Poster Presentations

Session I. Monday June 11th 16:00-17:30

Methodological Innovations in Dendrochronology

MI-1p Spatial heterogeneity of Phosphorous concentrations within tree rings – results from LA-ICP-MS measurements (Joerg Niederberger, Matthias Trottmann, Adrian Wichser, Martin Kohler, Davide Bleiner, and Juergen Bauhus)

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 analyse 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-2p A global digital archive of X-ray CT imaged tree cores (Tom De Mil, Joris Van Acker, Hans Beeckman, and Jan Van den Bulcke)

Forests are multifunctional providers of ecosystem services, directly and indirectly contributing to human well-being. Above all forests are the primary producers par excellence, containing more than 80% of the terrestrial biomass, providing non-timber forest products and wood: worldwide, forests provide more than 1.8 billion m³ of industrial round wood annually. Furthermore, forests represent a net carbon sink for human generated emissions, they also often provide clean water at a much lower cost than man-made substitutes like water treatment plants when managed accordingly and they can reduce possible health costs due to their function as particulate matter filters.
It stands to reason that we need to grasp the functioning of forests in order to ensure continuing provisioning of aforementioned services under a changing climate in what is often referred to as the Anthropocene. Tree rings, as archives of the past and biosensors of the present, offer the opportunity to do so, to study climate - tree-growth over decades to centuries (Babst et al. 2017),

yet we need large datasets and need to investigate beyond ring widths only.
At UGent-Woodlab (www.woodlab.be) we have been working towards the use of X-ray Computed Tomography (CT) scanning to obtain large datasets. Virtual increment cores are saved as multipage TIFF files, metadata is stored as well (minimally location and wood species) and can be processed using dedicated software. Pith-to-bark density profiles and ring widths can be obtained simultaneously, allowing for accurate biomass stock estimations, as well as productivity throughout the lifespan of a tree. Currently, more than 5000 cores (actually curated at the Tervuren xylarium - http://xylarium.africamuseum.be) have been scanned, most of them at a resolution of 110 micron. An overview of the metadata and the sample locations is given on http://www.dendrochronomics.ugent.be. Software routines such as density-based crossdating, annotations such as ring indications are tied to the images and archived such that future researchers have all information available, including the indicated ring boundaries. Efforts are being made for an online platform, and machine learning techniques are being developed to treat such large datasets.

MI-3p Introducing the Individualistic Growth Response network (IGR) (Ryszard J. Kaczka)

Individualistic growth response - i.e. the individual-specific and partly differing response of neighbouring trees to environmental conditions - is gaining more and more attention. Within this context, recent studies are of interest since they have shown the expression of climate-growth relationships to depend on soil conditions (Lévesque et al., 2013, Rehschuh et al., 2017) as well as distance to the forest edge (Buras et al., 2017) which may help to better understand the mechanisms driving trees individualistic responses. However, the aforementioned studies represent rather local to regional spatial scales and do not encompass broad-leaved tree species. Thus, additional insights from other species and over larger scales are desirable - ideally following a systematic and uniform approach.
Here, we present the international Individualistic Growth Response network (IGR) which aims at deepening our understanding of individual-specific tree growth by including several species and sites to represent a wide range of ecological conditions. A central principle of IGR is to apply a standardized dendroecological approach across the network, which allows for lowering investigator-specific biases and thus addressing general questions systematically. Currently, the network comprises data from 14 countries (ranging from Canada to China, but with a special emphasis on Europe) representing eight coniferous and three broad-leaved species. The poster presents initial research questions along with corresponding results obtained at an international workshop that takes place at Wageningen University and Research in February 2018.
IGR is a steadily growing network and we invite everybody to participate since this will further strengthen our expressiveness. A meet and greet at our poster will provide a good opportunity to discuss further research avenues and clarify open questions related to network-participation. We are looking forward to see you there!

MI-4p Pilot study of density structures using high resolution CT-scanning (Øyvind Paasche, Alexander Stine, Eivind William, and Nagel Støren)

High-resolution CT imaging of timber core samples has the potential to permit interrogation of the full three-dimensional density structure of tree growth while increasing the rapidity with which interannual density variability can be sampled. In this pilot study, samples from trees were collected from a high-altitude, continental area in central south Norway known as Rondane. Samples of near 200-year old *Pinus sylvestris* were collected close to the local tree line at 700 m altitude (N61.78, E9.72) and a ca 100-year old *Larix decidua* taken from the valley at 275 m altitude (N61.78, E9.54). Visualization of the selected tree ring samples was run in axial scan mode in a ProCon Alpha CT Core CT scanner at EARTHLAB, University of Bergen. Tube voltage was set to 58kV, current to 700mA and exposure time at 667ms. A total of 800 projections were made of the rotating sample,

producing 16-bit imagery (65 000 grey values) with a voxel (volume pixel) size of 20 microns. The 3D volume image was reconstructed using Volex software, and visualized in Avizo Fire 9.4 (FEI). High-resolution 3D-images indicate that interannual variability in earlywood and latewood density can easily be distinguished as well as other structures. We compare the variability in interannual density variability inferred from individual density profiles subsampled from individual cores and quantify the potential for error reduction by taking advantage of the full three-dimensional density structure. Next steps in this study involves collecting and analysing a larger number of samples that cut across environmental gradients running from the Valley floor and up to the local tree line.

Wood Anatomy and Modeling Wood Formation

WA-1p ROXAS - Quantifying xylem anatomy in angiosperms and conifers (Georg von Arx, Marco Carrer, and Angela Luisa Prendin)

Tree-ring anatomical features such as conduit size, density and cell wall thickness are nowadays recognized as valuable archives of past growth conditions. Compared to ring width that integrates conditions over an entire growing season, dendroanatomy, i.e. the analysis of anatomical features in time series of decades to centuries, can provide information about past growth conditions in an intra-annual resolution. Despite these promising perspectives, the wide use of dendroanatomy has been strongly limited by technical constraints, because measuring anatomical features is often very cumbersome and time consuming. This is why time series of wood anatomical features have been either short or based on a small subset of the sample such as a few radial files.
In this poster we present ROXAS: a specialized image-analysis tool that has been developed to overcome many of the previous constraints. ROXAS can be used for angiosperms and conifers, for (circular) branch and root samples as well as (linear) tree cores. It is designed to process large images of large samples and produce output for all conduits, even in conifers (up to 1,000,000 tracheids per sample). After automatic recognition of conduits and (with some limitations) ring borders, the user can efficiently improve the automatic output directly in the image. Besides ring width and conduit lumen dimensions, data output includes many additional parameters such as conduit position within the ring, mean hydraulic conduit diameter (Dh), theoretical hydraulic conductivity, conduit grouping (angiosperms), cell wall thickness of each conduit (conifers), Mork‰ index and wood density. ROXAS can be obtained at www.wsl.ch/roxas for free within the scope of the user policy, but depends on the commercial software Image-Pro Plus.

WA-2p Anomalous Annual Rings and Climate Extremes (Liudmila A. Gorlanova, Rashit M. Hantemirov, and Vladimir V. Kukarskih)

Analysis of anomalous structures in tree rings is the promising method of climatic extreme reconstruction. In contrast to ring width, growth anomalies are produced by very short-term events, and in some cases they occur within seasons that were not reconstructed as cold seasons using ring-width data. Three types of micro anatomical traces of larch (*Larix sibirica Ledeb.*) and juniper (*Juniperus sibirica Burgsd.*) from the Yamal Peninsula and the Polar Urals have been used for the reconstruction of such short extreme temperature events, namely, frost-damaged layers of cells - frost rings, thin-walled latewood cells - light rings and wood density fluctuations - false rings.
On the basis of anomalous structures analysis we reconstructed cold summers (light rings), summer frosts (frost rings) and abrupt temperature declines during the second half of the growing season (false rings) over the past 5500 years for the Yamal Peninsula and 1350 years for the Polar Urals. Comparison of our data with data from other regions of the world shows that there is agreement in the timing of many extreme temperature events. Most probably, these extremes have been caused by climatically effective explosive volcanic eruptions.

WA-3p Tall timbers - exploring tree ring anatomy and dendroclimatology potential of Eucalyptus diversicolor (karri) (Joshua S. Oliver, Alison J. O'Donnell, W. Lachlan McCaw, Edward R. Cook, and Pauline F. Grierson)

Eucalypts characterise the forests of Australia yet there have been no extended dendrochronologies developed from any of these hardwood species. Past attempts have been largely frustrated by the challenges of cross-dating trees with diffuse-porous growth rings, but have also investigated relatively few species. Capacity to delineate annual tree-ring boundaries within eucalypts (Eucalyptus and Corymbia species) would be enhanced by improved knowledge of anatomical wood traits and how these may vary from year to year and under different growth conditions. Here, we assess the potential for using *Eucalyptus diversicolor F. Muell* (karri) in dendrochronological research. Karri grows to more than 80 m in height and is thought to live for several centuries yet its potential for developing climate proxies is unknown. Our studies to date reveal that karri ring boundaries exhibit a unique vessel size gradient throughout each ring. Intra-ring vessels are largest and most abundant in the "early wood" and decrease in overall size at each ring boundary leading to an eventual break in vessel production, which marks the ring boundary. Visual identification of the ring boundaries has also been improved through bleaching of the wood and colour enhancement of digital images of tree cores. Based on samples of known-age stands, ring formation appears to be primarily annual and trees sampled from the same stands exhibit similar "marker" rings. We are now attempting to cross-date trees based on our new approach to determining ring boundaries in karri in order to then assess the extent to which karri may record environmental information in its growth.

