth of information contained in the fine-scale, cellular, and anatomical characteristics of growth rings can be leveraged for a better of understanding of the links between forests and their environment, from the cambium to the biosphere. This session welcomes contributions on all aspects of wood anatomical analysis and modeling, including but not limited to the development of high-resolution, tracheid, sub-annual, or wood property chronologies, qualitative and quantitative wood anatomy, image analysis and development of new sub-annual proxies, micro-coring techniques and repeated measurements, studies and simulations of xylogenesis and cellular properties, and research using wood anatomy and modeling to understand tree physiology and evolution.

Monday June 11th 14:45-15:30
Presentations WA1-3
(Breakout Room 2)

WA-1 Disentangling the climate-driven bimodal growth pattern in coastal and continental Mediterranean pine stands (Arturo Pacheco, J. Julio Camarero, Montse Ribas, Antonio Gazol, Emilia Gutierrez, and Marco Carrer)

Presented by: Arturo Pacheco

Mediterranean climate promotes two distinct growth peaks separated by summer quiescence in trees. This bimodal pattern has been associated to favourable growing conditions during spring and autumn when mild temperatures and soil-water availability enhance cambial activity. Climatic models predict progressive warming and drying for the Mediterranean Basin, which could shorten or shift the spring and autumn growing seasons. We explored this idea

by comparing two sites with different Mediterranean climate types (continental/dry and coastal/wet) and studied how climate drives the bimodal growth pattern in Aleppo pine (Pinus halepensis). Specifically we investigated the intra-annual changes in wood anatomy and the corresponding formation of density fluctuations (IADF). Trees on both sites were analyzed by dendrometer monitoring and by developing chronologies of wood anatomical traits. Radial-increment dynamics followed a similar bimodal pattern in both sites but coastal trees showed higher increments during the spring and autumn growth peaks, especially in autumn. The summer rest of cambium activity occurs almost one month earlier in the coastal than in the inland site. Lumen area and cell-wall thickness were significantly smaller in the continental site, while the increment rate of cell-wall thickness during an IADF event was much higher in the coastal pines. The accumulated soil moisture deficit was the main climatic constraint of tracheid enlargement in continental pines. Intra-annual density fluctuations were more frequent in the coastal trees where wood anatomy features recover to average values after such events, meanwhile inland trees presented a much lower recovery rate. Growth bimodality and the formation of density fluctuations were linked, but mild climate of the coastal site allows a longer growing season, which explains why trees in this area showed higher and more variable growth rates.

WA-2 Dynamics of cambial phenology in Abies pindrow along an altitudinal gradient in the northwestern Himalayas (Rayees A. Malik, Sergio Rossi, and Raman Sukumar)

Presented by: Rayees A. Malik

The process of wood formation in conifers, known as Xylogenesis, is largely influenced by regional climatic conditions. In colder regions, temperature is a critical climatic factor regulating the process of Xylogenesis. A good knowledge of cambial dynamics and wood formation in trees is crucial to understand how trees will respond to future climate change. To understand the dynamics of vascular cambium and dynamics of xylem formation in Abies pindrow, 10 trees each from 3 altitudinal sites (2300-3000 m) were selected in the northwestern Himalayas. The dynamics of cambial activity and xylem formation were monitored by collecting microcores from stems at weekly to biweekly intervals in 2014 and 2015. The fixed sections were analysed under a light microscope at 100-400 x magnifications. The different stages of Xylogenesis were differentiated based on various cell features like cell size, presence/absence of cytoplasm, glistening cell wall under polarized light, colour change etc.
We found that the duration of wood formation was significantly correlated with altitude. The mid-altitude trees showed similarity to high altitude trees in some features and to low altitude trees in other features. There was no significant difference between low and mid sites in growing season duration. While as growing season duration in high altitude site was significantly different than the low and mid site. Mid and the high site showed no significant difference in total cell number; while as low site has significantly higher cell number than other two sites. Further, there was no significant difference between 2014 and 2015. These findings provide new data on the timing and duration of wood formation and will help to quantify the response of tree growth to predicted climate warming in Himalayan conifers.

WA-3 Long-term meets high-resolution: 1000-yr cell-anatomical chronology from northern Finland (Georg von Arx, Markus Stoffel, Jan Esper, and Marco Carrer)

Presented by: Georg von Arx

Dendroanatomy is an emerging field in tree-ring sciences. It analyses variations in cell features along dated time series of woody-plant rings to extract novel and high-resolution environmental information. The sequential radial progression of cell growth from earlywood to latewood allows matching of intra-ring cell position with intra-annual time of formation. Furthermore, xylem cell structure and function are mutually linked. This means the structural properties of xylem cells define their function and inversely, woody plant responses to environmental variability influence the structural properties of xylem cells. Thus, several novel proxies related to water transport and carbon allocation can be derived from the same anatomical measurements. These characteristics make dendroanatomy an extremely powerful source of information. Yet, methodological improvements only recently allow accessing the full wealth of the xylem cell archive. Here we present a millennium-long cell-chronology of *Pinus sylvestris* established from the N-scan material in northern Finland. Chronologies of multiple cell parameters will be presented and the quality of the climatic imprint in cell-chronologies in terms of high- to low-frequency variability will be compared to other tree-ring proxies (TRW, MXD) available from the same site.

Mountain Dendrochronology

Session Chairs:

Dr. Peng Zhang; *Climate Prediction Lab., Chonnam National University, Gwangju, Korea*
Dr. Olga Solomina; Russian Academy of Sciences*, Moscow, Russia*
Dr. Hans Linderholm; *GULD, University of Gothenburg, Gothenburg, Sweden*

Mountain environments are particularly sensitive to climate change, and mountain ecosystems can be severely and rapidly affected by changes in temperature and precipitation patterns. Many mountain environments have experienced a higher rate of warming than the global average in the last century. Given the general lack of observational data and environmental indicators from, especially, high-elevation areas, trees can provide highly important information about past conditions as well as act as indicators of ongoing climate change. This session focuses on various aspects of tree-ring research in mountain areas. We welcome papers presenting investigations conducted in mountain environments, including, but not limited to, climate reconstructions, impact studies on both natural and human systems, tree-line dynamics, dendrogeomorphological and dendroglaciological investigations.

Tuesday June 12th 10:30-12:15
Presentations MD1-7
(Breakout Room 2)

MD-1 Topography Mediates Climate and Growth of High Elevation Bristlecone Pine in the Great Basin of the Western United States (Andrew G Bunn, Mathew W Salzer, Kevin J Anchukaitis, and Malcolm H Hughes)

Presented by: Andrew G Bunn

Topography at the scale of tens of meters affects air mass movement and shortwave radiative inputs resulting in complex patterns of maximum and minimum temperatures in mountains. Using climate surfaces interpolated from thermochron data we show that the patterns of growth in ancient Bristlecone Pine (*Pinus longaeva*) are mediated by topoclimate at the alpine treeline ecotone. For instance, trees at the same elevation can experience minimum daily temperatures that vary five or more degrees Celsius based on cold air pooling resulting from topography. We show that trees situated in biophysical settings with colder growing season temperatures are more sensitive to interannual and decadal temperature variability than trees at the same elevation growing in warmer topographic exposures. We present data on growth patterns, frequency response, frost-ring formation, and results from forward process modeling showing the importance of considering topography as a modifier to tree growth from trees on a single mountain slope and discuss the impacts for climate inference.

MD-2 Climate Change and tree-limit vegetation in Langtang National Park of Central Himalaya, Nepal (Kanchan Ojha, Narayan P Gaire, Kedar Rijal, and Ramesh Sapkota)

Presented by: Kanchan Ojha

High mountain ecosystems are considered particularly vulnerable to climate change. This study aims in analysing the climate change status and tree limit vegetation in Langtang National Park area. For this, an ecological and dendrochronological study of *Abies spectabilis* growing at the treeline was carried out at Lauribinayak region of Langtang National Park in the fall (August) of 2011. For this a random sampling was carried out in five rows each at 60 m elevation interval from 3,680 m to 3,920 m. In each sampling point five different nested quadrate plots were laid out in the five horizontal rows along the elevation. For tree species, 20m ×20m plot sizes were determined, for the shrubs 5m×5m on the two-opposite side of tree plot and for herbs 1m×1m quadrate was used in two consecutive side of shrub plot. Treecore samples were collected for dendrochronological analysis. Climate data analysis shows that there is a significant increase in atmospheric temperature over the area during the past 22 years. A total of 23 floral species belonging to 20 families were recorded in the area. The study area was dominated by Abies-Rhododendron forest. Average tree density for study area was 338 stems per hectare. The average radial growth of *Abies spectabilis* was found to be 2.36 mm per year. There was bell shape age distribution pattern of *Abies*

spectabilis with nonsignificant decreasing trend in the average age with increasing elevation. Hence shifting of tree line in the study area is sceptical. The driving processes of traditional land uses, grazing of livestock, logging at the tree line ecotone might be acting in the opposite direction to climatic warming and could therefore constrain climatically driven tree line advance. Also, some significant change in the temperature and rainfall pattern has been observed. Therefore, for the tree line dynamics study long-term holistic study of different aspects ranging from climatic, ecological, dendrochronological and anthropogenic aspect is necessary. Support of GIS mapping and accurate climatic data will be crucial to measure the exact tree line shift in the area.

MD-3 Response of multiple tree species to climate change and variability in Mt. Kanchenjunga area in Nepal Himalaya (Narayan Prasad Gaire, Ze-Xin Fan, Bimal Sharma, Prakash Chandra Aryal, Udya Kuwar Thapa, Santosh K. Shah, and Dinesh Raj Bhuju)

Presented by: Narayan Prasad Gaire

East Himalaya being one of the biodiversity hot-spot, climate change has more implications for this region. However, there is lack of the long-instrumental data to see long-term trend in climatic parameters and impacts of the climate change. This tree-ring study was carried out in the Kanchenjunga Conservation Area (KCA), eastern Himalaya region of Nepal. The objectives of the study were to develop tree-ring chronologies using multiple tree taxa, to assess climate response on tree growth and to understand the long-term climatic variability in the region. Four tree-ring chronologies of *Abies spectabilis, Juniperus recurva* and *Larix griffithiana* were developed using signal-free standardization techniques. The longest chronology is over 600 years for *A. spectabilis*. The dendrochronological potentiality was assessed using standard chronology statistics. All the series have shown overall positive growth trend in 20th century with some differences in the magnitude and oscillations in growth in between the period. The simple correlation analysis was used to understand the influence of climate (monthly total precipitation and average temperature) on tree growth of these conifer taxa. The *A. spectabilis* chronology shows significant negative correlation with March-May temperature and significant positive correlation with June-September temperature. The relationship with summer temperature for *A. spectabilis* is not stable over time and varies with site and age. However, for *L. griffithiana* and *J. recurva*, the relation with March-May temperature was statistically not significant. We observed positive relationship between growth of *J. recurva* and June-September temperature, and March-May precipitation. In case of *L. griffithiana*, there was a negative relationship between the growth and temperature in summer season. With precipitation, there was a significant positive relationship in May. The overall response indicates that these species are suitable for the past climate reconstruction from this region of east Nepal Himalaya, where long instrumental data is available only since early seventies of twentieth century.

MD-4 Environmental changes in the high-altitude plateau of the Central Andes (D.A. Christie, M.S. Morales, R. Villalba, M. Vuille, R.E. Coopman, J. Berenguer, C. Alvarez, G. Velázquez, D. Aliste, R. Rojas, and F. Flores)

Presented by: D.A. Christie

One of the largest high-altitude semiarid bioregions of South America is the Altiplano plateau in the Central Andes (~14°S-26°S). With a mean elevation of 4.000 m a.s.l. and many volcanoes up to 6.700 m a.s.l., this region has been the physical environment for the settlement of many local communities who have inhabited the region for thousands of years. Historically, human activities in the Altiplano have been strongly modulated by variations in climate, particularly water availability. Presently, instrumental registries demonstrate some changes in the Altiplano environment including less frequent rainfall events, sustained shrinking of glaciers and lakes, and a positive warming trend since the second half of the 20th century. These environmental changes have occurred in conjunction with a growing demand for hydrological resources as a result of population increase and expanding large-scale mining, which poses significant challenges for water resource management under the future scenario of climate change and the growth of cities. Tree-ring research since the last decade in the Altiplano utilizing the world's highest elevation woodlands formed by *Polylepis tarapacana*, has given us the opportunity to carry out various dendrochronological research across this vast semiarid Andean region. In this presentation, we will show ongoing work utilizing this resource to increase our knowledge of the temporal variation of some water-related components of the Altiplano including lake levels, glacier mass balance and the human occupation of high-altitude archaeological sites devoted to religious beliefs related to mountains as sources of water and fertility.

MD-5 Following the retreating ice – new results on Holocene glacier variability in the Alps (Kurt Nicolussi, Ruth Drescher-Schneider, Matthias Dusch, Melaine Le Roy, Fabien Maussion, Christian Schlüchter, and Hubert Steiner)

Presented by: Kurt Nicolussi

As with most glaciers in the world, Alpine glaciers are also retreating due to climate change. However, as these glaciers have retreated some of them have unveiled displaced and in-situ tree remains. Dendro-dates established on the base of the Eastern Alpine Conifer Chronology show that these tree remains usually date back to the first half of the Holocene. The tree-ring series established prove multi-centennial to millennial long retreat phases in this timer period. For some glaciers, i.e. Tschierva and Mont Miné, it can be proven that these long-lasting retreats were followed by advances beyond today's glacier extent. Current warming causes not only the retreat of glacier termini, but also the rise of glacier equilibrium lines. As a consequence, several high-elevated and formerly ice-covered Alpine passes have become free of ice. At few localities artefacts were discovered proving human activities at these passes in the mid and late Holocene. At the mountain pass Langrubenjoch (3017 m asl) boards, tree fragments and sticks were uncovered that date back to the Roman and the Bronze Age period. The wooden finds suggest that temporary huts or shelters existed at that mountain pass. For these time periods, Alpine glacier length records prove retreated terminus positions too.