WA-4p Using anatomical techniques to describe subfossil wood decay (Frederick Reinig, Holger GŠrtner, Fritz Schweingruber, Alan Crivellaro, Daniel Nievergelt, Jan Esper, Michael Friedrich, Gerhard Helle, Bernd Kromer, Sandro Morganti, Maren Pauly, Adam Sookdeo, Kerstin Treydte, Willy Tegel, Lukas Wacker, and Ulf Buentgen)

Multi-centennial to millennial tree-ring chronologies, consisting of different sources of relict wood material, are important for archaeological dating and paleoclimatic reconstructions. A variety of wood decaying processes, however, often hampers the analysis and interpretation of such wood. Here, we demonstrate that anatomical studies can provide unique insights into wood structure and quality, ideally improving the cross-dating success of highly decayed ring-width sequences. We therefore introduce state-of-the-art sample preparation, thin sectioning and staining techniques to some of the world’s best preserved Late Glacial pines that were growing ~ 130000 years ago in the current city of Zurich, Switzerland. Being characterized by different rates of biological degradation and mechanical failure, a careful consideration of wood anatomical parameters of our subfossil material not only facilitates cross-dating during periods of particularly narrow rings. It also reveals a better understanding of the direct and indirect factors that were possibly involved in the repeated forest dieback at the transition from generally cooler Late Glacial conditions into the overall warmer Holocene. Our results emphasize the relevance of using wood anatomical techniques routinely in the assessment of all kinds of relict wood, originating from historical constructions, archaeological excavations and subfossil deposits.

WA-5p Dendrochronological and radiocarbon dating of medieval buildings in th mountain part of Ingushetia (Northern Caucasus, Russia) (Vladimir Matskovsky, Umalat Gadiev, Andrey Dolgikh, Ekaterina Dolgova)

Ten most prominent medieval buildings – Christian churches, crypts, temples, sanctuaries, battle towers, and living buildings – in mountain part of Ingushetia that contain wooden construction elements were selected to b dated using natural science methods – radiocarbon and dendrochronological dating. These kinds of analyses ar performed for the first time in this region – previously all these buildings were only dated by historians, architects, and sometimes by archaeologists. We were not able to acquire dendrochronological dates due to th lack of long tree ring chronologies, but the obtained wiggle-matched radiocarbon dates will serve as new benchmarks for the chronology of architecture in the region. Also the developed floating tree ring chronologie will contribute to the improvement of dendrochronological network of the Northern Caucasus.

Dendroclimatology

DC-1p Dendroclimatological analysis of wild pear from Poland (Wojciech Antkowiak, and Anna Cedro)

European wild pear (*Pyrus pyraster*, syn. *Pyrus communis* subsp. pyraster L.) is widely distributed in Europe, but rarely studied by dendrochronologists. This study was aimed to assess the effect of climate on tree-ring width in the 5 largest Polish population of *P. pyraster*. On the basis of samples from 153 trees, 5 chronologies were constructed. Mean tree-ring width in the studied trees were from 1.1 to 2.4 mm. The performed analyses (pointer years, correlations, and response function) indicate that tree-ring width was strongly dependent on weather conditions in the year preceding formation of the tree-ring. Annual rings of pear trees were wide after cold and rainy summers and after long, warm, sunny and dry autumn, while in the current year, ring width was affected by insolation in February and July (positive correlations) and precipitation in July (negative correlation). Only in one population (Bielinek Reserve) we observed low similarity of the ring-width pattern and effect of climate on tree-ring width others wild pear populations. Bielinek Reserve is located in NW part of Poland, in dry and warm habitats: xerothermic grasslands *Potentillo-Stipetum capillatae* and *Adonido-Brachypodietum*, as well as thermophilous oak forest *Quercetum pubescenti-petraeae* in the forest-steppe reserve. Its tree-ring width was strongly related to precipitation and temperature in spring and summer. High precipitation resulted in wider tree rings, while dry years (associated with high air temperature) caused a decrease in tree-ring width. Another significant factor is precipitation in winter, which had a positive influence on tree-ring width.
The results obtained indicate the need for continue dendrochronological analyses.

DC-2p Application of hydrologic modeling to examine the climate-growth relationship of Alaska yellow-cedar (Callitropsis nootkatensis) in the North Cascades (Christopher Trinies, and Andrew G Bunn)

Natural variations in climate that occur on an annual or decadal scale influence tree growth. Climate sensitivity in trees has traditionally been looked at through the lens of easily interpolated variables, specifically temperature and precipitation, as proxies for energy and water limitation to growth. This has been the norm in part because the data are more readily available. In regions where a clear limiting factor exists, this has allowed us to reconstruct the climate thousands of years before any written record was made. However, the climate signal among trees in the Pacific Northwest tends to be mixed, varying by species, aspect, elevation, and multiple responses, making paleoclimate inference difficult. Recent analyses using hydrologic modeling (climate models developed for modeling streamflow) instead of the traditional temperature and precipitation correlations have allowed me to look at climate using environmental variables that are more relevant to plant growth in

the Pacific Northwest. I use the Variable Infiltration Capacity (VIC) model to look at the limiting environmental factors and tree-ring variability in Alaska yellow-cedar (*Callitropsis nootkatensis* (D. Don) Oerst. ex D.P. Little). I show that Alaska yellow-cedar growth is sensitive to growing season temperatures, and that the sensitivity is mediated by water stress. This work is novel in its approach in using Alaska yellow cedar to dig deeper into the relationship between growth and climate, and is an important step towards furthering our understanding of climate variability on the mesic western slopes of the northern cascades.

DC-3p Annual minimum temperature change over east central Tibetan Plateau inferred from Sabina tibetica tree rings since AD 1451 (Teng Li, and Jinbao Li)

Minimum temperatures have increased rapidly on the Tibetan Plateau (TP) in recent decades, but there is still a lack of long-term background information to evaluate the nature of the anomaly. Here we present a 709-year tree-ring width chronology from *Sabina tibetica* Kom. on the east central TP, with reliable coverage from 1451 to 2014. Based on the significant relationship between tree growth and annual minimum temperature (Tmin), from previous April to current March, we reconstruct the pApril-cMarch Tmin for the past 564 years. The re- construction shows six major warm (1490–1623, 1713–1729, 1784–1812, 1868–1877, 1918–1954, 1989–2014) and six major cold (1451–1489, 1624–1712, 1730–1783, 1813–1853, 1878–1917, 1955–1988) periods during the past five hundred years. The level of warming from 1989 to 2014 is unprecedented over the past five centuries. Comparison with other minimum temperature records indicates that our Tmin reconstruction re- presents large-scale temperature changes on the eastern TP. The positive correlation between the Tmin re- construction and the Atlantic Multidecadal Oscillation (AMO) suggests that the latter may have played a crucial role on multidecadal temperature variations over the east central TP, with high temperatures coincident with the warm phases of the AMO, and low temperatures related to the cold phases of the AMO, respectively.

DC-4p Reconstruction of the Interdecadal Pacific Oscillation (IPO) to CE 860 using tree-rings from Indonesia, Australia and New Zealand (Jonathan Palmer, Ed Cook, Chris Turney, Benjamin Cook, Pavla Fenwick, Kathy Allen, and Patrick Baker)

The southwestern Pacific region is known to be significantly influenced by the Interdecadal Pacific Oscillation index (IPO). Here we explore the use of a network of tree-rings and wood properties from Indonesia, Australia and New Zealand to determine the strength and spatial expression of their relationship to the tripole index of the IPO (t-IPO). From the available pool of proxies, 65 were selectively screened and used in regressions to calibrate/verify to the t-IPO over the period CE 1871-1975. The positive results then enabled the reconstruction austral "summer" t-IPO values extending back to CE 860. One concern was a potential geographic (i.e. local) bias of the proxies but an examination of the correlations to each of the three contributing t-IPO regions were similar. The spectral pattern showed the presence of strong ENSO and longer periodicities as well as coherency with some other published reconstructions. A pronounced negative IPO phase occurred in the 1580s with an associated step change to both more frequent but shorter duration phases.

DC-5p Five centuries of tree-ring based winter temperature analysis at Gongga Mountains, southeastern Tibetan Plateau (Jingxian LI, Jinbao LI, Teng LI, and Tsun Fung AU)

Tree-ring records are valuable in illustrating regional climate change over a long period of time with annual resolution, especially for areas lacking long-term climate records. Two ring-width chronologies of five centuries (1601-2014) were developed from Abies georgei Orr and *Sabina tibtetica* sites on

the Gongga Mountains, southeastern Tibetan Plateau. Significant positive correlations were identified between tree-rings and minimum temperatures, in particular in prior winter (previous December to current March). Pronounced warming of local temperature was identified, with the minimum temperature increasing more rapidly in the second half of the 20th century. Meanwhile, the widely observed divergence problem of tree growth and temperature in mid- and high-latitude regions was not observed at our sampling sites, indicating the complexity and multi-causality of the phenomenon.

DC-6p Dendroclimatic reconstruction in the Gilgit Baltistan region of Pakistan from three different genera (Sanjaya Bhandari, James H. Speer, Moinuddin Ahmed, and Adam Khan)

The Hindu-Kush Himalaya is a very important landscape to study for evidence of climate change. The Tibetan plateau is known as the third pole because its mass and elevational effect on global atmospheric circulation and energy balance. To understand the change in the climatic patterns over 500 years of the Gilgit Baltistan region in the Pakistan Himalaya, we have collected tree-core samples of *Pinus wallichiania, Picea smithiana*, and *Abies pindrow* from three different sites. The well cross-dated samples were standardized with an age-dependent spline and signal free standardization. With these samples, we have developed a 608 year (AD 1408-2015), 548 (AD1468-2015) year, and 255 (AD1761-2015) yearlong chronology of *Pinus wallichiania, Picea smithiana* and *Abies pindrow*, respectively. We have found three periods of above average growth, AD 1600-1625, 1770-1810, and 2000 to present in the *Pinus wallichiania* chronology. Recent growth of ring width since AD 2000 coincides with the present global warming. Our *Pinus wallichiania* chronology, mainly responded to June and July minimum temperature, and looks similar to the Cook et al. (2013) reconstruction with increasing temperature in 21st century. KNMI climate explorer was used to examine broad spatial patterns of climate response. We are also going to examine the response of *Picea smithiana* and *Abies pindrow* to the local and regional climate. With the help of tree growth responses to the climate, we will be able to reconstruct climate of the Gilgit Baltistan region from the perspective of the multiple tree species.

DC-7p Subboreal and subatlantic dynamics of the pine forest at raised bogs in Belarus (Maxim Yermokhin, and Vyacheslav Rakovich)

The main goal of the research is to reconstruct dynamics of the pine forest at raised bogs using the wood remains excavated from peat. Researches were carried out on the bog Chertovo in the central part of Belarus. The age of the bog is about 11 thousand years, but stumps of pine meet down to a depth of 3.0 m (about 5 thousand years ago). Based on the analysis of more than 350 samples of wood floating tree-ring chronologies were constructed.
In the period from 600 years BC to 800 years AD in the development of the bog there are four cycles of "overgrowing / bogging". The most unfavorable climatic conditions for the growth of pine trees at raised bogs developed during the Little Ice Age (1300-1700).
Despite the drainage of the bog in the 1915-1920s and the climate warming of the last decades, the growth of trees is still half as less than in first 1.8 thousand years of the development of forest ecosystems at the bog.

DC-8p Climatic upshot using growth pattern of Pinus roxburghii from western Nepal (Sugam Aryal, Dinesh Raj Bhuju, Deepak Kumar Kharal, Narayan Prasad Gaire, and Nita Dyola)

The middle mountain of Nepal Himalaya is experiencing higher rate of temperature rise. A dendrochronological study was carried out to verify and record the impact of this warming by using the tree-cores of *Pinus roxburghii* Sarg. from Bicharichautara village of Syangja in western Nepal

representing a middle mountain of Himalaya with sub-tropical climatic zone. For this total 50 cores of *P. roxburghii* were collected from 30 trees. The standard methodology was used for sample preparation and analysis. A 165-year long chronology spanning from 1851 to 2015 AD was constructed from the cores. The result showed that the tree ring chronology of *P. roxburghii* in study site was positively correlated with pre-monsoon (March and April) rainfall and negatively correlated with the temperature of November of previous growth year and February, March and April of present growth year. However, the analysis of climate response to temperature revealed that there was a negative response of chronology for pre-monsoon season especially for monthly average temperature of April of current year whereas the response with rainfall was positive for pre-monsoon season, but they were statistically insignificant. From this study, it was concluded that the growth of *P. roxburghii* was limited by the pre-monsoon temperature particularly by April temperature. This conifer (*P. roxburghii*) has been recommended as a good choice of tree for the past climate study. The main problem with this species is that it contains several false rings and sometimes there is absent ring as well. To overcome such problems, a detailed study encompassing anatomical features to identify and locate false and missing rings is suggested.

DC-9p The final results from the intra- and inter-method comparison of wood density measurements (Jesper Björklund, and the Density Comparison Consortium)

The maximum latewood density parameter (MXD) has repeatedly been associated with a raised sensitivity to temperature, compared to ring-width (TRW) and is therefore particularly important for the understanding of historical temperature changes. However, recent research has indicated inconsistencies of mean levels of MXD using different measurement techniques or utilizing different pre-treatments of samples. This is quite important because the combination of MXD data from mixed sources, without proper scaling to account for difference in mean levels, can severely and erroneously influence trend representation of climate reconstructions.
Controlling mechanisms to ensure the accuracy of mean levels in microdensitometric measurements were extensively explored early on, but as measurement techniques diversified little attention was paid to update mean level control, which could at least partly be responsible for observed discrepancies. Another issue given little attention since the introduction of the MXD proxy is the measurement precision. The amplitude of the measurement profile is related to the sample image clarity, the image resolution, the aperture of the photo sensor and the obliquity at which the photo sensor moves across ring boundaries and may have profound influence on obtained mean levels of MXD. Moreover, the narrow ring profiles become relatively more suppressed and can actually alter the inter-annual variation of MXD values. Not only this, because narrow rings often are systematically separated in time from wide rings, due to growth trends and memory effects, MXD measurements could potentially attain differences in long-term trends.
We show, by comparing microdensitometric measurements from 17 different laboratories and 5 different techniques that mean levels, inter-annual variation as well as signal strength, and long-term trends are reproduced differently among data origins, and that mean level control and difference in measurement precision is largely responsible.

DC-10p El Niño and SAM affecting tree growth in southernmost Patagonia (Mauricio Fuentes, Juan Aravena, Andrés Holz, Alvaro Gutiérrez, and Hans Linderholm)

It has been reported that Southern Annular Mode (SAM) is the main driver affecting climate in southern Patagonia. Nevertheless the signal of this mode of variability is weak in tree ring chronologies from this area, and mostly evident in extreme years. It is found that much of the influence of the pacific is also recorded as background signal in the chronologies evidenced also in extraordinary events but also at lower frequencies. The link between the tree growth and variability from the pacific is suggested by downstream transport of heat via westerlies from the southern ocean adjacent to Amundsen and Bellingshausen seas to Southern Patagonia. This mechanism

coincides with fluctuation of the Amundsen Sea lows index that is exceptional indicator for climate in west Antarctica.

DC-11p Little Ice Age Summer Temperatures in Northern Greece From a Long Black Pine Chronology (Athanasios Koutavas, and Alexandros P. Dimitrakopoulos)

We present a 750-year-long ring width chronology from black pines (*Pinus nigra*) in Valia Kalda National Park on the Pindus Mountains of northern Greece. The chronology shows a strong climate signal, which consists of significant negative correlation (r=–0.45) with summer temperature (Jun-Jul-Aug-Sep, JJAS), and positive correlation with summer precipitation. We exploit these relationships to reconstruct summer (JJAS) climate from ~1300 CE to present. In particular, we investigate the character of the Little Ice Age (LIA) in mountainous Greece as there are very few records from this region that cover this important climatic period. We find evidence for cooler/wetter summers in the 18th and 19th centuries (late LIA) but warmer/drier summers in the 14th through 17th centuries (early LIA) during some of the coldest periods of the LIA in Northern Europe, including the Maunder Minimum. This unusual pattern suggests the early LIA had a different climatic signature in Greece from Northern Europe, while the late LIA was similarly cool in both regions. We attribute the divergent early LIA pattern to atmospheric dynamics (akin to a positive NAO), and the more spatially coherent late LIA cooling to volcanic forcing. The temperature pattern reconstructed here from *Pinus nigra* on the Pindus Mountains is remarkably similar to an independent MXD summer temperature reconstruction from *Pinus heldreichii* on Mt. Olympus, just 150 km to the east, supporting the robustness of our reconstruction and its interpretation as a summer temperature signal.