MD-6 Age-dependent sensitivity of Pinus heldreichii Christ, Pinus peuce and Picea abies (L.) Karst. to snow-avalanche activity in Pirin Mountains (Bulgaria) (Olimpiu Traian Pop, Flaviu Mesesan, Ionela Georgiana Gavrila, Armelle Decaulne, Iulian Holobaca, Sonya Stoyanova, Petko Bozhkov, Ahinora Baltakova, Dimitar Krenchev, and Rossitza Kenderova)

Presented by: Olimpiu Traian Pop

In Pirin Mountains (Bulgaria), snow avalanches represent a common phenomenon which damages forests, properties, infrastructures and causes fatalities. In this mountain area, the snow-avalanche history is poorly documented by the historical archives and consequently information regarding the event frequency and spatial extent is lacking. Along the snow-avalanche paths, disturbed trees record in their annual rings evidence of past events and therefore represent a natural archive which can provide valuable information about past snow-avalanche activity. The aim of the present study is to analyse tree-ring records of avalanche impact in trees, in order to reconstruct the occurrence and spatial extent of past avalanche activity. For this purpose, three avalanche paths located in the Banderitsa valley (northern flank of the Pirin Mts.) have been investigated. Samples (cores and discs) collected from 261 trees (*Pinus heldreichii* H. Christ, *Pinus peuce* and *Picea abies* (L.) Karst.) damaged by snow avalanches have been analysed. Tree-growth anomalies (e.g. scars, callus tissues, onset sequences of tangential rows of traumatic resin ducts, compression wood and growth suppression sequences) associated with the mechanical impact produced by snow avalanches in trees were identified and were used to reconstruct the avalanche history within the investigated paths back to late 19th century. Differences in type, intensity and duration of tree-growth anomalies have been observed, depending on tree-species and age groups analysed. The reconstructed snow-avalanche frequency and maximum extent serve to define return periods within the runout areas of each path investigated. Within the study area, the tree-ring derived records provide the most consistent snow-avalanche chronology, which will further be integrated in the avalanche hazard zoning assessment.

MD-7 20 years of tree-ring research in the Scandinavian Mountains (Hans Linderholm, Björn Gunnarson, Peng Zhang, Maurricio Fuentes, Jesper björklund, Kristina Seftigen, and Sassa Chen)

Presented by: Hans Linderholm

This talk will summarise the work that has been ongoing in the central Scandinavian Mountains over the last 20 years. This work, where the environment is prefect for preservation of subfossil wood in shallow mountain lakes as well as dry wood on the ground, has resulted in one of the world's longest TRW chronologies, as well as MXD, BI and isotope chronologies spanning the last 1200 years. This talk will focus on recent efforts to boost the number of samples from dry wood covering the MCA, but will also provide a good story of how it all started.

Discrete Events and Extremes

Session chairs

Dr. Kathy Allen; *University of Melbourne, Melbourne, Australia*
Dr. Bethany Coulthard; *LTRR, University of Arizona, Tucson, Arizona, USA*

Worldwide, there is an increasing interest in the frequency and magnitude of extreme events like fires, floods, landslides, earthquakes, droughts, storms and forest pest outbreaks. Media coverage and public perception might suggest there have been more such events in the past several decades or so than ever before, but in the absence of long environmental records, it is impossible to determine whether or not this is really the case. Centennial- or even millennial-length palaeoenvironmental records arevital for testing whether extreme event frequencies, magnitudes and/or durations have been unusual in a long-term context. The rich spatiotemporal information documented in tree-ring records make them exceptional in this regard. we invite presentations for this session that use tree-ring data to evaluate the occurrence of extreme and/or discrete events, including changes in their frequency, severity and/or duration. It is equally critical to acknowledge the limitations of tree-ring records for detecting and analysing such events, and presentations that discuss these challenges and possible ways forward are also welcome.

Tuesday June 12th 12:15-12:30
Presentations EE1
(Breakout Room 2)

EE-1 Tree species diversity improves beech growth and alters its physiological response to drought in Belgium (Astrid Vannoppen, Kerstin Treydte, Pascal Boeckx, Vincent Kint, Quentin Ponette, Kris Verheyen, and Bart Muys)

Presented by: Astrid Vannoppen

The predicted increase in drought frequency and severity is expected to affect forest growth. Common beech, a widespread and economically important tree species in Europe, is known to be drought sensitive. It is thus important to increase our understanding about the effect of drought on the growth of beech in interaction with management to advise forest managers. Diversifying forests has been proposed as a useful management strategy to mitigate the effects of increasing drought on forest growth. In order to study if beech trees growing in more diverse forest patches are more resistant and resilient to drought compared to those growing in monoculture patches, a unique observational platform was set up in Belgium. Beeches growing along a tree diversity gradient (from monocultures to forest patches with up to 3 species) were selected. Combining dendrochronological and stable carbon and oxygen isotope data allowed for studying the effect of tree species diversity on beech growth and its reaction to drought regarding stem radial growth and isotope proxies for physiological performance. Enhanced stem radial growth and higher resistance to drought was observed for beech trees growing in diverse patches. During drought years the increase

in d13C compared to the years prior to drought in more diverse stands was less pronounced compared to beech trees growing in monocultures, indicating enhanced stomatal conductance and growth continuation of trees growing in mixtures. Until now the positive effect of diversity on beech growth and resistance seems to still outperform negative effects induced by drought; though increasing drought frequency and severity might override this in the future.

Tuesday June 12th 14:00-15:30
Presentations EE2-7
(Breakout Room 2)

EE-2 Site-specific radial growth responses of Pinus densata to climatic changes in southeastern Tibet Plateau (Rao-Qiong Yang, Pei-Li Fu, Ze-Xin Fan)

Presented by: Rao-Qiong Yang

Tree growth are various to climate. It is critical to investigate trees response to environment change. In this research, we contrast the growth variability and climate response variability in *Pinus densata* grew in different environment in southeastern Tibet Plateau. We collected more than 150 cores from 3 sites and analyzed their tree-ring width with climatological data. The result indicated that Growth response of *P. densata* to climatic changes were site-specific in southeastern Tibet Plateau. Growth of P. densata was limited by winter and spring moisture availability in Deqin but more sensitive to winter and spring temperature in Weixi and Shangri-la. These pines play an important role in carbon fixation and forest establishment in southwest China, this study will contribute to forest management.

EE-3 Estimating variability in the volcanic forced climate response using key year resampling (Mukund Palat Rao, Edward R Cook, Benjamin Cook, Rosanne D. D'Arrigo, Kevin J. Anchukaitis, Paul J. Krusic, and Allegra N. Legrande)

Presented by: Mukund Palat Rao

The climate response to volcanic forcing is commonly analysed using Superposed Epoch Analysis (SEA). Using SEA, we can determine the probability of random occurrence of the volcanic response within the original data. The volcanic response in SEA for which statistical significance is tested is usually calculated as the mean climate conditions averaged across all key years. Consequently, the variability in the climate response based on choices of different volcanic key years are inadequately described in conventional SEA. Here we present a modified version of the SEA that first generates multiple unique draws of the key years themselves and therefore describes the response in a probabilistic framework. This allows the examination of the full spectrum of observed responses to determine which volcanic events specifically caused stronger and weaker responses. Examining this volcanic response within this multiple resampling framework helps in addressing two inherent uncertainties in conventional SEA. The first being the possibility that the epochal mean is shifted or diluted

due to either a misidentified key year or the lack of information regarding eruption seasonality. The latter particularly being an issue when analysing the volcanic response in paleo-proxy records of seasonal climate variability such as tree-rings. The second uncertainty is that one of more volcanic events might have an outsized leverage on the mean response value across epochs. Using this modified SEA, we re-examine the volcanically forced climate response in a suite of tree-ring reconstructions of hemispheric drought and temperature over the past millennium, and in addition, analyse the associated variability in these volcanically forced responses.

EE-4 Hydrology and Hillslope Processes Explain Spatial Variation in Tree-Ring Responses to the 1983 Earthquake at Borah Peak, Idaho, USA (Matthew F. Bekker, Douglas P. Metcalf, and Grant L. Harley)

Presented by: Matthew F. Bekker

Dendrogeomorphic approaches have been commonly used to identify tree-ring responses to earthquakes, and have the potential to contribute new paleoseismic information. However, this potential is limited by the relatively low intensity of damage from earthquakes. We present a comparison of tree-ring responses in multiple species to the Mw 6.9 1983 Borah Peak, Idaho earthquake across three adjacent but distinct sites with different hydrologic settings, and different types and intensities of co-seismic mass movement. We analysed samples from 166 trees for a broad range of growth responses, including suppressions, releases, reaction wood, and traumatic resin ducts. The proportions of trees recording growth disturbances at the sites with clear hydrologic changes and/or co-seismic mass movement were twice as high (39–42%) as the site where these processes were less evident (19%), and probability density functions of percent change in growth for all crossdated trees echoed these results. Growth suppressions and reaction wood were common across sites, whereas traumatic resin ducts were only associated with rockfalls and landslides at one site. Growth releases were also primarily restricted to one site, and in contrast to previous studies, most of these likely reflected direct improvements in growing conditions via documented increased flow in springs and streams, rather than the indirect influence of reduced competition via the death of neighbouring trees. These results highlight the importance of site selection in dendroseismology, and particularly suggest that focusing on sites with potential co-seismic mass movement and hydrologic changes, sampling trees with and without external evidence of earthquake impacts, and understanding the connection between responses and site conditions may facilitate greater contributions of dendrogeomorphic approaches to paleoseismology.

EE-5 Extremes in summer hydroclimate in Tasmania (Kathryn Allen, Rob Evans, Stuart Allie, Greg Carson, and Patrick Baker)

Presented by: Kathryn Allen

Australia has a highly variable hydroclimate, creating challenges for the sustainable and effective water management. Very low volume inflows into water storages for drinking water, agriculture, or hydroelectric energy for a single year can have major socio-economic impacts

in Australia. However, low (but not necessarily extremely low) flows sustained over consecutive years, represent a much greater risk to Australia's cities, farms and agriculture. Our ability to estimate the likelihood of such events is severely limited by the short instrumental records (mostly < 100 years). Here we present two multi-centennial summer (Dec-Feb) hydroclimatic reconstructions (dam inflows) for Tasmania, one for northern Tasmania and one for western Tasmania. Both reconstructions are based on a mixture of ring width and wood properties chronologies (e.g. tracheid radial diameter, cell wall thickness, density, microfibril angle). The reconstructions explain ~32% and 35% respectively of the variance in inflows. In general, current conditions are well within the range of variability over the past nine centuries. Conditions more extreme than those in the 20th Century have occurred in the past for both seasons. Based on our reconstructions and a traditional frequentist approach, the number of low flow events in summer since the start of dam inflow records in Tasmania (~1946) is well above what would be expected. However, the frequency of multi-year low flow events in the instrumental record does not appear unusual compared to their occurrence in the much longer records. Our records indicate that the typical dry or wet spell lengths for both reconstructions are just under two years. Despite this, our reconstruction for western (but not northern) Tasmania suggests steadily decreasing inflows over the past 100 years. This is concerning because Tasmania's largest impoundments are located in western Tasmania.

EE-6 Tree rings and climate extremes in California (Daniel Griffin, Jacob Arndt, Matthew Trumper, Erica Bigio, and Kevin Anchikaitis)

Presented by: Daniel Griffin

Climate extremes have emerged as one of the quintessential forms of evidence for climate change in the modern era. In California, extreme swings between drought and wetness have expanded the statistical bounds of variability evident in instrumental records of hydroclimate. Published analyses with dendroclimatology indicate that the recent drought has been, by certain metrics, unusual in the context of the last millennium. However, many California tree-ring data are fifteen years or more out of date, precluding a critical comparison of the proxy system record during the extreme years of greatest interest. Here, we summarize our group's effort to update a subset of the most relevant moisture sensitive tree-ring records from drought stricken central and southern California. We present a systematic characterization of climate relationships inherent to the blue oak (*Quercus douglasii*) and big cone Douglas-fir (*Pseudotsuga macrocarpa*) data, with emphasis on diagnosing temporal stability in the relationships and proxy skill for matching instrumental period extremes. These new chronologies are then used to provide long-term context for the recent "hot drought" event and to make inferences about the relative role of temperature during important drought events of the last five centuries.

EE-7 Quantitative modeling of human-environment interactions using dendroclimatology (Jed Kaplan)

Presented by: Jed Kaplan

The role of past climate variability and change in influencing social dynamics is strongly debated, with interpretations ranging from strong environmental determinism to near total

indifference in the face of both short- and long-term climate change. Unique among widespread paleoenvironmental archives, tree-rings provide the information to reconstruct climate variability at the sub-decadal temporal resolution that is most relevant for human activities. Dendroclimatological reconstructions have been used to provide explanations for the rise and decline of complex societies, changes in land use, migration of peoples, and social conflict. However, most of these studies were based on correlations or associations between climate and interpretations of social dynamics, and the results are often equivocal – causal evidence for climate-driven social change is hard to prove. Here I demonstrate several examples of how we may use dendroclimatological reconstructions to inform quantitative process models of human-environment interactions, and test hypotheses on the role of climate in societal dynamics. The goal of these studies is not to provide causal proof that a particular climate event caused a social change, but rather to quantitatively exclude certain scenarios as being unrealistic or highly unlikely. To illustrate the method and demonstrate its potential, I will provide examples from New Zealand, on the role of the Medieval Climate Anomaly influencing the Maori impact on landscapes following their arrival, and from Southeast Asia, on the potential role of flood and drought on the decline of the Angkor society. My results demonstrate the potential of dendroclimatology for informing coupled models of human and natural systems, and the value of these results for understanding how societies respond to climate variability.

Tropical Dendrochronology

Session Chairs:

Dr. Jonathan Palmer, *School of Bio.Sci., Earth & Env. Sciences, University of New S.Wales, Sydney, Australia*
Dr. Laia Andreu Hayles, *Tree-ring Lab, Lamont-Doherty Earth Observatory of Columbia University, NY, NY, USA*

Tropical dendrochronology is challenging yet the quantity and range of recent publications demonstrates how many of us are willing to engage in this area. The number of species able to be crossdated has expanded, new approaches described and time periods extended. Of particular note has been chronology development in new geographic areas (such as Mozambique). As impressive as all these recent developments have been, the pressing need continues for palaeoclimate data and ecological understanding as tropical ecosystems and socio-economic cultures become more and more vulnerable to extreme climate events, deforestation and population growth. This session seeks to demonstrate the utility and use of tropical trees for providing insights into the tropical environment, global change or human development.

Wednesday June 13th 10:30-11:15
Presentations TD1-3
(Breakout Room 2)

TD-1 Tree-Ring Reconstruction of Wet Season Rainfall Totals in the Amazon (David Stahle, Daniela Granato-Souza, Lidio Lopez, Ana Carolina Barbosa, Max Torbenson, Ricardo Villalba, Song Feng, Jochen Schongart, and Gabriel de Assis Pereira)

Presented by: David W Stahle

The Amazon Basin is a globally important center of deep atmospheric convection, energy balance, and biodiversity, but only a handful of weather stations in this vast Basin have recorded rainfall measurements for at least 50 years. The available rainfall and river level observations suggest that the hydrologic cycle in the Amazon may have become amplified in the last 40-years, with more extreme rainfall and streamflow seasonality, deeper droughts, and more severe flooding. These changes in the largest hydrological system on earth may be early evidence of the expected consequences of anthropogenic climate change and deforestation in the coming century. Placing these observed and simulated changes in the context of natural climate variability during the late Holocene is a significant challenge for high-resolution paleoclimatology. We have developed four annual tree-ring chronologies from *Cedrela odor*ata in the eastern Amazon of Brazil and ten chronologies of *Centrolobium microchaete* in the southern Amazon of Bolivia. These exactly dated and well-replicated chronologies were all based on full or partial cross sections cut from recently felled trees in legal logging concessions. The chronologies are all moisture sensitive and have been used to compute two reconstructions of wet season rainfall totals, one for the southern Amazon based on *Centrolobium* and another for the eastern equatorial Amazon using *Cedrela*. Both reconstructions are over 200-years long, extend the available instrumental observations in each region by over 150-years, indicate interesting multi-decadal variability in both the 19th and 20th centuries, and are related to the same regional and large scale atmospheric dynamics responsible for the inter-annual variability of wet season rainfall totals in the instrumental observations.