DC-12p Solar signal in Solovki ring width conifer chronology, Russia (Olga Solomina, Vladimir Matskovsky, and Ekaterina Dolgova)

The problem of solar forcing of global and regional climate is far from its final solution. Solar signal is identified in many Holocene proxies, such as speleothems (Frisia et al., 2003; Duan et al., 2014), lake sediments (Hu et al. 2003), glacier fluctuations (Solomina et al., 2016) etc. Significant correlation of various solar activity proxies, usually sunspots numbers, with ring width and density was also often reported (e.g.Fritts, 1976), although the mechanisms of this interaction is not yet clear. We used a composite chronology from Solovki Islands (65°05′ N, 35°53′ E) to test the solar activity signal in the tree ring records. The chronology includes samples of living trees (*Picea abies* (L.) Karst, *Picea obovata* Lebed., and *Pinus sylvestris* L.) from 42 sites, as well as the dead wood from 21 architectural sites and it covers the period 1186-2008 CE. Both spruce and pine site chronologies composing the regional Solovki chronology are temperature sensitive. The composite Solovki chronology itself also positively correlates with the sum of temperatures exceeding 10° C and 15° C (Matskovsky, 2013). Comparison of the Solovki RCS ring width regional chronology with the Total Solar Irradiation reconstructed from 10Be isotope series derived from two ice core records from Central Antarctica (South Pole and Dome Fuji stations) (Delaygue and Bard, 2010) demonstrates the best agreement between the two curves at the multidecadal level (R=0,63). Specific frequency of pointer years also correlates with average solar activity derived from 10Be. The lowest solar activity as well as the narrowest conifer rings occurred during the Spörer Minimum (around CE 1450). Since that time positive trends are observed in both curves. Earlier Kononov et al. (2009) found a good agreement between pine (*Pinus sylvestris* L.) ring-width chronology and sunspot numbers for the last 400 years from the neighbouring Khibiny Mts region. Furrier analysis of Solovki chronology revealed the cycles 14, 17, 23, 35, 45, 79, 114, 341 years long. Three of them are close to the solar cycles (14-17,~80 and 340 years long). This research is funded by the Russian Scientific Foundation № 17-77-20123.

DC-13p Seasonal Precipitation and Pacific Teleconnection Reconstructions Inferred from Southwestern U.S. Conifer Sub-annual Tree-Ring Growth (Nicholas Miley, Emanuele Ziaco, and Franco Biondi)

Teleconnections linked to the El Niño-Southern Oscillation (ENSO) and to the Pacific Decadal Oscillation (PDO) play a prominent role in determining frequency and intensity of precipitation across the southern tier of the United States. Accordingly, tree-ring chronologies from this region allow inference into equatorial Pacific dynamics over several hundred years. In 2016 we collected 167 stem increment cores from Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) at eight sites straddling the border between Arizona and New Mexico. These samples were combined with existing chronologies from the International Tree Ring Data Bank (ITRDB) to reconstruct seasonal and inter-annual regional precipitation patterns back to the 16th century. Earlywood and latewood chronologies showed a precipitation signal for winter and summer respectively. While the latewood portion of annual tree ring growth correlated well with the monsoonal rains in July - August, earlywood and total ring width chronologies presented a November - February precipitation signal matching the Southern Oscillation Index (a measure of ENSO). When viewed in relation to the PDO, the strength and consistency of the earlywood and total ring width winter precipitation signal increased in the warm PDO phase and decreased in the cool phase. Our analysis is paving the way for a multi-proxy approach to understanding the linkages between local precipitation patterns and the teleconnections that influence those patterns, providing a reliable basis to investigate the dynamics of these phenomena in the Anthropocene.

DC-14p A blue intensity temperature record from a drought sensitive White Spruce site in central Alaska (R.C. Oelkers, L. Andreu-Hayles, R. D'Arrigo, R. Wilson, G. Wiles, N. Davi, and K. Anchukaitis)

Tree rings in northern latitudes have widely been used for reconstructing past summer temperature. However, many studies have described a lack of temperature sensitivity of boreal forests during the last decades of the 20th century. This issue, known as the Divergence Problem, has been reported more often in ring-width data (TRW) than in records of maximum latewood density (MXD). Therefore, the climatic signatures of these density time-series have been historically valuable for reconstructing temperature in these boreal regions. An alternative density parameter in dendrochronology that is receiving increased attention is latewood Blue-Light intensity (LWBI), which is a measurement of the intensity of visible light reflected from a ring boundary that gives a value related to its density. LWBI is relatively inexpensive and fast, alternative to MXD, and is emerging as a useful tool for assessing past temperature variability where ring-widths are diverging. Here, we present a multi-centennial tree-ring record from white spruce at Mt. Sukakpak in Central Alaska that records both drought and temperature variability. TRW was positively correlated with summer temperature during the 1st half of the 20th century, however, this relationship was unstable and almost disappeared in the 2nd half of the 20th century. During this latter period, we found a strong positive correlation with drought expressed by the Standard Precipitation-Evapotransporation Index (SPEI) in the summer season, and by the Palmer Drought Severity Index (PDSI) during the spring. In contrast, LWBI was positively and significantly associated with summer temperature variability consistently throughout the 20th century. Our results indicate that while radial growth of white spruce became drought limited in the Sukakpak site, the maximum tree-ring density remains sensitive to temperature. This study highlights the importance of using a multi-parameter approach to analysing the climatic response of boreal forests and demonstrates the advantage of LWBI data for creating robust temperature reconstructions in weak or mixed-signal TRW sites.

Tropical Dendrochronology

TD-1p Climate sensitivity and potential vulnerability of pinabete (Abies guatemalensis) forests in Totonicapán, Guatemala (Talia Anderson, Daniel Griffin, Kevin Anchukaitis, Diego Pons, and Matthew Taylor)

The lack of long-term meteorological records from Central America impedes our ability to understand climate variability in the Neotropics. We present a novel 168-year-long tree-ring chronology of *Abies guatemalensis* Rehder (*Pinaceae*; *pinabete*) from Totonicapán, Guatemala to assess climatic influences on tree growth and the potential vulnerability of forests in the western highlands to climate change. This study adds to a burgeoning tree-ring chronology network throughout Central America and confirms annual ring formation and methodical crossdating in *pinabete* lower in its elevational range. Analysis of complex ring morphology exposes intriguing patterns of false rings and suppression that may later prove useful for studying sub-seasonal environmental conditions. We find that late summer and dry season precipitation are critical drivers in annual ring-width variability and observe a statistically significant negative relationship to temperature. On a broader scale, we highlight the asymmetrical relationship between tree growth and ENSO with pronounced connections to El Niño events and variable responses to La Niña. Considering our results in light of future climate model projections for Central America, we suggest that these forests will become increasingly susceptible to widespread drying and higher temperatures. Such shifts could fundamentally jeopardize an endemic and endangered tree species that has been traditionally preserved by K'iche' communal governance and that is highly regarded for its ecosystem services and role in the Guatemalan economy.

TD-2p Application of dendrochronology to paleoenvironmental studies of subtropical lakes in Taiwan (Ludvig Löwemark and Björn Gunnarson)

By combining paleolimnological and dendrochronological data, a deeper insight into past environmental changes and how they have interacted with landscape evolution can be obtained. In a study of Lake Tienchi, on Lanyu Island, situated in the Pacific Ocean about 70 km east of the southern tip of Taiwan, sedimentological, geochemical, geomorphological, and dendrochronological data were combined to elucidate the enigmatic history of the lake. Indigenous people on Lanyu consider the lake a holy place because of a large number of dead trees left in the lake, giving it a rather eerie atmosphere. From a paleoenvironmental perspective, the question arises how the lake formed, and when and why the trees died.

To address this, several trees were sampled for radiocarbon dating, and two dead trees were sampled with increment borers and analysed with an Itrax XRF Core Scanner. Both from optical observations and from the X-ray radiographs, irregular rings could be observed, but no cross dating could be performed. (Over 90 radiocarbon samples where taken from the bark to the pith, in order to wiggle match to the northern hemisphere ^{14}C curve). Thereby both the age of the sampled tress, and the approximate year of their death could be determined. The results showed that trees in the deeper part of the present lake died around 1920-1930, while trees in the margin survived into the 1970. Because no living trees were found in the lake and no dead tress outside the present perimeter, the conclusion is that the trees died due to stress caused by the formation of the lake. Sedimentological, geochemical, and 210Pb dating lends support to the hypothesis that the lake formed in the early 1900's, possibly due to a landslide, and that fluctuating lake levels gradually increased stress until the trees died. Future research will aim to combine lacustrine paleoclimatic records and $d^{18}O$ variations in tree rings in the vicinity of the lake catchment in order to understand and reconstruct typhoon intensity and monsoon system variability.