TD-2 Spatial rainfall reconstruction for the districts of Kerala, South India inferred from tree-rings of Tectona grandis (Santosh K. Shah)

Presented by: Santosh K. Shah

A spatial rainfall reconstruction for the districts of Kerala was attempted using point-by-point regression approach, based on a tree-ring record of teak (*Tectona grandis*). Kerala is a state in South India on the Malabar Coast and lying between northern latitudes 8° 18'N and 12° 48'N and eastern longitudes 74°52'E and 77°22E with 14 administrative districts. Tree-ring chronology spanning 1590-2000 C.E. was prepared using both tree cores from living trees and left overs stumps. The tree-ring chronology was correlated with rainfall of each districts and found May rainfall was significantly positive. Based on this relationship, spatial reconstruction of May rainfall for each district was attempted. The strength of each reconstruction model was assessed with calibration and verification statistics. In addition the reconstruction was also compared with independent regional rainfall of peninsula India and southern India sub-division rainfall records. The May rainfall is important for the sowing of autumn variety of paddy and other crops. The district wise rainfall reconstruction helps to understand the long-term dynamics of rainfall in relation to agricultural domain of the state. The precipitation in Kerala is significant for the Indian subcontinent as the Monsoon enters

the landmass from this part first. The timing and intensity of precipitation recorded in Kerala is observed judiciously and is important for the large agriculture dependent population of the Indian subcontinent.

TD-3 Tree-ring periodicity and radiocarbon bomb-pulse dating for tropical tree species (Guaciara M. Santos, David A. Herrera-Ramírez, Tatiana E. Boza-Espinoza, Alfredo F. Fuentes, Jorge I. del Valle, Daniel Ruiz-Carrascal, and Paula L.M. Gonzalez)

Presented by: Laia Andreu-Hayles

In temperate climates, winter dormancy of trees usually ensures the annual nature of tree rings, and thus in dendrochronology it is common practice to assume annual periodicity when: (1) there is common tree growth variability shared among trees; (2) significant interannual correlations with meteorological records are found. However, in tropical environments the determination of annual periodicity can be more complex and further testing is recommended. Here, we use a high-precision radiocarbon (^{14}C) bomb-pulse dating (BPD) of several wood rings selected before and after the ^{14}C bomb spike nuclear test (i.e. 1950s-1960s) to provide an independent validation of annual growth rings. Specifically, we tested the accuracy of the calendar dates obtained by dendrochonological methods in two tree tropical species in South America, in Bolivia *Pseudolmedia rigida* (Klotzsch & H. Karst.) Cuatrec. collected in the Madidi National Park (14°33'S, 68°49'W), and in Colombia *Prioria copaifera* Griseb. (Leguminoceae) from the Atrato River floodplains (7°20'N 76°57'W). A perfect agreement was found between the dendrochronological and ^{14}C dates of the *Pseudolmedia rigida* samples, but strong discrepancies were detected for *Prioria copaifera*. Although the BPD results demonstrated a lack of annual tree growth periodicity in 3 trees, the *Prioria copaifera* chronology passed all the standard dendrochronological quality tests: successful crossdating (EPS > 0.85) and significant correlations with streamflow, gridded precipitation over the watershed and climate indices linked to ocean and atmospheric patterns across the Pacific, as well as with SSTs. Side-by-side measurements were done for both species, thus artefacts due to ^{14}C sample preparation or measurement procedure were unlikely, as well as due to any non-structural carbohydrate residue in holocellulose extract. This work provides an effective independent method of validating dendrochronological calendar dates for the recent past (e.g., for the last 60 years) and cautions that in the tropics the annual periodicity of tree layers cannot be taken for granted.

DendroHydrology

Session Chairs.

Dr. Santosh Shah, *Birbal Sahni Inst. of Paleosciences, Lucknow, India*
Dr. Ulf Buentgen; University of Cambridge*, Cambridge, UK*

Dendrohydrology aids in studying long-term, hydrologic phenomena based on tree growth hydroclimatic reconstructions at local to regional scales. It is focused on river and stream flow reconstruction beyond the existing gauge record. The long-term flow reconstructions help management and planning of

various water resources. In addition to extensions of gauge flow records, its application also includes drought analysis, analysis of extremes and periodicity of rare hydrologic phenomena. In the recent decade methodology of discharge reconstruction has advanced from linear regression to Hierarchical Bayesian Regression and estimation of reconstruction uncertainty through maximum entropy bootstrap.

Wednesday June 13th 11:15-12:00
Presentations DH1-3
(Breakout Room 2)

DH-1. Human cause of recent Yellow River drying-up from a 1,200-year flow reconstruction (Jinbao Li, Shang-Ping Xie, Edward R. Cook, Fahu Chen, Jiangfeng Shi)

Presented by: Jinbao Li

The Yellow River is the lifeblood of the dry north of China and cradle of Chinese culture and civilization. Since the late 1960s, the Yellow River flow decreased substantially and often dried up in the lower reach without reaching the sea. Climate change and human disruption have been suggested as major causes of the flow reduction, but quantification of their relative contribution is challenging as the gauge records are brief and heavily disturbed by dam construction. Here we use a basin-wide tree-ring network to reconstruct the Yellow River flow for the past 1,200 years, and show that the flow exhibits marked amplitude variations that are closely coupled to the hydrological mean state swings at multi-decadal to centennial timescales. The river flow varied coherently with the Tibetan Plateau and the Northern Hemisphere temperatures, with increased flow in warm periods and vice versa for a reduction. Recent flow should have increased to the highest level of the past 1,200 years if there were no human disruption. Human interventions caused a loss of nearly half of natural flow since the late 1960s, most responsible for recent downstream drying-up events.

DH-2. Southern California perfect drought: How common? (Connie Woodhouse, David Meko and Erica Bigio)

Presented by: Connie Woodhouse

Southern California benefits from having a diversity of water supplies, with local groundwater meeting about one third of the water needs, and surface water supplies coming from both northern California and the upper Colorado River basin. This diversity buffers the region against the impacts of severe drought in any one watershed. In the years 2012-2015, Colorado River and Sacramento River flows and southern California precipitation were all below the median, the longest such period in the instrumental record. Concurrent drought in all three water supply regions, or southern California “perfect droughts,” have occurred four other times since 1906, but typically persisted for only two years, with events separated by a decade or more. In this study, we use reconstructions of streamflow for the Colorado and

Sacramento Rivers, and a reconstruction of southern California precipitation to evaluate the frequency and timing of “perfect droughts” over the past six centuries in some detail. We examine the phasing and periodicity of hydroclimatic variability among the three basins using wavelet-transform coherency to determine if phases of coherence over the past six centuries are evident in the reconstructions. Our results show that over this time period, multi-year “perfect droughts” have occurred with some regularity, but at a higher frequency during some intervals of time. For example, five events occurred in a little over three decades in the 1700s. Over the 16th and 17th centuries, coherency at multidecadal time scales is evident for both wet and dry periods, suggesting periods when drought events are in phase. We also use a set of extended reconstructions to examine the occurrence of “perfect droughts” during the 12th and 13th centuries to assess the character of these droughts during the medieval period. In contrast to the 2- to 4-year region-wide droughts documented over the past six centuries, the longer reconstructions document widespread 7- and 9-year events within the span of less than three decades (1130-1158). In addition, at the end of the 13th century, there were seven years of “perfect drought” conditions within a 10-year period. These findings again confirm the unusually severe drought conditions during the medieval period in the western US. While southern California’s diversity of water supplies reduces its vulnerability to drought, these results suggest that natural hydroclimate variability has produced frequent and sometimes extremely persistent, “perfect droughts” in the past. To our knowledge, there is no reason similar droughts could not occur in the future, with the difference that they would undoubtedly occur under warmer temperatures.

DH-3. Shingo River flow reconstruction from Upper Indus Basin using ring-widths of Abies pindrow (Santosh K. Shah, Gregory C. Wiles, Nivedita Mehrotra, Uttam Pandey, and Rakesh Chandra)

Presented by: Santosh K. Shah

A tree-ring width chronology of *Abies pindrow* (West Himalayan Fir) was developed from Sindh valley, Kashmir, Northwest Himalaya. The composite chronology is based on 134 tree cores and extends from 1654 to 2013 C.E. Correlations with monthly river discharge data from this cold desert region of Kargil, a district of the Ladakh region of Northwest Himalaya show a strong relationship with April through July river flow. In this region, agriculture is the primary land use with about 91 percent of the workforce engaged in this pursuit alone. Agriculture here depends primarily upon irrigation and 9,470 hectares of a village area of 18,922 hectares or approximately half of the district is irrigated. Thus, the availability of water in the river and irrigation canal system is vital and its management can benefit from a longer term perspective developed from the tree-ring records. With this aim in mind, a linear regression model of river discharge was developed and reconstructed for a 4-month average (April-July) discharge for the Shingo River, that drains the Upper Indus River Basin. The reconstruction spans 243 years (1760–2002 C.E.) and accounts for 44% of the total variance of the calibration period of 1978-2002 C.E. This long-term reconstruction is coherent with the river flow proxies at other sites from the Upper Indus Basin and it is consistent with isotopic records of the Karakoram and tree-ring based precipitation records from the Kashmir Valley.

Thursday June 14th 10:30-11:00
Presentations DH4-5
(Breakout Room 2)

DH-4. Regional discharge reconstruction from tree-ring δ13C and δ18O values in eastern Canada (Lauriane Dinis, Christian Bégin, Martine M. Savard, Joëlle Marion and Pierre Brigode)

Presented by: Lauriane Dinis

Climate change plays a major role in determining future water availability and quality in several parts of the world. With the potential for hydroelectric development on the Churchill River, Labrador, it is important to understand the influence of climatic conditions on river discharge to foresee potential climate change effects on future productivity. Persistent drought events recorded between 1940 to 1960 and 1985 to 2000 underline the significant risk that changing climate may represent for energy supply, infrastructure security, and Canadian economy. Typically, predictive climatic models use historical temperature and precipitation records. In the study region (eastern Canada), climatic data cover less than seventy years and long reconstructions from natural archives are inexistent, which means it is unrealistic to simulate hydro-climatic variabilities and estimate future drought risks. In the boreal climate, tree-ring δ13C and δ18O series can: (1) be directly linked to climatic conditions, individually or in combination, and (2) reflect river discharge, a regional integration of overall climatic conditions. This study aims at improving the knowledge of long-term hydrologic variability in eastern Canada by reconstructing regional discharge from tree-ring δ13C and δ18O series. Two sites were selected, 40 km north and 8 km south of the Churchill River, to produce tree-ring δ13C and δ18O series extending from 1800 to 2009. Individual and combined isotopic results show significant statistical correlation with summer index discharge from three rivers near the Churchill ($r = -0.61$, -0.59 and -0.67 for δ13Cmean, δ18Omean and δ13C_δ18Ocombined, respectively; $n = 41$; $p < 0.05$; δ13C_δ18Ocombined series normalized with a z-score that integrates C and O isotope variations with the same weight). Therefore, summer index discharge has been reconstructed from the combined δ13C and δ18O data using a linear regression model. The resultant discharge series agrees with a discharge reconstruction obtained from the ANATEM method (1880-2009 period), which is based on a reanalysis of geopotential height fields and on similarities between days of reconstruction and observation. The reconstructions significantly correlate together ($r = 0.43$; $n = 130$; $p < 0.05$), as well as with Churchill River data ($r = 0.55$ and 0.71 for tree ring isotopes and ANATEM, respectively; $n = 18$; $p < 0.05$). The discharge reconstructions also show an overall significant long-term decrease from 1880 to 2009, and short-term decreases associated to drought periods (e.g. 1889-1892, 1935-1942, 1945-1948). The part of the isotopic reconstruction extending beyond the ANATEM reconstruction also shows periods of low discharges (e.g. 1807 to 1828 and 1845 to 1861). These results suggest that this part of Canada has experienced an overall decrease in summer discharge over the past 200 years.

DH-5. Six centuries of Upper Indus Basin streamflow variability and its climatic drivers (Mukund Palat Rao, Edward R. Cook, Benjamin I. Cook, Jonathan Palmer, Maria Uriarte, Naresh Devineni, Upmanu Lall, Rosanne D. D'Arrigo, Connie A. Woodhouse, Moinuddin Ahmed, Muhammad Usama Zafar, Nasrullah Khan, Adam Khan and Muhammad Wahab)

Presented by: Mukund Palat

Our understanding of the full range of natural variability in streamflow, including how modern flow compares to the past, is poorly understood for the Upper Indus Basin (UIB) because of the short instrumental gauge record. To help address this challenge, we use Hierarchical Bayesian Regression (HBR) with partial pooling to develop six centuries long (1394-2008 C.E.) streamflow reconstructions at three UIB gauges (Doyian, Kachora, and Gilgit), concurrently demonstrating that HBR can be used to reconstruct short records with interspersed missing data. At one gauge (Partab Bridge), with a longer instrumental record (47 years), we develop reconstructions using both Bayesian Regression (BR) and the more conventionally used Principal Components Regression (PCR). The reconstructions produced by PCR and BR at Partab Bridge are nearly identical and yield comparable reconstruction skill statistics, highlighting that the resulting tree-ring reconstruction of streamflow is not dependent on the choice of statistical method. Reconstructions at all four gauges indicate flow levels in the 1990s were higher than mean flow for the past six centuries. While streamflow appears most sensitive to accumulated winter (January-March) precipitation and summer (MJJAS) temperature, with warm summers contributing to high flow through increased melt of snow and glaciers, shifts in winter precipitation and summer temperatures cannot explain the anomalously high flow during the 1990s. Regardless, the sensitivity of streamflow to summer temperatures and projected warming suggests that streamflow may increase in coming decades, though long-term water risk will additionally depend on changes in snowfall and glacial mass balance.

Dendrochronology and Non-traditional Species

Session Chairs:

Dr. Jonathan Palmer, School of Bio.Sci., Earth & Env. Sciences, University of New S.Wales, Sydney, Australia
Dr. Neil Pederson; Harvard Forest, Petersham, Mass., USA

This session is not focused on trees! Other organisms, such as shrubs and corals, can use dendrochronological principles to provide paleoclimate and paleoecological information in geographic areas where trees are absent. These organisms often survive under more severe environmental conditions beyond treelines at high elevations, at high latitudes, or in deserts and oceans. They thus provide challenging opportunities for extending tree-ring studies into treeless environments. As such, these frontier studies are expanding the dendrochrological footprint of paleoresearch. The session has been popular in past WD conferences and aims to be a platform for sharing pioneering research progress and experiences as well as challenges for the future.

Wednesday June 13th 11:15-12:00
Presentations NT1-3
(Breakout Room 1)

NT-1 Strong climate control of growth and recruitment in the world's highest growing vascular plants (Jiri Dolezal, Veronika Langova, Jan Altman, Pierre Liancourt, Martin Macek, and Fritz Hans Schweingruber)

Presented by: Jiri Dolezal

Age determinations and ring-width analyses provide information on longevity of the species and on their growth and recruitment dynamics in response to climate change. This knowledge is of particular interest for alpine species at range margins exposed to rapid environmental change. We studied climate-growth and climate-recruitment relationships in several alpine herbs which occupy the world's highest elevations in Himalayas and attain extraordinarily high age (70-80 years) on root collars 0.2 – 15 mm thick. We identify prominent climate factors, widely believed to govern the growth and recruitment processes, along an unprecedented elevation gradient (5200 – 6000 m) in cold ecosystems of Ladakh, an arid mountain landscape of the Transhimalaya of Northwest India. Several key findings emerged from the application of anatomical age and growth analyses using dendroecological techniques: (i) strong climate control over seedling establishment and radial growth, (ii) diverging plant responses to climate change as a function of elevation, with warmer summers supporting growth and establishment at higher elevations, which is cold and wet, and reducing it at lower elevations, which is hot and dry, and (iv) high species longevity and slow radial growth. The high longevities imply low turnover rates and a long-term persistence of the Himalayan alpine plant populations. At the same time, the results also suggest the ability of alpine forbs to respond rapidly to climatic variation. Variable climate signals along the aridity and low-temperature stress gradients reinforce the necessity of a species- and population-dependent differentiation for the assessment of impacts of climate change on species performance and geographic range shifts.

NT-2 Integrating radiocarbon dating and dendroecology to understand stand dynamics in temperate forests of southeast Australia (Melissa Fedrigo, Stephen B Stewart, Sabine Kasel, Vladimir Levchenko, and Craig R. Nitschke)

Presented by: Melissa Fedrigo

The temperate forests of southeast Australia have a diverse understorey community of small trees, shrubs and tree ferns. The dynamics of these communities over long time periods is largely unknown. Complicating our understanding of stand dynamics is the inability to use the dominant eucalypts to understand disturbance history as they do not form annual growth rings and the common occurrence of tree ferns that do not form woody growth rings or growth zones. Tree ferns can dominate forest understories, growing to over four meters in height and altering light conditions required for tree and shrub recruitment. Tree ferns are

slow-growing and shade tolerant with the ability to resprout following fire. Understanding how these communities respond to disturbance and change over time requires an integrated understanding of both tree fern an associated tree/ shrub dynamics. In this study, we use radiocarbon dating of the tree ferns Cyathea australis and Dicksonia antarctica and standard dendroecological measures of the associated tree/ shrub communities to: (1) reconstruct the age distribution of tree fern species using a size-age model; (2) compare tree fern age structure to the co-occurring tree/ shrub community; and (3) compare age cohorts of tree fern and tree/ shrub with observed disturbance history in 10 temperate forest stands. Despite similar growth allometries, C. australis demonstrated a growth rate four times faster than D. antarctica. The distribution of tree and tree fern ages both aligned with historical fire events with increased tree fern abundance occurring with increased time-since-fire. Pulses of tree fern recruitment aligned with known snowfall events that caused extensive canopy damage in the region. The utilisation of both radiocarbon dating and dendroecology enhances our knowledge of the temporal dynamics of southeast Australian temperate forests and extends the number of species that can be used to reconstruct disturbance history in the region.

NT-3 Novel records of flooding in the arid zone - growth and stable isotope chronologies of Tecticornia auriculata (Chenopodiaceae) (Pauline Grierson, Alison O'Donnell, Celia Mitchell, Cassandra Howell, Grzegorz Skrzypek, and Hamish Robertson)

Presented by: Pauline Grierson

We examined the growth and longevity of the C3 chenopod shrub *Tecticornia auriculata* (Paul G.Wilson) K.A.Sheph. & Paul G.Wilson, growing on the Fortescue Marsh, in the semi-arid subtropics of northwest Australia. The Marsh is a 1200 km2 wetland and nominated Ramsar site subject to periodic flooding associated with cyclones and tropical lows. Field surveys coupled with analysis of growth rings and radiocarbon dating of stem wood were used to develop size and age structures of populations from four sites of differing flooding regimes. Wood was characterised by growth comprised of successive layering of secondary xylem of regular width with no rays apparent. Wood sections also exhibited several wider growth bands, defined primarily by colour change coupled with a change in vessel size. The number of layers was strongly and linearly related to stem basal diameter, while the number of bands, comprised of varying numbers of successive layers, was also significantly correlated with basal area ($R2=0.78$; $P<0.001$). Radiocarbon dates were used to confirm that the bands identified in the wood samples were likely annual growth rings and confirmed that the largest and likely oldest shrubs surveyed were between 16 and 20 years old. This age coincides with the most extensive and prolonged flooding of the Marsh in the last century, and indicates that this extreme event was stand replacing. The potential maximum age of *T. auriculata* shrubs thus remains unknown. Whole wood analysis of growth rings for oxygen isotope composition ($\delta 18O$) revealed significant correlations of growth with rainfall, including signatures of minor flooding associated with cyclones across the region since 2001. Carbon ($\delta 13C$) and oxygen isotope compositions were positively correlated over the full chronology ($R2=0.54$; $P=.005$). However, highly enriched $\delta 13C$ signatures (-19 ‰) also suggest reduced growth associated with both major flood events and drought/increased salinity throughout the measurement period, and possible shifts in photosynthetic behaviour of this putative C3 species. Overall, this pilot study demonstrates that *T. auriculata*, which is widespread across

arid and inland western Australia, may be useful for analysis of both localised and regional patterns in climate and/or hydrological change in playa-dominated systems.

Thursday June 14th 10:30-11:15
Presentations NT4-6
(Breakout Room 1)

NT-4 Crossdated marine sclerochronologies from bivalve mollusks and teleost fish (Bryan Black, and James H. Speer)

Presented by: James H. Speer

Climate variability and change substantially impact the structure, productivity, and functioning of marine ecosystems, yet establishing these relationships is limited by the relatively short timespans of observational records. Over the past decade, this issue has been increasingly addressed by applying dendrochronology techniques to the annual growth increments of bivalve mollusks and teleost fishes. These crossdated sclerochronologies are well replicated, span multiple trophic levels and functional types, and can be readily integrated with physical or biological records to yield ecosystem-level perspectives on climate impacts. In the northeast Pacific, a network of sclerochronologies (20+) is rapidly expanding and represents a tool to identify key climatic variables and their effects within and among species, trophic levels, and ecosystems. For example, a Pacific rockfish and salmon chronologies have been combined with records of seabird reproductive success and tree-ring chronologies to document the importance of winter climate in the California Current and adjacent terrestrial systems. Moreover, California Current chronologies inversely covary with chronologies from the Gulf of Alaska and eastern Bering Sea, highlighting broad-scale synchrony and the contrasting effects of environmental forcing to marine productivity. Similar efforts are underway in the North Atlantic and the Southern Ocean. However, more work is necessary to identify species or sites that will fill gaps or complement existing datasets. Just as importantly, there is potential to incorporate modeling into these almost exclusively correlative studies to more effectively investigate the mechanisms underlying observed climate-growth relationships and forecast the possible impacts of climate change.

NT-5 Multi-Proxy Reconstructions of Northeast Pacific Decadal Variability from trees and bivalves (Bryan Black, and Daniel Griffin)

Presented by: Daniel Griffin

Decadal-scale climate variability in the Northeast Pacific Ocean profoundly influences fisheries production, forest growth, wildfire, drought, and snowpack in western North America. However, considerable and long-standing uncertainly remains regarding its behaviour prior to CE 1900 and the extent to which instrumental period dynamics may have been atypical in a multi-centennial context. Here, we target the leading EOF of SST in the northeastern Pacific

(ARCSST) as an index of Pacific Decadal Variability, which has been dynamically linked to sea level pressure and unlike the Pacific Decadal Oscillation Index, retains a linear warming trend. An ARCSST reconstruction was generated from a broad network of target-sensitive North American tree-ring data processed with signal-free standardization to preserve medium and lower frequency signals common to the original data. In a preliminary analysis, the mean of the approximately 50 chronologies significantly correlated ($p < 0.01$) to the target variable explain 60% of the variance in cool-season ARCSST. Reconstruction skill is independently verified by three marine bivalve (Pacific geoduck; *Panopea generosa*) chronologies, the mean of which accounts for over 50% of the reconstruction variance over the common 1870-1900 interval. A nested reconstruction spans over 500 years and indicates that i) PDV is dominated by penta-decadal cycles, ii) century-long periods of relative quiescence can occur, iii) 20th century regime shifts are typical, but iv) late 20th century warming appears to be atypical in the longer-term context. Moreover, the reconstruction closely tracks paleofisheries datasets, particularly northern anchovy (*Engraulis mordax*) abundance inferred from scale deposition rates in the Santa Barbara Basin.

NT-6 Dendrochronological Fieldweeks as a tool for education and research into big picture questions (James H. Speer, Bryan A. Black, Margot W. Kaye, Christopher M. Gentry, Richard S. Maxwell, and Grant Harley)

Presented by: James H. Speer

The North American Dendroecological Fieldweek (NADEF) has been functioning for 27 years. Our main focus is the education of novice dendrochronolgists in all aspects of a tree-ring research project, but we can do more with this educational tool. In the past, NADEF has made a point of choosing new locations around North America with a specific focus on alternating between western and eastern sites to be more accessible for potential participants and to explore new field areas. Group leaders have used this opportunity to develop trial projects in new areas that have often been enlarged into more comprehensive projects, such as masters theses or dissertations. Our current effort that is supported by a US National Science Foundation grant is to focus on one field site for five years (two in the past and three more to come) where we can develop more comprehensive scientific data and answer larger questions about the effects of climate change on the landscape through tree stress and insect outbreaks. The compilation of this data from multiple projects over five years enables us to build to a greater understanding of the field site, in this case the Greater Yellowstone Ecosystem. Fieldweeks have become a popular educational mode around the world, starting with the International Fieldweeks from WSL and organized by Fritz Schweingruber. Currently, multiple fieldweeks are conducted every year in various countries. We encourage the organizers and participants of the diverse fieldweeks to think about how big science can be accomplished through these intensive data collection opportunities while maintaining and even enhancing the educational experience for these burgeoning scientists.

Dendroecology

Session chairs

Dr. Xiaohua Gou; *College of Earth and Env. Sciences, Lanzhou University, Lanzhou, China*
Dr. Amanda Young; *Dept. Geography, Penn State University, University Park, PA, USA*
Dr. Neil Pederson; *Harvard Forest, Petersham, Mass., USA*

Trees are sessile organisms. Their environment, however, is in perpetual motion. To survive the fluctuations that occur over the centuries and millennia, trees have evolved adaptations that allow for their persistence through times of good fortune as well as times of adversity. Over the last century, people have learned to detect and interpret the signals embedded in wood that reflect the changes in a tree's environment. From these signals, we can answer questions such as, "How do trees respond during times of great environmental variation?", "What factors impact tree growth and survival?", and "Do these factors change across locations over time?", "Are they dependent on a tree's size or canopy position?". Answers to questions like these can help us better anticipate how trees, forests, and ecosystems might respond as the global environment continues to change. Forecasts of major environmental changes are clear, but the impacts of these changes on vegetation are not. The session on DendroEcology is open to all studies that show how we use signals embedded in wood to help us better understand the coming changes in the ecology of our world.

Thursday June 14th 11:15-12:30
Presentations DE1-5
(Breakout Room 1)

Climate-Disturbance Relations

DE-1 Carbon and water cycling of endangered Fitzroya cupressoides rainforests and their vulnerability to climate change (Rocio Urrutia, Jonathan Barichivich, and Jorge Perez-Quezada

Presented by: Antonio Lara

The temperate rainforests along the Pacific coast of Southern South America (38° - 56°) contain some of the longest-lived and highest biomass forests worldwide. The water-dependent *Fitzroya cupressoides* (alerce) forests that grow in this region have the second-longest lived trees worldwide (>3600 years) and carbon stocks >500 Mg C/ha. Due to widespread logging and human set fires Fitzroya is classified as an endangered species and it is both nationally and internationally protected. The research area corresponds to the Alerce Costero National Park in the Coastal Range of Southern Chile (40° 10' S- 73° 26' W, 850-980

m of elevation), which is characterized by high annual rainfall (>4000 mm), dry summers, and very shallow metamorphic soils (30-40 cm depth). Our on-going research aims to evaluate the climate drivers of carbon and water cycling. We are estimating carbon (net primary production and respiration) and water budgets precipitation, interception, evapotranspiration). We are evaluating the vulnerability of Fitzroya forests on the basis of ecophysiological functions, and tree-growth patterns. These old-growth, slow growing and carbon massive ecosystems are a valuable study model to understand carbon and water cycling of old-growth forests in response to climate change worldwide.