TD-3p Trees of the Never Never: new chronologies from a monsoonal Australian conifer (Kathryn Allen, Matthew Brookhouse, B. Dahl, D. Norrie, Ben French, and David Bowman)

An understanding of tropical climate dynamics is crucial for modeling future changes in climate and for developing appropriate adaptation measures. In Australia's Top End – the northernmost region of Australia's Northern Territory – there are very few continuous instrumental records that extend back for more than 50 years. Thus, a need exists to improve understanding of long-term climate variability in the region using palaeoclimate proxies. However, a combination of frequent fire, impacts of tropical cyclones and absence of annual growth rings in many of the dominant tree genera means there are very few opportunities to develop pre-instrumental tree-ring chronologies for the Top End. *Callitris intratropica* is a termite resistant but fire sensitive conifer with a broad distribution across northern Australia with known dendrochronological potential. Although several chronologies from the species have been developed for northern Australia, all of these are short (< 100 years) and/or have low sample depths. These two factors are significant barriers to developing reconstructions from the species for the period prior to instrumental records. We present two new chronologies based on this species from the Arnhem Land coast in Australia's Top End. One of the chronologies spans over 250 years while the other is currently 129 years long. Both chronologies have much greater sample depth than previous chronologies, containing165 (*Korlobirrahda*) and 69 (*Murganella*) samples respectively. These new ring width chronologies have a strong local area drought signal (SPEI) at the end of the wet season, a signal that is consistent with findings from dendrometer observations of growth responses in the species.

TD-4p Chronology Development and Drought Reconstruction from Araucariaceae Trees in Subtropical Australia (Heather A Haines, Nathan B English, Jon M Olley, Jonathan G Palmer, Quan Hua, and Justine Kemp)

Many parts of tropical and subtropical Australia lack both annually-resolved long-term instrumental climate data and proxy climate records. This limits our understanding of past climate patterns and future variability in this region. Tree species in these regions may have numerous ring anomalies and are understudied resulting in uncertain relationships between tree growth and climate. Recent research of trees in the Araucariaceae family has attempted to address these issues with the goal of developing long-term climate reconstructions in tropical and subtropical Australia. Araucariaceae trees are commonly found across northern and eastern Australia and are longer lived than many other local non-temperate species. They are known to produce growth rings that are mostly annual, and their growth appears sensitive to climate. Two subtropical Araucariaceae species, *Araucaria cunninghamii* and *A. bidwillii*, were studied at three locations in subtropical Southeast Queensland, Australia. Ring anomalies including false, faint, locally absent, and pinching or wedging rings, were identified. Bomb-pulse radiocarbon dating was applied to *A. cunninghamii* trees which allowed for the identification of anomalous ring boundaries. Additionally, dendrometers were installed on trees of both Araucaria species so that the climate variables influencing seasonal growth could be identified. It was found that moisture conditions drive annual growth in Araucariaceae trees but that the onset and cessation of the growth season is dependent on temperature. Annual growth was confirmed through this analysis and the suitability of these species for climate reconstruction proven. Following this, a 164-year drought reconstruction for Southeast Queensland was developed using *A. cunninghamii t*rees from the subtropical rainforest of Lamington National Park.

Forest Inventory

FI-1p. Remote Primary Forests - European Primary Forest database (Volodymyr Trotsiuk, Miroslav Svoboda, Radek Bace, Vojtech Cada, Pavel Janda, Jakub Malek, Martin Mikolas, Jonathan Schurman, Kristin Svobodova, and Ondrej Vostarek)

Forests world-wide are known as an important net carbon sink and are thus a key component of the terrestrial carbon cycle. However, carbon fluxes and storage vary regionally and with inter-annual to long-term environmental change. Existing models of forest growth dynamics include large uncertainties, which ramify and lead to divergence in forecasts how climate change will impact the future terrestrial carbon cycle. To reduce these uncertainties, it is necessary to extend and combine assessments of current observation networks using novel analytical approaches and data sources. We compile a unique dataset of 850 permanents inventory plots distributed across a 1,500 km geographic gradient in the last remnants of primary forests in Europe. At each plot (0.1 ha) we: recorded coordinated, structure, growth and health of a total 63,000 trees; extracted tree cores from 18,000 individuals; measured regeneration and deadwood at each plot; accessed LAI through hemispherical photo; documented biodiversity traces. Long-term disturbance patterns reconstructed from tree-ring chronologies were linked to spatial variation in stand structure and contemporary disturbance patterns.
Such a dataset allow for the best use of the wealth of available long-term monitoring data, for both integrative analyses and modeling exercises. It can serve as input to an essential step in numerical forecasting: the data assimilation step that brings together all the heterogeneous data sets at differing temporal and spatial resolutions to a data product that could directly be used.

FI-2p. The climatic drivers of NDVI and tree-ring based estimates of forest productivity are spatially coherent but temporally decoupled in Northern Hemispheric forests (Kristina Seftigen, David Frank, Jesper Bjorklund, Flurin Babst, Benjamin Poulter)

Radial growth and foliage dynamics of trees both play a significant role in the terrestrial carbon cycle. Yet, crucial knowledge gaps exist in how these two growth components are linked. Our goal is to help bridge these gaps by providing a northern hemispheric survey of the connections between, and drivers of, inter-annual wood and canopy-landscape dynamics and phenology. We compared a multi-species network of ~700 annually resolved radial tree-growth records to the Global Inventory Modeling and Mapping Studies-Normalized Difference Vegetation Index (GIMMS-NDVI) of plant foliar dynamics. Tree-ring data were assimilated into the simple process-based Vaganov-Shashkin-Lite model to derive xylem phenology on a monthly basis, and contrasted against NDVI estimates of canopy phenology. We additionally determined the key climatic drivers for all of these vegetation measures. We find broad-scale agreement in the phenology and growing season climate response between radial tree growth and seasonally integrated canopy-landscape dynamics, which are both limited by temperature in the Arctic-boreal zones and by moisture availability in temperate and arid systems. On a monthly basis, however, we observe a temporal asynchrony in the climate signals at mid- and high latitudes, where the strongest climate response of the remote sensing record occurs around leaf flush, whereas an early- to mid-growing season signal dominates the tree-ring growth. Our comprehensive study helps elucidate the unique contributions of foliar and radial growth to terrestrial carbon cycling and the timescales at which they operate. While we observed that both measures have similar overall temperature and precipitation constraints, these two growth components are sensitive to distinct seasonal windows. Our study suggests that joint assessment of both leaf and stem growth is required to address productivity of forests, and demonstrates that these seasonal sensitivities must be considered prior to combining and interpreting these two metrics.

Session II. Wednesday June 13th 8:30-10:00

Mountain Dendrochronology

MD-1p Blue Intensity shows more stable dendroclimatic signal than tree-ring width at a Himalayan treeline (Niels Schwab, Karolina Janecka, Ryszard J. Kaczka, Jürgen Böhner, Ram P. Chaudhary, Thomas Scholten, and Udo Schickhoff)

Himalayan treelines are exposed to above average climate change impact, resulting in complex tree growth-climate relationships for Himalayan Silver Fir (*Abies spectabilis*) at central Himalayan treelines. Here we present a first application of Blue Intensity (BI) proxies (early wood BI, late wood BI, delta BI) in the Himalaya, tested on *Abies spectabilis* tree-rings, in order to determine BI-climate relationships and their stability in comparison to the performance of tree-ring width (TRW). The analyses were conducted with more than one century long gridded temperature and precipitation data. The results showed significantly unstable dendroclimatic signals over time, except early wood BI which exhibited a stable positive correlation with spring temperature over the whole analysed period from 1902 to 2012, in line with findings of Sano et al. (2005) for early wood minimum density. Correlations of all BI parameters with climate variables resulted in longer significant evolutionary interval correlations in comparison to TRW. In general, we found more numerous significant static correlations of BI parameters with climate variables showing higher correlation coefficients. In opposite to early wood BI, TRW correlated with climate weakly in early and mid-20th century. These results present *Abies spectabilis* BI as a suitable surrogate for wood density parameters and promising climate proxy for the Himalaya.

MD-2p Growth–climate relationships of Himalayan hemlock along elevational gradients (Jiri Doležal, Vít Pejcha, Jan Altman, Kristina Sohar, and Martin Kopecký)

High mountains are among the most vulnerable regions to climate change and therefore a matter of global concern. Here, we present the climatic–growth relationships of Himalayan hemlock (*Tsuga dumosa*) and their course in time and space along an elevational gradient in the central Nepal. 130 increment cores were collected from six sites between 2500 and 3100 m a.s.l. on the southern slopes of Dhaulagiri Mt. Tree-ring widths were measured and cross-dated for a period 1608 - 2016. After standardization, we built site-level chronologies and analyzed relationships between the tree-ring chronologies and monthly climatic variables. The largest climate changes in the region over the past one hundred years were increasing summer (June – August) temperatures and decreasing summer monsoon and winter precipitation. Annual radial growth was positively correlated with temperatures during summer monsoon, and negatively correlated with pre-monsoon spring temperatures. In particular, the ring-width in high-elevation trees increased with the occurrence of warm and less rainy July and August, while the growth in low-elevation trees decreased with drier and warmer weather during April and May. The growth in both the high- and low-elevation trees increased also with higher April and previous November precipitation, suggesting that water from melting snow prevents water stress in the pre-monsoon period. High-elevation tree-ring proxies of summer temperatures indicated several prolonged cooler periods (1730-1760, 1800-1830, 1950-1970), when growth was reduced, interspersed with several warmer periods (1690-1720, 1760-1770, 1850-1870, 1910-1920, 1940-1950, 2000s), when growth was promoted. Our results suggest that growth of Himalayan hemlock was accelerated by climate warming at the higher elevation, while decreasing winter precipitation reduces its growth at the lower elevation. If future conditions differ between summer and winter seasons, this could accentuate contrasting growth trajectories along species elevational range. Diverging climate–growth relationships along elevation

gradient highlight a complex pattern of climate-induced tree responses in the Himalayas, reinforcing the necessity of a population-dependent differentiation for the predictions of climate change impacts on species performance and range shifts.