DE-2 Dendrochronological Analysis of Dynamics of Conifer Treeline Ecotones under influence of Changing Climate in Northern Western Mountainous regions of Bhutan Himalaya (Yeshey Khandu, Anan Polthanee, and Supat Isarangkool Nayuthaya)

Presented by: Yeshey Khandu

Natural treeline ecotones of alpine tree species at high elevation mountain forming transition zone from timberline to treeless alpine vegetation are early indicators of vegetation response to change in climate and are sensitive to climate. However, the focus on impacts of environmental changes and climate change on treeline dynamics, forests and biodiversity aspects were made by few in Himalayan region. Further, such study was not done at all on dendroclimatology incorporating multiple response of treeline ecotones to changes in climatic and various environmental conditions. As such this is the first report of dendroclimatology and dendroecology in relation to dynamics of treeline ecotones in Bhutan.
This dendrochronological investigation was carried out in very remote regions of very complex and extreme climatic conditional environments of Bhutanese mountains to reconstruct past climatic regimes over last 300 years and evaluate dynamics of treeline ecotones of *Abies densa* Griff trees.
This research was conducted at elevation of 3937-4305 masl in Lunana and at 4074-4313 masl. in Laya in North Western mountainous regions of alpine conifer forest dominated by tree species *Abies densa* Griff at their ecological margins. The layout and position of sampling transect bands at treeline ecotones were controlled by distance along altitudinal gradient, seed source zones and extend of regeneration coverage. Coring tree-ring samples and measuring tree heights and diameters were carried out in band transects. Tree ring chronology was developed using dendrochronological techniques and statistics. Regional local meteorological data and global grid data (CRU TS 322) were used for calibration and verification of tree-ring data used for reconstruction of climate for past regimes and also to relate the influence of past climatic conditions on ecological and regeneration dynamics of treeline ecotones. Principle of correlation/regression coefficients were used to quantify relationships between tree-ring chronologies and climate variable surface-air temperature. Result of dendrochronological analysis confirms increasing trend of natural radial growth of *Abies densa* trees at treeline ecotones of both regions has portrayed higher positive correlation with increasing trend of mean annual temperature. Thus, the influence of biological age and size of *Abies densa* trees on growth of tree-ring widths has been dominated by influence of time series increment trend of warming temperature over past centuries in this north-western region. As such, these natural tree-ring widths portray directly, obviously without standardisation, the trend of global rising temperature. Natural radial growth rate of trees standing at and below this elevational limit of 4305 masl. are all on increasing trends portraying influencing time series trend of increasing temperature. All

these indicate evidence of warming climate in the region.
Demographic structure portrays that tree density, tree size and age decrease along with increasing elevation gradients in both regions. Results reveal increasing profuse regeneration and higher rate of recruitment with rising temperature with maximum during the period of 1950 to 2012 across elevational gradients in both regions. The results also reveal upward expansion of treeline ecotone at rate of 1.043 m/year in Lunana and reached stagnant position at 4305 masl. after 1977. Similarly, the upward expansion of treeline ecotone at rate of 0.92 m/year was revealed in Laya and regeneration expansion became stagnant after 1973 at 4313 masl.. These upward expansions of treeline ecotones of this *Abies densa* trees were driven by rising temperature and referring to overall trend upon past regeneration establishment and growth pattern under this rising temperature, the treelines are expected to advance upward the mountain slope in future. However, influential benefits of warming temperature upon these recent stable positions of treeline regenerations, perhaps, affected by non-climatic factors like dominance of Krummholz Rhodoendron trees and unstable geological conditions like rockslides in supressing regeneration recruitments.
All in all, these results provide data base on reconstructed annual mean temperature based on natural tree-ring chronology over last 300 years and dynamics of treeline ecotones as indicator of climate change in very flung remote regions of Bhutan for the first time. Further, these relationships between treeline ecological dynamics and climate change will help to provide understanding and prediction upon ecological consequences of global warming on forests located in very remote areas and upper most distribution limits of the mountainous regions.

DE-3 Effects of climate and air pollution on the growth of urban trees (Giuliano Maselli Locosselli, Evelyn Pereira de Camargo, Tiana Carla Lopes Moreira, Enzo Todesco, Maria de Fátima Andrade, Carmen Diva, Saldiva de André, Paulo Afonso de André, Julio da Motta Singer, Luciana Schwandner Ferreira, Paulo Hilário, Nascimento Saldiva, and Marcos Silveira Buckeridge)

Presented by: Giuliano Maselli Locosselli

Urban trees are key to the mitigation and adaptation of cities to climate change, for providing different environmental services like the reduction of temperature and storm water run-off. These environmental services increase proportionally with tree size, and it is important to understand how the urban environment affects trees growth. The purpose of this study was to access the role of climate and air pollution on the growth variability of Tipuana tipu trees in the megacity of São Paulo, Brazil. For this purpose, we sampled increment cores of 41 trees of T. tipu in a heterogeneous part of the city that includes industries and residences. We tested the effect of spatial / temporal variability of climate and air pollution on trees growth. The results of the spatial analysis show that trees grow faster in the warmer parts of the city, while the growth rate decreases in areas under higher levels of air pollution. These results are supported by the temporal analysis, which shows that the annual growth of T. tipu is positively related to temperature. On the other hand, higher annual concentrations of particulate matter smaller than 10 micrometers (MP10) negatively affects trees growth. It is important to note that MP10 has a stronger effect on annual growth of trees than climate. Therefore, the growth of urban trees may be impacted by higher levels of air pollution, usually found in in developing countries, which may limit the potential of trees to provide environmental services.

Climate-Ecology-Growth Relations

DE-4 Density dependent climate-growth responses of Siberian Larch at the latitudinal forest-tundra ecotone (Xanthe Walker, Melissa Boyd, Heather Alexander, and Michelle Mack)

Presented by: Xanthe Walker

The northern boundary of the boreal forest is expected to shift northward in response to climate warming. This will result in a decrease in the albedo of areas currently covered by tundra vegetation, an increase in terrestrial carbon sequestration, and an alteration of biodiversity in the current low Arctic. Northward forest expansion is often considered an infilling process rather than a direct latitudinal advance. However, increases in stand density (i.e. infilling) might confound the direct impacts of climate on tree growth. In this study, we examined the growth-climate responses of Siberian Larch (*Larix sibirica*) in Northeast Siberia in order to enhance our understanding of the feedbacks between density and growth in an area that has undergone substantial climate warming and where significant changes are expected at the forest-tundra ecotone. Specifically, we sampled 21 sites, ranging in density from 0.03 to 3.70 stems ha-2. In association with increasing stand density, we found that mean ring width significantly decreased ($R2 = 0.68$, $p < 0.01$). Preliminary growth-climate responses indicate that trees in low and medium density stands are positively responding to summer temperatures, whereas trees in high stand density are complacent to the ameliorating climate. These results suggest that the expected infilling process for forest expansion into tundra ecosystems might be slowed due to density dependent competitive interactions altering the ability of trees to positively respond to climate warming. Although climate is often considered the most important factor controlling the position of the northern forest tundra boundary our results elucidate the need to incorporate density dependent responses into models and predictions of climate change and its effects on the northern forest-tundra ecotone.

DE-5 Growth rates and drought resilience of managed red pine forests in northern Minnesota, USA (Samantha M. Jones, Doug N. Kastendick, Brian J. Palik, and Alessandra Bottero)

Presented by: Samantha M. Jones

Silvicultural thinning is a common forest management practice applied to modify stand structure and composition. Red pine (*Pinus resinosa*) as an ecologically and economically important tree species of the Great Lakes region has long been the subject of research efforts, but fewer studies have explored how specific silvicultural treatments influence the response of these forests to a changing climate.

This research builds on a long-term thinning methods study on the United States Forest Service Cutfoot Experimental Forest in northern Minnesota, where natural-origin red pine stands established in the late 1860s have been receiving various periodic thinning treatments since 1950. Current work is examining the differences in growth patterns and drought response between these treatments.

Related studies indicate short term-drought response advantages in reduced density stands

that reverses over time as residual trees grow larger and demand greater water resources. This research aims to expand on that finding by examining whether targeted thinning strategies (such as thinning from above, the removal of larger trees) increase stand-level drought resistance and resilience.

Thursday June 14th 14:00-15:30
Presentations DE6-11
(Breakout Room 1)

DE-6 Large-scale disturbance legacies and the climate sensitivity of primary Picea abies forests (Volodymyr Trotsiuk, Miroslav Svoboda, Jon Schurman, Pavel Janda, Radek Bace, Vojtech Cada, Martin Mikolas, Tom Nagel, Rupert Seidl, Shawn Fraver, Dominik Kulakowski, Milos Rydval, and Jesper Bjoerklund)

Presented by: Volodymyr Trotsiuk

Determining the drivers of shifting forest disturbance rates remains a pressing global change issue. Large-scale forest dynamics are commonly assumed to be climate driven, but appropriately scaled disturbance histories are rarely available to assess how disturbance legacies alter subsequent disturbance rates and the climate sensitivity of disturbance. We compiled multiple tree ring-based disturbance histories from primary *Picea abies* forest fragments distributed throughout five European landscapes spanning the Bohemian Forest and the Carpathian Mountains. The regional chronology includes 11,595 tree cores, with ring dates spanning the years 1750,Äì2000, collected from 560 inventory plots in 37 stands distributed across a 1,000 km geographic gradient, amounting to the largest disturbance chronology yet constructed in Europe. Decadal disturbance rates varied significantly through time and declined after 1920, resulting in widespread increases in canopy tree age. Approximately 75% of current canopy area recruited prior to 1900. Long-term disturbance patterns were compared to an historical drought reconstruction, and further linked to spatial variation in stand structure and contemporary disturbance patterns derived from LANDSAT imagery. Historically, decadal Palmer drought severity index minima corresponded to higher rates of canopy removal. The severity of contemporary disturbances increased with each stand's estimated time since last major disturbance, increased with mean diameter, and declined with increasing within-stand structural variability. Reconstructed spatial patterns suggest that high small-scale structural variability has historically acted to reduce large-scale susceptibility and climate sensitivity of disturbance. Reduced disturbance rates since 1920, a potential legacy of high 19th century disturbance rates, have contributed to a recent region-wide increase in disturbance susceptibility. Increasingly common high-severity disturbances throughout primary *Picea* forests of Central Europe should be reinterpreted in light of both legacy effects (resulting in increased susceptibility) and climate change (resulting in increased exposure to extreme events).

DE-7 Influence of sampling and disturbance history on climatic sensitivity of temperature limited conifers (Miloš. Rydval, Daniel Druckenbrod, Miroslav Svoboda, Volodymyr Trotsiuk, Pavel Janda, Martin Mikoláš, Vojtěch Čada, Radek Bače, Marius Teodosiu, and Rob Wilson)

Presented by: Miloš Rydval

Accurately capturing medium-to-low frequency trends in tree-ring data is vital to assessing climatic response and developing robust reconstructions of past climate. Non-climatic disturbance can affect growth trends in tree ring width (RW) series and bias climate information obtained from such records. It is important to develop suitable strategies to ensure the development of chronologies that minimize these medium-to-low frequency biases. By performing high density sampling (760 trees) over a ~40 ha natural high elevation Norway spruce (*Picea abies*) stand in the Romanian Carpathians, the suitability of several sampling strategies for developing chronologies with an optimal climate signal for dendroclimatic purposes was assessed. There was a roughly equal probability for chronologies (40 samples each) to express a reasonable (r = 0.3 - 0.5) to non-existent climate signal. While showing a strong high-frequency response, older/larger trees expressed the weakest overall temperature signal. Although random sampling yielded the most consistent climate signal in all sub-chronologies, the outcome was still sub-optimal. Alternative strategies to optimize the climate signal, including very high replication and principal component analysis, were also unable to minimize this disturbance bias and produce chronologies adequately representing climatic trends, indicating that larger scale disturbances can produce synchronous pervasive disturbance trends that affect a large part of a sampled population. The Curve Intervention Detection (CID) method, used to identify and reduce the influence of disturbance trends in the RW chronologies, considerably improved climate signal representation (from r = 0.28 before correction to r = 0.41 after correction for the full 760 sample chronology over 1909-2009) and represents a potentially important new approach for assessing disturbance impacts on RW chronologies. Blue intensity (BI) also shows promise as a climatically more sensitive variable that, unlike RW, does not appear significantly affected by disturbance. We recommend that studies utilizing RW chronologies to investigate medium to long-term climatic trends also assess disturbance impact on those series.

DE-8 Segregating the influences of climate, age-structure and disturbance events on above-ground woody biomass growth in the Carpathian Picea abies forests (Jesper Björklund, Milos Rydval, Jon Schurman, Volodymyr Trotsiuk, Vojtěch Čada, and Miroslav Svoboda)

Presented by: Jesper Björklund

Woody biomass plays a fundamental role for tree and forest functioning and it is a key component in the terrestrial carbon (C) cycle. The growth of aboveground woody biomass is the aggregated result of external responses to climate, soil-fertility, fire- wind- insect disturbances etc. Here we aim to segregate the different external factors for growth in a vast Carpathian arc network of Norway spruce stands. The size, the randomized sampling design, and the complementary biometrics data recorded, makes this network an ideal

testing ground for the quantification and segregation of external influences on tree growth. With an a priori knowledge of the spatial and temporal variability in climate and weather, and the occurrence of, and fingerprint of, disturbance events, we hypothesize that differences and similarities among forest stands in the Carpathians are mainly caused by 1) climate on inter-annual timescales, 2) disturbance pulses on decadal scales, 3) age-structure and climate on multi-centennial scales, and 4) climate and soil characteristics on average growth rates.
To segregate external factors of tree growth, we will employ two methods based on the principle of "Aggregate tree growth" but using two different analysis perspectives. The first method, called "Curve Intervention Detection" is based on individual time-series analysis of tree-ring series and focuses on external disturbance detection. The second method is a recombination and modification of the "Signal-free approach to dendroclimatic standardization". It is based on detection of signal-in-common through chronology building and the assumption that external signal factors operate at different spatial scales. We thus hypothesise that differences between chronologies at different spatial scales could represent disturbance histories. Finally, we compare band pass filtered "climate" and "disturbance" chronologies of biomass and identify at which frequency each factor is most influential.

DE-9 Variability in climate-growth responses of three tree species: Insights from the south Baltic Sea tree-ring network (Jill Harvey, Marieke van der Maaten-Theunissen, Tobias Scharnweber, Karolina Janecka Ernst van der Maaten, Adomas Vitas, Igor Drobyshev, Roberts Matison, Kristina Sohar, Ryszard Kaczka Anna Cedro, Lena Muffler, Robert Weigel, Roberto Cruz-Garcia, Alar Läänelaid, Āris Jansons, Jurgen Kreyling, and Martin Wilmking)

Presented by: Jill Harvey

The effects of climate warming on trees and forest ecosystems are thought to be greatest in high elevation and latitude environments and also in moisture-limited regions, however, recent research documents considerable climate change effects in temperate forests in Central and Northern Europe, where reduced timber yield, declining resilience, increased mortality and disturbance activity have been attributed to changing climate conditions. The south Baltic Sea region includes the lowland areas (~0-200 m asl) of Germany, Poland, Latvia, Lithuania, Estonia and Sweden surrounding the southern Baltic Sea between ~51-60N and 9-28E. Maritime and continental influences modulate climate across this region set between the continental interior of Europe and the Atlantic Ocean. European beech (*Fagus sylvatica*), oak (*Quercus sp.),* and Scots pine (*Pinus sylvestris*) are present in much of these temperate forest ecosystems. Here we present a new tree-ring network focused on the temperate forests of the south Baltic Sea lowlands. Collaboratively compiled, this network includes 320 sites and 6380 trees with contributions from the International Tree-Ring Database (82 sites). The purpose of this network is to characterize the (1) spatial and temporal variability in tree growth and climate relationships and (2) growth responses to 20th century extreme climate events in the south Baltic Sea region. In this preliminary analysis, we evaluated the tree growth-climate relationships over the periods of 1920-1970, 1943-1972 and 1973-2002 AD using interpolated CRU (ClimateEU) monthly climate data. Key findings indicate the growth of *Quercus sp*. is significantly related to late winter/early spring temperature regime and growing season moisture availability (precipitation sums and SPEI). When comparisons are drawn between the 1943-1972 and 1973-2002 AD intervals, most site chronologies of

P. sylvestris exhibit enhanced and earlier growth responses to winter temperature for the 1973-2002 AD period. Across the network and over time, the growth of F. sylvatica exhibits a strengthening negative relationship with June temperature in the growth year and summer temperature in the previous year, while radial growth was mainly related to previous year and growth year moisture availability (SPEI). These findings suggest that the strength and timing of relationships between climate and radial tree growth are not temporally consistent at many sites between 1943-2002 AD and could reflect a regional response to broad-scale climate changes. These are important insights in order to estimate future growth trends and possible changes in climate sensitivity under future climate change scenarios.

DE-10 Anthropogenic changes impact drought sensitivity across a savanna-forest biome boundary (Kelly Heilman, Neil Pederson, Valerie Trouet, and Soumaya Belmecheri)

Presented by: Kelly Heilman

In Midwestern North America, ongoing anthropogenic changes that affect tree growth typify the landscape: Not only has atmospheric CO2 likely increased intrinsic Water Use Efficiency (iWUE) of trees, but climate has become both increasingly warmer and wetter, extensive land-use cleared most original forests, and fire suppression converted open savannas to closed forests. In the context of these anthropogenic changes, how do changes in CO2 affect tree growth and drought sensitivity? We developed an experimental design that allows us to explore how differences in CO2, stand structure, and moisture conditions affect drought sensitivity. Specifically, we compare the pre-1950 drought sensitivity of "past" trees (trees established before 1950) to post-1950 drought sensitivity of "modern" trees (trees established after 1950) with the same age and size classes, in the same ecosystem type (savannas or forests), and in paired years of similar drought conditions. After controlling for stand size, tree age, and climate, "modern" trees are less drought sensitive than the "past" trees in the same age/size class. This is consistent with drought sensitivity changes expected with increased CO2 and iWUE. However, the differences between modern and past trees are context dependent: drought sensitivity differences are greater in sites with dry climate and edaphic conditions and can vary by both age/size class and species. Due to concurrent anthropogenic changes, impacts of rising CO2 may be masked or exacerbated by other anthropogenic changes. Experimental approaches accounting for many factors affecting tree growth are necessary to constrain estimates of changes in growth or drought sensitivity due to rising CO2.

DE-11 New beech forests growing at their rear edge. Hope or trap for climate change? (Oihane Díaz, Joan Pino, Marina Palmero-Iniesta, and Josep María Espelta)

Presented by: Raquel Alfaro-Sánchez

Deforestation is still considered a major threat for biodiversity conservation at a global scale. Yet “forest transition” during the XX century induced a steady establishment of “new forests” in some regions (e.g Europe) owing to the widespread abandonment of marginal agricultural lands. For example, almost 22% of current forests in Spain established after

1950 and they already account for 25% of the total C pools, while in the European Union forests are expanding at a rate of 0.8 million hectares per year since the 90s, a trend expected to continue in the near future. Interestingly, the comparison of the Spanish forest inventory data suggest that new forests are growing faster than pre-existing ones and are less sensitive to water stress, probably owing to their development in flatter areas with deeper soils. This situation could be especially relevant for those populations at the southern limit of the species distribution that are threatened by warming and the increase in drought episodes after climate change. Beech (*Fagus sylvatica*) forests in Catalonia (NE Spain) are located at one of the southern ranges of this species distribution in Europe and offer a unique opportunity to compare the growth patterns, the response to climate and the resilience to extreme climatic episodes of new and pre-existing forests. Nineteen monitoring plots were stablished in Catalonia's beech forests in 2017, seven plots were set in the pre-existing forests and 12 plots in the new ones. From these plots we collected forest inventory data and cored at least 30 trees per plot. Our preliminary analyses indicate that new beech forests are growing faster than pre-existing ones when comparing similar age classes.

Friday June 15th 10:30-12:30
Presentations DE12-19
(Breakout Room 1)

Disturbance Ecology

DE-12 Tree-rings highlight a conservation conundrum for the critically endangered Leadbeater's Possum in southeastern Australia (Patrick Baker, Craig Nitschke, and Tim Willersdorf)

Presented by: Patrick Baker

Leadbeater's Possum is a critically endangered arboreal marsupial that inhabits tall eucalypt forests in a small area of southeastern Australia. It was previously thought to be extinct, but was rediscovered in the 1960s. In recent decades Leadbeater's Possum has been the focus of intense controversy because the forests that are its preferred habitat are also highly valuable for commercial timber production. It requires two key habitat features: 1) large, hollow-bearing trees for nesting and 2) a dense, connected understorey of Acacia and other species for foraging and movement. To date, most research has focused on hollow-bearing trees with the assumption that the understorey element is always present. However, the Acacias that are the Leadbeater's Possum's preferred foraging habitat are relatively short-lived. We reconstructed the historical dynamics of the understorey component of these forests using several tree species known to have annual growth rings. We found that the understorey species were an ephemeral component of the forest, that their abundance, growth, and vigour were negatively associated with the amount of Eucalyptus in the stand, and that the dynamics of the understorey and overstory often decoupled several decades after the stand-initiating disturbance. These findings have important implications for conservation strategies aimed at maintaining or increasing current Leadbeater's Possum habitat within these landscapes.

DE-13 Recruitment and growth dynamics of a temperate forest understorey species in south-eastern Australia (Helen Vickers, Sabine Kasel, Thomas Duff, and Craig Nitschke)

Presented by: Craig Nitschke

Studies on stand dynamics in the temperate forests of southeast Australia are limited due to a lack of annual growth rings in eucalypts that dominate the forest canopy. The understory of these forests is however characterised by diversity of woody species that are suitable for dendroecology. One species that offers high potential is *Pomaderris aspera* (Rhamnaceae), though the presence of annual rings has not been examined. P. aspera regenerates prolifically after fire with some anecdotal evidence of regeneration between fires. *P. aspera* is known to compete in the first 10 to 15 years after fire with Eucalyptus at which time the eucalypts overtops it. How *P. aspera* responds over the subsequent inter-fire period under competition with Eucalyptus has not been studied. In this study, we investigate the recruitment and growth dynamics of *P. aspera* to determine post-fire population demography and the impact of stand development on growth. The majority of recruitment was found to occur in a pulse following known fire events; however, at the oldest site intermittent recruitment events were observed up to 45 years post-fire. A cyclic pattern in release and suppression events were detected with suppression events dominating growth patterns between 10 and 15 years and after 60 years post-fire. Release events were more likely to occur between 30 and 50 years. Our results suggest that changes in stand and canopy structure can be elicited from the growth responses of this species. In forests that are dominated by eucalypts, the ability to determine disturbance history and stages in stand development from understorey species provides a mechanism that can help understand how the temperate forests of southeast Australia respond in time and space to disturbance.

DE-14 Growth response of Pine trees under two different environmental conditions: A comparative study (Afsheen Khan, Margaret Evans, Paul R Sheppard, Donald Falk, and Moinuddin Ahmed)

Presented by: Afsheen Khan

Increasing human populations and their needs for living, tourism, and other life standards brought about infesting the green cover at a greater rate. Murree area is well known for tourism due to thick moist temperate pine forest as its main attraction for tourists in Pakistan, which has undergone a tremendous decrease in standing stems every year since many past decades. This fast deforestation gives a hard task for the trees in the area to survive in an actively fluctuating environment. This study reveals the growth pattern of trees (severely affected pine trees) in highly disturbed areas with the comparison to those pine trees growing in natural conditions. Sustainability or dendroclimatological potential of any tree species primarily based on ring-width characteristics, i.e., ring-width pattern, sensitivity and correlation. By using ring-width measurements, we calculated basal-area increment to identify and compare the growth trend in these two kinds of areas. This study would also be helpful for the assessment of potential of forests to grow in such environment. Sampling was conducted in highly disturbed areas to compare the ring-width characteristics between disturbed and undisturbed areas. This also shows the response and future trends of trees towards disturbance.

DE-15 A 4000 year multi proxy analysis of fire in the Snowy Mountains, Australia (Tim Willersdorf, Kathy Allen, Scott Mooney, Patrick Baker)

Presented by: Tim Willersdorf

Wildfire acts a major disturbance to forests worldwide. In the Australian context, fire has acted as a dominant force shaping the biota for millennia. Changes in human occupation, from Aboriginal occupation 45 000 years BP to European arrival in the late 18th century, have brought shifts in human attitudes towards fire, with the current European mindset being one of control and fire suppression. We used tree-ring analyses, combined with soil charcoal analysis, to provide a multi-millennial, multi-proxy reconstruction of fire in the sub-alpine Eucalyptus pauciflora woodland of the Snowy Mountains, Australia. We aimed to investigate if fire regimes have changed as a result of recent warming, or colonization by Europeans. Forest age structures indicate despite two recent high intensity fires, the present fire regime is still one of mixed-severity, with partial tree mortality. Charcoal levels show a remarkable increase in inputs in the 20th Century, indicating a distinct shift in fire regime coinciding with European occupation.

DE-16 Use of tree-ring based fire and forest histories in collaborative forest management in the United States (Peter M. Brown)

Presented by: Peter M. Brown

Land management agencies in the United States - as in many areas of the world - have been shifting from top-down, command-and-control governance to models based on collaborative input from a variety of stakeholders. Stakeholder collaborative groups help set land management policy and direction, assist in project implementation, and provide learning through adaptive monitoring. Collaborative governance is increasingly seen as a means to build better adaptive capacity of social-ecological systems, especially in the face of future impacts on ecosystems from climate change, severe ecological disturbances, and increased human land use. In this talk, I outline how concepts of historical ranges of variability in fire and forest history derived largely from dendroecological data provide a crucial scientific foundation in recent efforts to shift to a collaborative governance model in forests of central Colorado. These efforts are directed primarily at reducing the ecological and social impacts of wildfires in montane forests where much of the “wildland-urban interface” is found, and that were historically characterized by frequent, low-intensity wildfires. I also provide examples from Mongolia and China of how models for collaborative governance based on dendroecological data could be used within the context of current social, ecological, and economic realities.

DE-17 The common juniper wood traits network – a tool for environmental North Hemisphere reconstructions (Jiří Lehejček, Allan Buras, Rohan Shetti, Marco Carrer, Jesus Julio Camarero, Jakub Trojan, and Martin Wilmking)

Presented by: Jiří Lehejček

Junipers (Juniperus communis) is the most widespread coniferous species in the world. The species can serve as a sensitive environmental proxy archive (e.g. summer temperature, or ice-sheet melt reconstructions) covering time scales to several centuries. This combination of large spatial and long temporal coverage provides unique opportunities to reconstruct and study the paleo-environment in regions and to infer important feedbacks and future consequences to global climate dynamics.
To tap this resource, we are currently building the North Hemisphere common juniper wood traits network (Fig. 1). So far, 17 locations – mainly along the Northern Atlantic coast and in the Mediterranean – have been sampled. In the network, we will also include existing data-bases such as the shrub-hub and the tundra trait data-base. However, concerted field campaigns covering Asia and N. America are still missing.
Here, we invite the scientific community to contribute to the common juniper wood trait network with the benefits of co-authorship and network access for each data contributor. We have developed a sampling procedure to guarantee the comparability of the collections. Sampling per site takes approx. two person days, and involves measurements of basic plant traits and stem sections for dendro-ecological and wood anatomical analyses.

DE-18 ITRDB in ecological research: challenges and opportunities (Shoudong Zhao, Neil Pederson, Loïc D'Orangeville, Janneke HilleRisLambers, Emery Boose, Caterina Penone, Bruce Bauer, Yuan Jiang, and Rubén D. Manzanedo)

Presented by: Rubén D. Manzanedo

The extensive data and coverage of the ITRDB shows great promise to address macroecological questions regarding physiology, demography, and ecosystem functions. However, there are significant gaps in the ITRDB that limit the insights we can obtain from the data. Strategic and organized group efforts are necessary to improve the database. We quantified this biases and unbalances on the database and provide tools to guide the scientific community in addressing them and thereby increasing the global representability of this invaluable database. We discuss how the ITRDB database can be useful to study fundamental ecological questions, using case studies of the mechanisms behind tree longevity and the drivers of population synchrony.

DE-19 Tree rings as records of changes in air quality and past impact of human activities on environmental conditions (Paolo Cherubini)

Presented by: Paolo Cherubini

Air pollution is one of the most important problems related to industrialisation and is of major concern to societies for its effects on the environment and on human health. In the past two decades, the attention of science and society has been particularly focused on the effects of particulate pollution. In rapidly industrializing regions of the world, particulate pollution is a serious environmental problem that is influencing air quality and human health, along a similar trajectory to that previously experienced by currently developed nations. Monitoring atmospheric pollution in industrial areas is essential to infer past levels of contamination and to evaluate the impact for environmental health and safety. However, the first stations measuring air pollutants were installed during the 1980s, and data currently available in most regions cover at best the past 30 years. We hypothesize that the chemical composition of tree-ring wood can be used for monitoring spatio-temporal variability of air pollutants and fine particles, to extend air quality data back in time. Tree rings can be used as indicators of the environmental (not only climatic) conditions in which trees have been growing, e.g., to reconstruct the impact of air pollution, because their chemical and physical characteristics depend on the environmental conditions in which they grew. The concentration of chemical elements in tree rings has been studied using a combination of dendrochronological and chemical methods, i.e., dendrochemistry, for example, for tracing changes in nutrient availability in declining forests. However, uncertainty surrounds the use of dendrochemistry to monitor air pollution impacts and its temporal resolution scale. While some encouraging results have been reported in acidification studies, the actual suitability of dendrochemistry to provide unbiased evidence of the impacts of trace metal pollution has been questioned, although it seems that many of the problems can be overcome by appropriate investigation designs. Moreover, the effect of particulate pollution on plants is still largely unknown and in trees almost unexplored. We analysed tree rings formed in different years and close to different pollution sources, using standard dendrochronological methods, tree-ring stable isotopic (^{13}C, ^{18}O, ^{15}N) analyses, radiocarbon analyses (^{14}C), chemical analysis using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), and computer-tomography imaging and chemical microanalysis at the synchrotron. We found changes in the chemical composition of tree-ring wood related to changes in air quality and air pollution episodes and trends. In this talk, I will give a short review of relevant dendrochemical studies, suggesting possible reasons why many have failed to provide annual-resolution information. I will use case studies close to an asbestos factory, a steel factory and Mount Etna, an active stratovolcano in Italy, to show that changes in the chemical composition of tree-ring wood, measured using high-resolution LA-ICP-MS, enabled us to reconstruct past air pollution episodes and trends. Moreover, I will provide evidence that nanoparticles deposited on tree leaves are taken up through stomata and transported through the phloem into the xylem of trees.