MD-3p Dendrochronological study in the mountains of Southern Siberia and Western Mongolia (Mariia Mukhanova, Syromyatina Margarita, and Chistyakov Kirill)

The study took place in the arid mountain forests of Southern Siberia (Russia, Altai and Tuva Republics) and Western Mongolia (Bayan-Ölgii aimag). Continental and extra-continental climates with big range of temperatures and low precipitation, mountain terrain and existence of permafrost formed sparse forest cover. Trees are growing in the extreme conditions that make them sensitive to the natural factors dynamics. During the last six years, we are providing here dendrochronological researches devoted to the identification of short- and long-term tree's growth dynamics, natural factors' influence on tree-ring growth as well as comparison of these characteristics between Russian and Mongolian sites. The dendrochronological data were collected on the upper (2300–2400 m on the Russian site, 2500 m on the Mongolian site) and lower tree lines (1900–2100 m) on the north-facing slopes. Sample cores were taken from 777 living trees of *Larix sibirica* from 55 sites. Dendrochronological analysis results in four regional ring-width chronologies. Three of them are reflecting tree's growth on the upper tree line in the Russian Altai, Tuva Mountains and Mongolian Altai, respectively. They are characterized by good correlation (r>0,5) with each other and show common periods of high growth since the second half of the 16th century till the end of the 17th century, depression during the 18–19th centuries and high growth since 1890s. Also, there is some rise during the last 30 years. These chronologies contain 12–17, 25–29, and 32–33-yr cycles. The tree-ring growth is limited mostly by June-July air temperature (r=0,5–0,7). Another one chronology is reflecting tree's growth on the lower tree line in the Mongolian Altai. It shows mostly low growth during 16–19th centuries with little increase in the middle of the 17th century and high growth since 1920s with negative trend during last 10 years. This chronology contains 8, 14, 22 and 42-yr cycles. The tree-ring growth is sensitive to June-July precipitation and has good correlation with May-June streamflow data (r=0,7). Strong signal of nature factors permit to use these regional tree-ring chronologies for reconstructions of hydrometeorological parameters.
Support for research in the Ob river basin was provided using the Russian Science Foundation (project № 17-77-10041). Research in the Yenisei river and Khovd river basins was provided using Russian Foundation for Basic Research (№15-05-06611_a, №15-05-10186_к), the Russian Geographical Society (project №08/2016-И)

MD-4p Climate signal in Abies tree rings in the Garhwal Himalaya (Kristina Sohar, Jan Altman, Vít Pejcha, Martin Kopecký, and Jiri Dolezal)

High-mountain areas are some of the most vulnerable regions to climate change and therefore, together with the rapid growth of human population and extensive land-use changes, a matter of global concern. Our knowledge of climate variability in the mountain areas is deficient due to temporally and spatially limited weather records, wherefore climate dynamics studies must use proxy data, e.g. tree rings. Here, we aim to clarify the climatic responses and their course in time and space of *Abies pindrow* Royle growing in Garhwal, northern India. We collected increment cores of 250 trees from eight sites at 3000 to 3750m a.s.l. We measured and cross-dated tree-ring widths, and built site chronologies, with 550 years old as a longest. Both static and moving correlation and response functions between the tree-ring width chronologies and monthly climatic variables were computed. The largest climate changes in this western Himalayan region over the past one hundred years are increasing temperature (September–April) and decreasing summer monsoon (July–September) and winter precipitation (December–January). Preliminary results show that the growth of *Abies*, regardless of site altitude, is negatively correlated with pre-monsoon spring temperature (March–May). This suggests a drought-stress signal, wherein the high temperatures cause internal

water deficit as a result of increased evapotranspiration, and cooler conditions promote increment growth by reducing evapotranspiration. In addition, *Abies* growth benefits from early spring and monsoon precipitation. Thus, these long chronologies will be a good basis for reconstruction of spring temperature, monsoon or drought in the Garhwal Himalaya.

MD-5p Conifer Radial Growth Response to Recent Seasonal Warming and Drought from the Southwestern USA (Charles Truettner, William R. L. Anderegg, Franco Biondi, George W. Koch, Kiona Ogle, Christopher Schwalm, Marcy E. Litvak, John D. Shaw, and Emanuele Ziaco)

Future droughts are expected to become more severe and frequent under future climate change scenarios, likely causing widespread tree mortality in the western USA. Coping with an uncertain future requires an understanding of long-term ecosystem responses in areas where prolonged drought is projected to increase. Tree-ring records are ideally suited for this task. We developed 24 tree-ring chronologies from 20 U.S. Forest Service Forest Inventory and Analysis (FIA) plots in the southwestern USA. Climate variables were derived from the PRISM climate dataset (800-m grid cells) to capture the bimodal precipitation regime of winter snow and summer monsoonal rainfall, as well as warm-season vapour-pressure deficit (VPD) and winter minimum temperature. Based on mixed linear models, radial growth from 1948 to 2013 for four conifer species (*Pinus edulis, Juniperus osteosperma, Pinus ponderosa*, and *Picea engelmannii*) responded negatively to warm-season VPD and positively to cold-season precipitation. *Pinus* spp. benefited from warm-season precipitation linked to the North American monsoon, and *Pinus* spp. and *J. osteosperma* radial growth increased with warmer cold-season minimum temperature. However, warmer cold-season minimum temperatures countered the beneficial influence of cold-season precipitation for radial growth in *Pinus* spp. and *J. osteosperma*, while *P. engelmannii* was unaffected. Also, enhanced drying effects of warm-season VPD associated with decreased cold-season precipitation negatively affected radial growth of *Pinus* spp. and *P. engelmannii*. Of the four conifer species studied, *Pinus* spp. are most affected by droughts since 1948, while *P. engelmannii* and *J. osteosperma* appear to be more resilient. Investigating seasonal climate responses and interaction effects on radial growth in areas impacted by severe drought helps identify species that may be particularly at risk from climate change impacts in the Anthropocene.

MD-6p A regional snow avalanche chronology reconstructed from tree-rings in Parâng Mountains (Southern Carpathians, Romania) (Ionela Georgiana Gavrila, Flaviu Mesesan, and Olimpiu Pop)

Snow avalanche is one of the main natural hazards in high areas of Parâng Mountains being a threat to human and tourism infrastructure. In the context of continuously development of tourism activities and related infrastructure, a better understanding of behaviour of snow avalanche geomorphic process is needed for avoiding hazard and associated risks. In the absence of historical records, tree rings are valuable natural archives that may serve to reconstruct the past geomorphic activity. The aim of this study is to provide a regional reconstruction of snow avalanche events in Parâng Mountains and to document the frequency and spatial extent of events within three paths. A total of 234 Norway spruce (*Picea abies* (L.) Karst.) and sycamore (*Acer pseudoplatanus* L.) trees showing scars, tilted trunks, broken crown or branches were sampled along tree avalanche paths from western and central part of mountain area. Analysis of growth disturbances from the sample collection (430 increment cores, 38 stem discs, 1 wedge) allowed the identification of a minimum frequency of snow avalanche past events spanning roughly between 1900-2015. Based on events chronology determined for each path a regional avalanche activity index (RAAI) was calculated in order to identify common avalanche events for all the investigated paths. The identified event years will be further analysed in conjunction with meteorological data to determine the triggering conditions of regional avalanche activity. Regional patterns of event frequency from Parâng Mountains will be correlated with similar events from other mountain areas, which could serve to obtain a synthesis of avalanche regime for Romanian Carpathians. This result can contribute to an

accurate avalanche hazard zonation and could be included in the risk mitigation planning in order to reduce exposure of tourists and related infrastructure to geomorphological hazard.

Discrete Events and Extremes

EE-1p Landscape instability, permafrost and remote infrastructure corridors: reaction-wood analyses using black spruce, Alaska (Alexander K. Stewart, Trent D. Hubbard, Catherine Heinrich, Helen Eifert, and Maria Leech)

Alaska's infrastructure corridors are some of the more remote in North America; providing access to critical resources from a regional (e.g., Trans-Alaska Pipeline System) to a local scale (e.g., remote Alaska Native communities). Many corridors were developed quickly and with limited planning and understanding of cold-regions engineering in geologically complex terrains with widespread permafrost. This results in unique climate-driven maintenance requirements with a projected need of an additional $6.1 billion for normal wear-and-tear costs until 2030 (Larsen et al., 2008). In collaboration with the Alaskan Department of Transportation and Public Facilities and the Alaska Division of Geological & Geophysical Surveys, we have leveraged reaction-wood analyses in black spruce (Picea mariana) to evaluate landscape stability along important infrastructure corridors in three sites across Alaska-Northway Junction, Tonsina Hill, and Treasure Creek. At each site, 60 samples from 30 visibly tilted trees were collected, digitized, and quality checked using COFECHA software with reaction-wood years recorded. At Northway Junction along the Alaska Highway in east-central Alaska, an area of discontinuous permafrost of low to moderate ice content, there was a site-wide, rapid onset of reaction wood in 1989. Widespread tilting of trees on a retrogressive mass movement, likely a response to thawing permafrost conditions, necessitated an expensive road realignment. At the Tonsina Hill site along the Richardson Highway south of Glennallen in an area of sporadic permafrost, rapid onset of reaction wood began in 1978 and is likely associated with permafrost degradation due to increased heavy-equipment traffic from emplacement of the Trans-Alaska Pipeline. At the Treasure Creek site near Fairbanks, remote-sensing image analysis and geophysical data indicate land instability in an area of permafrost degradation, but the reaction wood signal is weak and monotonous from 1950 to the present (mean of 7 percent of recorded growth); this likely represents characteristic tree instability above frozen ground of variable ice content. Because each site is situated atop permafrost, unstable ground is expected under certain conditions (e.g., riverbank retreat, human influence) exacerbating the relatively quiescent process of permafrost thaw. As Alaska continues to modernize in concert with record population growth (10-fold increase in the past 70 years), efforts to recognize, mitigate, and/or prevent permafrost-thaw-induced landscape changes have become a focus for infrastructure projects. Improved evaluation of infrastructure siting and smarter technologies could help minimize the effects of permafrost thaw on human concerns.

EE-2p Are cool temperate rainforests sensitive to drought? The role of climate and drought on the growth of Nothofagus cunninghamii in southeast Australia (Linda Parker, Stefan Arndt, Sabine Kasel, Cristina Aponte, Patrick Baker, Tim Willersdorf, and Craig Nitschke)

Understanding how changes in water availability will affect species distributions is becoming increasingly important as drought is predicted to become more frequent and intense with climate change. The “millennium drought” that occurred across Australia from 1997 – 2008 has been implicated in the decline of some iconic temperate rainforest species in southeast Australia, in particular, *Astelia australiana*. Cool temperate rainforests typically occur in riparian areas and on sheltered sites where precipitation is high and temperatures cool. However, little is known about the response of temperate rainforests to past droughts in the region. The aim of this research was to explore the climate-growth response of the dominant rainforest species *Nothofagus cunninghamii*

(Hook.f.) Heenan & Smissen over the past century and to compare its growth between known drought events and non-drought years. Growth of *N. cunninghamii* was positively correlated to summer precipitation and winter heat moisture index but negatively correlated with winter precipitation indicating that growth for the species is best in years with wet summers and warm-dry winters and poorest in years with cold wet winters. No relationship between annual growth and drought occurrence was found indicating that water availability has not been a limiting factor during the millennium drought or in past droughts. Our results indicate that water availability remains sufficiently high in rainforest areas and likely ameliorates the impact of drought on the rainforest community. This suggest that these rainforests can act as refugia during times of drought and may allow some species to persist in areas where future climate becomes warmer and drier.

EE-3p How a strange day [or a few] impacts the life of trees and their legacy in temperate mesic forests (Caitlin Keady, Cary Mock, M. Ross Alexander, Mattew K. Lau, Myvonwynn Hopton-Ahmed, Dario Martin Benito, Dave Orwig, Ben Poulter, Katherine M. Renwick, Herman H. Shugart, and Emery Boose)

Systems dominated by trees would appear to be resistant to rapid environmental change. The obligate persistence of trees, because of their inability to purposely move over space, induces lagged responses and some resistance to turbulent global change. Rapid warming, increased climatic variability, and the increased frequency of severe weather events would appear to challenge this concept of resistance. As a result, a key question in ecology is, “what tipping points exist in a tree’s resiliency and to what degree might acute climatic events affect that resiliency?” Newly developed and more readily accessible datasets of high-resolution measures of climate allow us to investigate the impact of severe weather events on trees. Given that such events are historically rare, tree-ring records provide scientists a larger window to potentially study more than one of these extreme events. Explicitly here, we first utilize high-resolution climate records to investigate the influence of extreme events and narrower windows of time on the radial growth trees in the eastern US temperate forest. We then review existing literature on the strange days that appear to have had a legacy on the dynamics of tree growth, carbon uptake, canopy disturbance, and forest development. Regarding extreme events, have found that a late frost (a ‘false spring’) constrained the growth of Acer saccharum in New York State’s Adirondack Mountains and in southwestern New Hampshire, was associated with nearly half of 22 drought-related eastern US mortality events during the 20th century, we find that 10 are associated with severe frosts or cold events, and in 1774 likely triggered a period of elevated tree mortality. The last event cascaded through human, wildlife, and tree populations. The impact on trees continues to have a legacy on a large swath of southeastern US forests. Together, these pieces of evidence indicate that the rare combination of extreme events, some as ephemeral as a few days, can impact temperate mesic forests for centuries.

EE-4p Sudden shifts in wintertime Aleutian Low variability revealed in a 550-year record of storm-damaged trees from Southeast Alaska (Benjamin V. Gaglioti, Daniel H. Mann, A. Park Williams, Gregory C. Wiles, Rose Oelkers, Benjamin M. Jones, and Laia Andreu-Hayles)

The alternation of the Aleutian Low pressure system (AL) between its strong and weak regimes underlies North Pacific decadal variability (NPDV), which in turn has global impacts on the ocean-atmosphere system including effects on droughts, wildland fires, and salmon harvests in western North America. Unfortunately, our understanding of NPDV dynamics has been severely limited by the lack of long-term, annually resolved records of conditions during winter, the season when the AL is most active. Here we present a calendar-dated record of winter storminess back to CE 1450 based on traumatic resin ducts (TRD) in mountain hemlocks (*Tsuga mertensiana*) growing near treeline in Southeast Alaska. Resin ducts develop in response to winter storm damage caused by snow loading, ice abrasion, and high winds, all of which are enhanced during a strong AL. The post-CE 1900 period is not exceptional in the TRD record, despite modeling that links anthropogenic warming to a

stronger AL. The TRD record shows that the AL's bimodal shifts were occurring as early as CE 1450, but that a fundamental shift in AL dynamics happened ca. CE 1700 when both regimes became 2-3 times longer and significantly stormier. We speculate this shift was triggered by warming in the tropical Pacific. Our new, winter-specific record shows that the AL has the previously unsuspected capacity to radically change its regime durations, which has implications for North Pacific and North American ecological and human systems that affected by the NPDV.

Dendroecology

DE-1p Species-specific tree growth responses to drought in the eastern United States (Tsun Fung Au, Benjamin Lockwood, Neil Pederson, Grant Harley, Kimberly A. Novick, Richard P. Phillips, Matthew Therrell, Justin T. Maxwell)

Abrupt changes in climate can result in species-specific responses and create shifts in forest composition. For example, extreme climate events like drought can lead to tree mortality or reduced carbon uptake. Of particular interest is the impact of drought in the mesic forests of the eastern US, where there is potential of drought converting this biome from a carbon sink to a carbon source. In this study, we use tree-rings to ask: (1) How do two co-occurring species, sugar maple (*Acer saccharum*) and white oak (*Quercus alba*), differ in drought response? (2) Are site-specific differences more important than species-specific traits in influencing the drought response of these two species? and (3) Can the isohydric/anisohydric framework explain differences in growth-climate response of these two species? We sampled co-occurring sugar maple and white oak in 7 forests and, in total, 317 tree cores from 168 individual trees were synthesized. All the cores were processed with standard dendrochronological approach. The samples were detrended to remove biological growth trends and non-climatic signals to maintain the climate-related responses. Pearson's correlations were employed to analyse the growth response with climate variables such as maximum temperature, minimum temperature, precipitation and Palmer Drought Severity Index (PDSI) during the common period between the tree cores and instrumental data.
Our results show that both sugar maple (*Acer saccharum*) and white oak (*Quercus alba*) show significant positive response to June precipitation and PDSI and negative response to June maximum temperature ($p<0.05$), except for one site respectively for both sugar maple and white oak . These results suggest soil moisture in June plays a determinant role in controlling the growth of both species. However, white oak shows a consistently stronger response to soil moisture than sugar maple.
These results suggest the co-occurring sugar maple and white oak respond differently to soil moisture but the iso/anisohydric framework does not explain differences in climate-radial growth response. The inconsistent responses to June soil moisture may be attributed to the site characteristics and age-related growth. Understanding species-specific responses to drought could enhance our knowledge on the possible impacts on the ecosystem services provided by sugar maple and white oak.