Isotopes and Tree-rings

Session Chairs:

Dr. Laia Andreu-Hayles; *TRL-LDEO, Columbia University, NY, USA*
Dr. Kevin Anchukaitis; *LTRR, University of Arizona, Tucson, Arizona, USA*

The stable isotopic analysis of tree-rings is an increasingly important tool within tree-ring research for understand past climate variability, atmospheric circulation, and plant physiological responses to climate and other environmental variables. In parallel with these developments come new challenges to our mechanistic understanding of isotope fractionation and the methods and application of these techniques. This session will explore the full range of recent developments in isotope dendrochronology including: analytical methods, tree physiology, novel or advanced applications, and isotopic data analysis. We invite talks on topics including the development of new tree-ring isotope records, large-scale data syntheses, methodological and technical advances, mechanistic and modeling studies of isotope systems, and uncertainty quantification.

Thursday June 14th 11:00-12:30
Presentations IT1-6
(Breakout Room 2)

IT-1 Smart increment borer - a new electric device for automated sampling of tree-ring cores (Akira Kagawa)

Presented by: Akira Kagawa

For tree-ring isotope research, cores with large diameter (12mm) is ideal, however, manual sampling of 12-mm cores is physically very demanding. Here we report a newly developed device for automated sampling of tree-ring cores (Kagawa & Fujiwara 2017). The device employs a battery-powered electric wrench and the complete system to drive the boring operation weighs less than 10 kg. It is capable of sampling both 5-mm and 12-mm diameter cores of up to 80-cm length from the hardest hardwood. Compared to equipment used in previously published articles, this device demonstrates a superior torque-output/total-weight ratio. The device is also capable of facilitating the starting operation of a 12-mm increment borer. Our automated tree-ring sampling device consists of five major components: power wrench, gearbox, reaction bar, winch socket and increment borer. A Makita electronic wrench drives the input of the gearbox to generate low-speed, high-torque output on the other side. The gearbox contains either one gear, or combination of the two gears connected coaxially, to shift the gear ratio from 1:24 to 1:118. We normally start increment borer by pushing the

electric wrench and the reaction bar to insert the threaded part (the first 3cm of the tip). When pushing force from one operator is not sufficient to start the borer, we set the reaction bar in horizontal direction so that two or three persons can push the reaction bar to increase the pushing force of the borer bit against the bark. By simply reversing the electric wrench, we can rotate the bit counter-clockwise and extract the bit out from the stem. When the bit became stuck by passing into a rotten wood part in the tree stem, the “Decorum extractor” (Loader & Waterhouse 2014) worked effectively in combination with Smartborer. The biggest advantage of Smartborer is manifested in its reaction bar design. No other device developed so far has the reaction bar designed to absorb reaction force with the operator’s leg and arm. Driving a 12 mm borer bit into a tree requires a large torque, especially when sampling a long core from hardest hardwood, such as oak and teak. When sampling cores for wood quality research, where the next tree to be sampled is close, we were able to increase the sample throughput by more than three times compared to the manual procedures.

IT-2 Oxygen isotopes in tree rings as atmospheric moisture proxy (Kerstin Treydte)

Presented by: Kerstin Treydte

Climate models project a marked increase in heat waves and droughts even in high rainfall areas of Europe for the 21st century. Such projections, however, still contain huge uncertainties, and empiric proxy data are required to reduce model uncertainties. Besides insight into the tree’s physiological response to climate change is of high relevance for predicting how tree growth and thus the terrestrial carbon and water cycle will respond to future environmental conditions. Oxygen isotopes in tree rings can provide valuable insight into the water uptake by trees and their physiological response to hydroclimatic variation. This holds particularly in temperate, low elevation regions where traditional tree ring parameters such as tree-ring width or maximum late wood density are limited in recording strong climatic signals. In this talk I will present some recent mechanistic and paleoclimatic studies that convincingly demonstrate the applicability of oxygen isotopes in tree-rings as recorders of hydroclimatic, and particularly atmospheric moisture variability. Examples range from seasonal, local scales to multi-century continental scales.

IT-3 Tropical cyclone reconstruction using oxygen isotopes in tree-ring cellulose (Jan Altman, Jiri Dolezal, Jong-Suk Song, Olga N. Ukhvatkina, Alexander M. Omelko, Pavel V. Krestov, and Kerstin Treydte)

Presented by: Jan Altman

The most prominent trend of the increasing intensity of tropical cyclones (TCs) over the last few decades was recorded for the western North Pacific (WNP) and further changes in TC activity are projected to occur here. The validity of future TC projections is restricted by limitations on the length and quality of observational records and more high-resolution proxy records are needed to investigate the climate forcing of TC activity. More knowledge on the

long-term pattern of TC activity will help us to understand whether recent rapid changes are within the range of long-term natural variability or if these extraordinary changes are part of a trend associated with more recent climate change. Here we provide new insights into the long-term TC variations in WNP by using oxygen isotope ratios ($\delta^{18}O$) of tree-ring cellulose of Quercus mongolica. Precipitation from TC systems is markedly lower in $\delta^{18}O$ than normal rainfall by 10-20‰. Such depleted rainwaters can remain in the soil for several weeks following the event and significantly change late-wood oxygen isotope composition (e.g. Miller et al. (2006). First comparison of latewood $\delta^{18}O$ residuals (deviations from the mean of 4 individual tree-ring series) with instrumental records of past TCs showed that virtually all negative deviations of tree-ring $\delta^{18}O$ correspond with the occurrence of typhoons in the same year. This is also supported by superposed epoch analysis. We suggest that further utilization of oxygen isotope composition of tree-ring cellulose will enable attributing significant TC changes to specific climate forcing and thus further improve our understanding of TC dynamics.

IT-4 Combining growth, WUE $\delta^{13}C$, $\delta^{18}O$ and $\delta^{15}N$ measurements to reflect on white spruce $\delta^{15}N$-ring series as environmental indicator (Martine M. Savard, Christian Bégin, Joëlle Marion, Jérôme Laganière, and Anna Smirnoff)

Presented by: Martine M. Savard

Several studies have investigated tree-ring $\delta^{15}N$ series to understand perturbations in the natural forest N cycle due to changes in N deposition rates, emissions from anthropogenic sources or soil N loss and retention. These studies contributed to suggesting that tree-ring $\delta^{15}N$ values may stand as environmental indicator, but most of them were of local scale and based on short $\delta^{15}N$ series. The development of the environmental indicator however would gain from examining the relationships of N availability with a combination of several tree-ring measurements at the regional scale. Here we explore these links for white spruce growth, water use efficiency (WUE, calculated using ring $\delta^{13}C$ values), $\delta^{13}C$, $\delta^{18}O$ and $\delta^{15}N$ series from two stands, at 31 (SV) and 38 km (S2) from oil sands operations releasing acidifying emissions (NOx, SOx) since 1967 in northeastern Alberta, Canada.
When scrutinizing the century-long tree-ring results for the two sites, the most striking features are: (1) decrease of BAI after 1970 at SV, inversely correlating with acidifying emissions (less significant decrease at S2); (2) strong statistical links of WUE with summer Tmax and precipitation before the onset of operations, and weaker links after the onset of operations, at both sites; (3) strong positive correlation of WUE with anthropogenic acidifying emissions at all sites (including four partly characterized sites in a 75 km radius); (4) strong positive link between $\delta^{13}C$ and $\delta^{18}O$ series at S2 before operations, weaker after operations; (5) strong positive correlation of WUE and $\delta^{15}N$ values at SV, but a significant negative one at S2; and (6) correlation of acidifying emissions with $\delta^{15}N$ values, positively at SV and negatively at S2. These observations suggest that white spruce trees of the two sites use similar foliar strategies for reacting to the combined effects of climate change, rising pCO_2 and acidifying emissions after the onset of operations, i.e., lowering stomatal control and increasing photosynthetic control. Interestingly, these intrinsic mechanistic changes similar at all characterized sites underline the regional scope of the foliar response to changes in air quality. However, these mechanisms cannot explain the inverse $\delta^{15}N$ responses to anthropogenic emissions at SV and S2. A change of the overall soil $\delta^{15}N$ values

due to accumulation of anthropogenic N reported to be 15N-depleted relative to air N2 could account for the post-1967 low tree-ring $\delta^{15}N$ values as seen at S2, but could not explain the increasing trend at SV. Rather, site-specific differences in tree-species diversity, mycorrhiza-root associations, and soil microbiome may have triggered diverse chains of isotopic fractionation of N prior to its assimilation by trees. We are currently investigating some of these extrinsic mechanisms.
In summary, our current data set suggests that intrinsic mechanisms control $\delta^{13}C$ changes of regional range, whereas local extrinsic biogeochemical changes due to acidifying emissions may govern $\delta^{15}N$ trends. Our ongoing research aims at discriminating the main extrinsic controls on the $\delta^{15}N$ trends and assessing the applicability of this indicator for environmental research.

IT-5 Increased intrinsic water use efficiency but contrasting tree growth trends of Himalayan fir forests along elevation gradients in the central Himalaya, Nepal (Shankar Panthi, Ze-Xin Fan, and Achim Bräuning)

Presented by: Shankar Panthi

Global rise in temperature and atmospheric carbon dioxide concentration [CO_2] during the past century, and their critical impacts on tree growth and forests productivity have become key concern worldwide. High-elevation forests have become increasingly vulnerable during the past decades, however long-term tree growth trends and their physiological responses to global changes in the Himalayan region is poorly understood yet. Studying long-term tree growth trends and intrinsic water use efficiencies (iWUEs) of high-elevation forests are of great significance to global change ecology. Combining techniques of dendrochronology and tree-ring stable isotopes ($\delta^{13}C$) data, present study aimed to assess long-term growth-trends and tree physiological responses of high-elevation forests to global changes along elevation gradients. Tree ring increment cores of Himalayan fir (Abies spectabilis) were collected along elevation gradients in the central Himalaya. Standard dendrochronological procedures were followed for sample preparation, tree ring measurements and cross-dating. Stable carbon ($\delta^{13}C$) isotopes were measured from alpha-cellulose extracted from of precisely dated tree rings for different elevation bands and iWUEs were estimated. Long-term tree growths showed decreasing trends over time at lower elevations and dry sites, while increasing trends over time at higher elevations and humid sites. iWUEs have been increased at all elevations in past century with elevated [CO_2] and climate warming, meanwhile increasing iWUEs do not necessarily enhance tree growth. The findings of this study reveal that Himalayan fir forests continue to increase up to an optimum level of climate warming and elevated [CO_2] depending on how much could trees adjust to those changes.

IT-6 Trends in plant water use efficiency (Alienor Lavergne, Heather Graven, and Colin Iain Prentice)

Presented by: Alienor Lavergne

Understanding plant responses to rising atmospheric CO_2 and climate changes is crucial to accurately predict future changes in terrestrial carbon and hydrological cycling. Water-use

efficiency (WUE, i.e. the carbon gained per unit of water loss) is an important tracer of the physiological control on the exchange of water and carbon dioxide between terrestrial ecosystems and the atmosphere. Elevated CO_2 concentrations tend to increase carbon uptake and to reduce stomatal conductance, both effects leading to an increase in WUE. Progress has been made in estimating the magnitude of changes in WUE over the 20th and 21st centuries, and attempts have been made to disentangle the biological and physical processes and feedbacks responsible for these variations. However, the magnitude of the increase in plant WUE estimated by different methods differs strongly amongst studies, indicating unresolved issues with these methods. Moreover, current Earth System Models (ESMs) produce inconsistent and often unrealistic magnitudes and patterns of variability of WUE. Here we review the biological and physical processes influencing WUE variations and trends, with the aim of deciphering the processes responsible for discrepancies observed within and across spatial scales. Our findings suggest ways in which both numerical modeling and the interpretation of data could be put on a firmer basis.

Thursday June 14th 14:00-15:00
Presentations IT7-10
(Breakout Room 2)

IT-7 Towards Reconstructing the Frequency and Origin of North American Monsoon Precipitation at its Northwest Boundary (Franco Biondi, Michael Dettinger, Simon Poulson, Emanuele Ziaco, and Adam Csank)

Presented by: Charles Truettner

Precipitation associated with the North American Monsoon (NAM) is a dominant source of warm-season moisture input in the American Southwest. In 2012-2015, Nevada and California experienced a severe drought with initial relief from anomalous precipitation events starting in the late-summer of 2015 linked with strong monsoonal storms at its northwest boundary. Pacific frontal storms continued to provide precipitation through the 2016-2017 cool season ending the severe drought. This recent drought, and a unique data collection program in the Sheep Range of southern Nevada, provide an opportunity to examine drought termination signals in *Pinus ponderosa* tree rings at an unusually high resolution. We collected stem microcores from twelve P. ponderosa individuals at the NevCAN Sheep Range Montane site, a state-of-the art meteorological station that records subhourly weather and ecophysiological measurements, north of Las Vegas on biweekly intervals throughout the 2015 and 2016 growing seasons. In addition, cumulated precipitation samples were taken at the site, and a tree-ring chronology spanning 1640-2015 was developed from tree cores extracted from 33 P. ponderosa trees located at the site. We are currently working on a $\delta^{18}O$ and $\delta^{13}C$ earlywood and latewood Î±-cellulose isotope chronology dating back to 1640 to interpret the frequency of NAM precipitation at the site. In addition, high-resolution $\delta^{18}O$ and $\delta^{13}C$ measurements from microtome slicing (~20 µ) will be compared to δ 18O and δ 2H in precipitation and stem water to interpret how P. ponderosa of various sizes respond to precipitation events. Analysis of modern meteorological records indicate that the NevCAN P. ponderosa stand is situated at the northwest boundary of the NAM region and that monsoonal precipitation at this site is well correlated with high-altitude precipitation across a

broad surrounding area. Thus, dendroclimatic reconstruction of monsoon fluctuations at the site has broad sub-regional implications.

IT-8 Circulation changes from stable isotopes in Ethiopian tree-rings (Iain Robertson, Marcin Koprowski, Eyob Gebrehiwot Gebregeorgis, Zewdu Eshetu Tommy Wils, and Park Williams)

Presented by: Iain Robertson

The hydroclimate of equatorial east Africa is complex with precipitation originating from the Indian and Atlantic Oceans. As the instrumental climate data are short and existing global climate models have little skill at recreating seasonal rainfall variations in eastern Africa, there is need for an indirect measure of past climates to improve our knowledge of the complex climate in this region. The determination of stable isotopes from absolutely-dated tree-ring chronologies allows inferences to be made about past climates and wider circulation patterns.

IT-9 Past summer temperature in Northern Patagonian Andes inferred from δ13C in Fitzroya cupressoides (Valérie Daux, Aliénor Lavergne, and Ricardo Villalba)

Presented by: Valérie Daux

There are markedly fewer well-dated proxy records for the Southern than for the Northern Hemisphere. We explored the potential of carbon isotopic composition in the tree-ring cellulose (δ^{13}Ccell) of *Fitzroya cupressoides* to reconstruct past climate variability. The δ^{13}C cell variations are influenced by summer sunlight radiation. As a result they were strongly - although indirectly – related to summer temperatures. Within the calibration period, the fraction of temperature variance explained by the δ^{13}Ccell proxies is 62% ($n = 81$, $p < 0.001$). A 200-year long δ^{13}Ccell chronology was developed on the eastern slope of the northern Patagonian Andes (41°S). It shows cold summer temperatures in the second part of the 19th century and in the mid-20th century followed by a warmer period. The 20th and the early 21st centuries were warmer (+0.6°C) than the 19th century. Reconstructed summer temperature variations were modulated by both low-latitude (El Niño–Southern Oscillation) and high-latitude (Southern Annular Mode) climate forcings. Our reconstruction agrees well with previous ring width based temperature reconstructions for the region and comparatively enhances the low-frequency variations in the records. The present study provides the first reconstruction of summer temperature in South America for the period 1800–2011 entirely based on isotopic records.

IT-10 Tree ring isotopes infer large-scale primary productivity and reveal water availability as a main driver of tree growth (Mathieu Levesque, Laia Andreu-Hayles, William Kolby Smith, A. Park Williams, Martina L. Hobi, Brady W. Allred, and Neil Pederson)

Presented by: Neil Pederson

Historical and future trends in terrestrial net primary productivity (NPP) and its response to global change are largely unknown because of the lack of long-term, high-resolution data. The longest flux-tower records and satellite-based estimates cover at most the last three decades, while forest inventories have multiannual to decadal gaps between consecutive measurements. We tested whether annually resolved tree-ring stable carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotopes can be used as proxies for estimating past NPP at local and regional scales. Stable isotope chronologies from four sites within three distinct climatic environments in the eastern United States (US) were compared in time and space against satellite-derived NPP products, including the Moderate Resolution Imaging Spectroradiometer (MODIS) NPP product (2000–2015), the long-term Global Inventory Modeling and Mapping Studies (GIMMS3g) NPP dataset (1982–2011) and the newest Landsat NPP product (1986–2015). Tree-ring isotopes, in particular $\delta^{18}O$, correlated strongly with the three satellite NPP products at the study site level and across large geographical regions. The results are generally consistent among the studied tree species and under contrasting climatic conditions. Stable isotopes also revealed that water availability, not elevated CO_2 and reduced acid deposition, was the main driver of gas exchange and growth in these broadleaf forests. These findings represent an important breakthrough for estimating long-term changes in terrestrial productivity at the biome scale using tree-ring stable isotopes.

Methodological Innovations in Dendrochronology

Session Chairs:

Dr. Alexander Stine; Dept. Earth & Climate Sciences, San Francisco State University, San Francisco CA. USA
Dr. Rob Wilson; School of Earth & Environmental Sciences, St. Andrews University, St. Andrews, Scotland

Dendrochronology (and its associated sub-fields) is a constantly evolving scientific discipline. Whether the research focus is ecological analyses, historical dating or climate reconstruction, statistical methods employed today have utilized the ever increasing computational power of modern computers allowing the processing and analysis of large data-sets and measurement of physical variables that would simply not have been possibly a few decades ago. As analytical costs have significantly reduced over the last decade, dendrochronology is poised for a golden age of chemical analysis through the utilization of stable isotopes and trace elements that could open the discipline to a whole new spectrum of environmental analyses. Also, tree-ring data-sets are expanding both spatially and temporally (for example, with the inclusion of historical and sub-fossil material) and extracting useful

ecological and climatologically information from heterogeneous data-sets is a significant challenge. We invite papers that detail new statistical, analytical and theoretical methods as well as novel measurements, equipment, and field methods relevant for any sub-discipline in tree-ring research that will continue the development of the science towards the 22nd century.

Friday, June 15th 10:30-12:30
(Breakout Room 1)

MI-1 Implications of Liebig's law of the minimum for tree-ring reconstructions of climate (Alexander Stine, and Peter Huybers)

Presented by: Alexander Stine

Liebig's law of the minimum posits that the growth factor that is least abundant, relative to physiological requirements, controls plant growth. This principle implies that a limiting environmental factor can be inferred from historical growth patterns, and such reconstruction is generally achieved by averaging collections of standardized tree-ring records. Averaging is optimal if growth records are composed of a signal of interest plus unrelated noise. If variable growth across trees instead reflects the operation of the Law of the Minimum, averaging is no longer optimal because certain variations reflect a local, more-limiting factor. Here we use a large collection of tree-ring records to show that growth patterns reflect local operation of Liebig's Law. The local signature of Liebig's Law is found at both temperature- and moisture-limited sites, and in both tree-ring width and tree-ring density. Recognition that the Law of the Minimum operates at the level of individual trees can be leveraged to improve the skill of dendroclimatological reconstructions. Climate reconstructions based on trees undergoing the highest relative growth in a given year systematically outperform those using a mean chronology, especially at sites where relatively more trees were sampled. Improvements in reconstruction skill occur across all frequencies, with the greatest increase at the lowest frequencies. These results suggest the potential for better reconstructing historical climate variability through pairing intensive tree-ring sampling with a focus on those trees experiencing the highest relative growth.

MI-2 A framework for determining the vulnerability of tree populations to climatic change: a case study of Chamaecyparis thyoides from along its contiguous latitudinal distribution (Caroline Leland, Daniel Bishop, Jessica Pearl, Kevin Anchukaitis, Myvonwynn Hopton-Ahmed, Dario Martin-Benito, and Neil Pederson)

Presented by: Neil Pederson

Many European forests have become phosphorus (P) limited in recent decades, possibly due to increased nitrogen deposition, soil acidification and improved tree growth. Dendrochemical analyses of P might enable a retrospective analysis of P nutrition of trees and provide

valuable information about the effects of short-term changes (recycling efficiency) as well as of long-term environmental trends on the P availability in forest ecosystems.
We elaborated and further developed the Laser Ablation ICP-MS methodology to measure P in individual year rings. Our ongoing work has shown that the recovery of P in wood samples using the LA-ICP-MS approach is very good. However, owing to the relatively small area captured (we used laser shots producing holes of 100 μm), single shots may not adequately represent the spatial heterogeneity of P distribution within tree-rings. This spatial variation increases the noise in our data and makes the identification of signals from environmental effects more difficult.
So far we focused on spatial patterns of P within tree rings that might have been caused by temporal variation in P through different seasonal uptake or immobilization strength. However, the difference in P content between early wood and late wood was not significant. Therefore, we will test approaches to capture the spatial variation in circumferential direction within tree rings. In addition, we analyze wood anatomical structures like parenchyma rays of deciduous and conifer trees. Here we want to see how these nutrient rich tissues differ from the surrounding woody biomass and if there is also a variation within this structures e.g. in radial direction.
We found for *Picea abies* stronger radial variability in element concentration, in sapwood as well as in heartwood, compared to circumferential direction. In contrast, for *Fagus sylvatica* we found reverse results, here the variability was stronger in circumferential than in radial direction. This stronger variability for *F. sylvatica* seemed to be caused by parenchyma rays. At *F. sylvatica* parenchyma rays showed for all nutrients higher element concentrations than the surrounding wood, in sapwood as well as in heartwood. Additionally, we found that P concentrations in *F. silvatica* tree rings are considerably higher than in *P. abies*.

MI-3 PlotRings: an R function to draw and animate tree-ring series (Darwin Pucha-Cofrep, Wernicke Jakob, Korpela Mikko, and Bunn Andy)

Presented by: Darwin Pucha-Cofrep

"PlotRings" is a new R function into the Dendrochronology Program Library in R (dplR), which makes a simple plot, drawing all rings from tree-ring series on a Cartesian plane of up to four cardinal directions (N, S, E, W) defining the eccentricity of the stem. It can be plotted using only data from one ratio, or up to four different radii from same tree. This function can plot each individual ring as an animation within the R-GUI, as a GIF file, or it can plot all rings at once. This function also provides a basic summary statistics of an approximated stem disc.

MI-4 The wisdom of crowds: how could citizen science empower the world dendro-data? (Jakub Trojan, and Jiri Lehejcek)

Presented by: Jakub Trojan

Citizen science belongs to the most effective approaches to collecting data from large scale areas or large quantities. There are many citizen science platforms / infrastructures, which could be used for dendro-ecological research. If we compare the number of citizen science projects according to their purpose, we realize that the number of those dealing with dendrology is not as high as in other fields, despite the environmental character of most

citizen science projects. Thus we analysed the active citizen science projects in different platforms focusing mainly on established citizen science initiatives (such as ALA's BioCollect, SciStarter, GBIF, etc.). We dealt with the number of projects, their spatial-temporal framework, number of participants, used technologies (and techniques) and other relevant aspects upon which a comparative analysis was conducted. As a result, we discuss the role of citizen science projects in contemporary dendro-ecological research, underlying the possibilities which these could projects bring to the researchers. We also discuss the scientific relevance of the collected data and their further use. The contribution is based on state-of-the-art research conducted under the European Union COST Action CA15212 (Citizen Science to promote creativity, scientific literacy and innovation throughout Europe).

MI-5 Tracing anthropogenic pollution through dendrochemistry (Eva Rocha, Björn Gunnarson, and Steffen Holzkämper)

Presented by: Björn Gunnarson

The growing concern regarding pollution effects on the environment and human health demands new control strategies and monitoring tools. In this study we assess the potential of using dendrochemistry as a forensic tool to investigate chemical contamination patterns in the surroundings of a former glass factory in Southern Sweden. Tree-ring width chronologies were produced from exposed and non-exposed sites. Using energy disperse X-ray fluorescence (EDXRF) technique, tree cores of Scots Pine (*Pinus sylvestris*), Norway spruce (*Picea Abies*) and *Populus tremula* (European Aspen) were analysed for their elemental composition in accordance with previous soil analysis done in the area. Traces of barium and considerable alteration of the chlorine profiles were successfully detected confirming the potential of the method to record environmental releases. The dendrochemical analysis also highlighted the differences in the response of tree species to elements uptake (root sensitivity) and the importance of metals bioavailability. Finally, the adopted sampling strategy is of outmost importance to the success of the method.

MI-6 Autocorrelation patterns in New Zealand and Tasmanian tree species (Jonathan Palmer, Kathy Allen, Ed Cook, and Pavla Fenwick)

Presented by: Jonathan Palmer

Within a tree-ring series, the correlation of one ring to its previous values at different steps of time (or lags) is called autocorrelation or serial correlation. Most ring-width series are autocorrelated to a significant extent - something also sometimes described as 'biological memory effects'. A summary of the autocorrelations of a time series for different lags is called the autocorrelation function (ACF). The partial autocorrelation function (PACF) is a summary of the relationship between a tree ring in a time series with those at prior time steps or lags, but with the relationships of intervening steps removed. Here we explore the ACF and PACF of 13 different species from New Zealand and Tasmania (Australia) to see if they have any specific patterns or common memory effects. All ring-width series from across all sites were first standardised the same way and then the index series for each species was pooled together to determine their autocorrelation values. The results show that each species appears to have its own ACF and PACF patterns. Several species showed a high first

order PACF value followed by lower values for several other lags. Related species from both countries showed broadly similar patterns. One species (*Phyllocladus glaucus*) appeared unique with a negative first order PACF followed by three consecutive positive values. These biological memories could potentially bias climate regressions or responses to large volcanic eruptions. However, the consistency of the ACF and PACF patterns between modern and subfossil collections is encouraging for climate interpretations.

MI-7 Exorcising "divergence" using Blue Intensity in the southern Yukon (Rob Wilson, Laia Andreu Hayles, Ed Cook, Rosanne D'Arrigo, Nicole Davi, Lisi Habebauer, Paul J. Krusic, Brian Luckman, David Morimoto, Rosie Oelkers, and Cheryl Wood)

Presented by: Rob Wilson

One of the regions in the Northern Hemisphere (NH) that shows the so-called "Divergence Problem" (DP) most strongly is the Yukon Territory and inland Alaska. Previous research has shown that the DP is expressed in ring-width (RW) data, and studies from northern Alaska and the Yukon, using maximum latewood density (MXD), have shown a temporally stable response with summer temperatures for this variable. Reasons for DP in RW data include increased tree-growth related moisture limitation due to warming and drying, heterogeneity issues within instrumental climate data and trend biases related to standardisation methodologies. Blue Intensity (BI) provides a potentially cheaper, but related, variable to MXD. In this study we measured BI from 17 white Spruce sites in south-west Yukon and explore a variety of detrending and compositing methodologies to ascertain whether BI can overcome temporal instabilities noted in the RW data for the region. Although BI expresses a weaker common between-tree signal than RW (RBAR 0.17 vs. 0.32), its relationship with summer temperatures is stronger. Age-dependent spline detrending within the signal-free framework consistently returns the strongest calibration results for both RW and BI. The RW data calibrate (1944-1997) most strongly with June/July maximum temperatures (Tmax) with a range of 14-34% explained variance depending on compositing method and detrending choice. All models fail validation (reduction of error and coefficient of efficiency) and residual analysis. BI, on the other hand, calibrates (with MJJA Tmax) strongly with a range of 43-51% with excellent validation. Experiments using both RW and BI are inferior to using BI alone. By compositing all the BI data across the region, the new SW Yukon summer temperature reconstruction goes back to AD1337 where replication is at least 15 trees. Comparison to other TR based summer temperature reconstructions from the Gulf of Alaska, Wrangells and Northern Alaska shows good agreement at decadal and high frequencies, but the Yukon BI data appear limited in their expression of centennial-scale low frequency variation. This is likely related to the use of the data-adaptive age-dependent-spline approach to detrending that can still remove low frequency variation even when using signal-free methods. Experiments using regional curve standardisation have yet to be performed. Superposed Epoch Analysis shows that there is no mean response to major volcanic events expressed in the RW data, but the BI data shows an immediate (T+0 year) response to high latitude NH events, but a lagged (T+4 year) response to low latitude events. Finally, calibration experiments using different periods since 1900 and different sites, suggest that the temperature signal expressed by the BI data is likely systematically biased due to resolution issues of scanned images of conifer samples. Calibration coherence ranges from 30-60% for rings > 0.5 mm, but reduces to 10-40% for rings < 0.40 mm. The utility of BI for dendroclimatology is still in an exploratory phase, but the results from the southern Yukon

are encouraging and appear to overcome known DP issues in the region. The remaining hurdle for BI is the capture of centennial and longer-scale variability.

MI-8 DendroTools: R package for studying linear and nonlinear responses between tree-rings and daily environmental data (Jernej Jevšenak, and Tom Levanič)

Presented by: Jernej Jevšenak

The dendroTools R package was designed for the analysis of the statistical relationships between tree-ring parameters and daily climate data. The core function of the package is daily_response(), which works by sliding a moving window through daily climate data and calculating statistical metrics with one or more tree ring proxies. In addition to linear regression, it is possible to use a nonlinear artificial neural network with the Bayesian regularization training algorithm (brnn). dendroTools provides the opportunity to use daily climate data and robust nonlinear functions for the analysis of climate-growth relationships. Models should thus be better adapted to the real (continuous) growth of trees and should gain in predictive capabilities. The dendroTools R package is freely available in the CRAN repository.