DE-2p Increasing disturbance occurrence along the southern slopes of Himalayas (Jan Altman, Kristina Sohar, Martin Kopecky, and Jiri Dolezal)

Himalayan forests are facing tremendous pressure from changing climate and these changes are projected to increase. Furthermore, these ecosystems are highly vulnerable due to the increasing human pressure. Interactions between changing activity of various disturbance agents, changing climate and increasing exploitation of natural resources will consequently affect disturbance dynamics. Here we aim to reveal long-term variability in disturbance frequency along the longitudinal gradient (75-83¬∞ E) of southern slopes of Himalayas. The forest disturbance history was reconstructed by detection of growth releases. Data were collected on 40 sites and we gathered radial-growth data for 17 species covering the altitude from 1700 to 4300 m a.s.l. Our preliminary results suggest increasing disturbance frequency in last decades. Although we cannot

retrospectively determine the responsible disturbance agent(s), our findings indicate rapid changes in disturbance dynamics. We suggest that most important factors responsible for changes in disturbance frequency were: 1) increase of summer monsoon precipitation as a consequence of global warming and 2) increasing logging. In addition, these factors are also responsible for increasing number of landslides and flood disasters. The projected climate changes are likely to continue in current trend of increasing disturbance frequency. We conclude that vulnerable forests should be identified, and policy makers should prioritize the interventions to improve long-term resilience to increasing pressure from natural disturbance agents and climate change.

DE-3p 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)

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 master's 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.

DE-4p Disturbance history and formation of tree species patterns in the old-growth Korean pine-broadleaved forest, Sikhote-Alin mountains, Russian Far East (Alexander Omelko, Olga Ukhvatkina, Alexander Zhmerenetsky, Tatyana Petrenko, and Lidya Sibirina)

Natural disturbances play a crucial role in the dynamics of forest communities. They affect the regeneration, growth and spatial patterns of tree, shrub and other species as well as their coexistence. Research into the disturbance history of forest communities is necessary to understand how modern stands were formed and to predict their future structure and species composition. Variations in the intensity, frequency, and spatial distribution of disturbances have a spatio-temporal effect on the regeneration, growth, and survival of trees, and the regeneration of certain tree species, in turn, can affect future disturbance regimes. An important factor affecting the structure of plant patterns is the light condition mosaic determined by canopy gaps. Therefore, it is necessary to understand how the gaps appear during the development of plant patterns within the scope of the study territory.

Korean pine (*Pinus koraiensis* Siebold et Zucc.)-dominated forests are the main forest vegetation type in the Sikhote-Alin mountain range of the southern portion of the Russian Far East. Wind is the primary disturbance factor on this territory. Wind causes a wide range of disturbance events, from individual tree falls to large blowdowns.

We used a dendroecological approach to reconstruct the disturbance history of the old-growth Korean pine. We also used point pattern analysis (pair-correlation function, K2 function, distance to

kth neighbor Dk, and spherical contact distribution function Hs) to describe the process of plant pattern formation for five dominant tree species with different life strategies Our findings demonstrate that there were no intense, stand-replacing disturbances from 1800-2000. Low- and medium-intensity disturbance events predominated, and the most probable cause of these disturbances was wind-throw due to strong winds. The age structure of the coniferous species indicates recruitment continuity, so the stand is unevenly aged, but regeneration waves associated with the disturbances can be distinguished. We found similarities between the processes of pattern transformation for the different species. Namely, they transform from pronounced aggregated distributions of plants at several spatial scales to a random pattern. This transformation of pattern structure occurs because the young plants accumulate under a canopy and require significantly improved light conditions that can only be found in gaps to transition into the virginal and young-generative stage. In turn, the process of gap formation is stochastic, and the stand is characterized by a low-intensity disturbance regime. Thus, the pre-generative plant patterns are filtered by randomly formed gaps, and thus only individual randomly distributed plants reach the canopy.

DE-5p Northern forest tree populations are physiologically maladapted to drought (Miriam Isaac-Renton, David Montwé, Andreas Hamann, Heinrich Spiecker, Paolo Cherubini, and Kerstin Treydte)

Northern forests at the leading edge of species distributions may not show increased primary productivity under climate warming, instead being limited by climatic extremes such as drought. Looking beyond tree growth to underlying physiological mechanisms is fundamental for accurate predictions of forest responses to climate warming and drought stress. Working within the experimental structure of a 30-year genetic field trial for a widespread conifer, we analyse relative contributions of xylem plasticity (n=1170) and inferred stomatal response (n=2340) to drought tolerance in populations from across a 4000 km species range. We show a range of isohydric to anisohydric behaviours due to genetic adaptation: Trailing edge populations exhibit anisohydric properties while tree populations in central areas of the species distribution are plastic to environmental change due to isohydric behaviours. Northern forest tree populations showed lower drought tolerance and growth due to a suite of physiological maladaptation. Due to drought, therefore, northern areas most probably do not profit from climate warming and would rather benefit from cautious implementation of assisted migration.

DE-6p Methods for reconstructing wildfire histories (Peter M. Brown)

Wildfire is a key – although often discounted in ecological texts – evolutionary force. Woody plants exhibit a variety of adaptive traits to respond to wildfire that can be generally grouped into resistance vs. resilience strategies. These strategies result in differing lines of physical evidence recorded either in individual trees or community structure that, using tree-ring dating methods, provide data that are used to reconstruct past fire frequencies, severity, seasonality, fire size and spatial patterning – collectively, the “fire regime”. This talk will summarize key components of the science of pyrodendroecology by: 1) reviewing patterns of evidence left by variations in fire regime components; 2) describing methods used to infer the processes that formed those patterns; 3) discussing limitations in the inferences that can be made using evidence and methods available, especially in reconstruction of fire severity; and 4) discussing how pyrodendroecological evidence is coupled with dendroclimatic reconstructions and other historical data to provide broader understanding of long-term ecological and evolutionary dynamics.

DE-7p Forest fire history and its link to climate and ENSO (Karma Tenzin, Edward R. Cook, and Paul J. Krusic)

Chir pine (*Pinus roxburghii* Sarg.) develops fire scars and has the potential to develop a long-term fire

history and its possible link with climate. Fire severity can be expected to increase with warmer and drier conditions, though this varies regionally given the projected climate scenario. The use of tree-ring dating techniques to date the frequency of fire is a common application in dendrochronology. Using the Chir pine fire history chronology from Autsho, Lhuntse, researchers are now able to extend the use of the data they have collected to study the fire frequency and occurrence of fire in Bhutan and its link to local climate and ENSO. At least 1-5 fire scars from 18 samples were identified. The exact year in which a fire scar was formed was determined using the cross-dating techniques. The corresponding fire events were correlated with climate and El Nino/Southern Oscillation (ENSO) events.

DE-8p The common juniper wood traits network ‚Äì a tool for environmental North Hemisphere reconstructions (Jiří Lehejček, Allan Buras,,Rohan Shetti, Marco Carrer, Jesus Julio Camarero, Jakub Trojan, and Martin Wilmking)

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.

Methodological Innovations in Dendrochronology

MI-1p Spatial heterogeneity of Phosphorous concentrations within tree rings – results from LA-ICP-MS measurements (Joerg Niederberger, Matthias Trottmann, Adrian Wichser, Martin Kohler, Davide Bleiner, and Juergen Bauhus)

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 analyse 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-2p A global digital archive of X-ray CT imaged tree cores (Tom De Mil, Joris Van Acker, Hans Beeckman, and Jan Van den Bulcke)

Forests are multifunctional providers of ecosystem services, directly and indirectly contributing to human well-being. Above all forests are the primary producers par excellence, containing more than 80% of the terrestrial biomass, providing non-timber forest products and wood: worldwide, forests provide more than 1.8 billion m³ of industrial round wood annually. Furthermore, forests represent a net carbon sink for human generated emissions, they also often provide clean water at a much lower cost than man-made substitutes like water treatment plants when managed accordingly and they can reduce possible health costs due to their function as particulate matter filters.
It stands to reason that we need to grasp the functioning of forests in order to ensure continuing provisioning of aforementioned services under a changing climate in what is often referred to as the Anthropocene. Tree rings, as archives of the past and biosensors of the present, offer the opportunity to do so, to study climate - tree-growth over decades to centuries (Babst et al. 2017), yet we need large datasets and need to investigate beyond ring widths only.
At UGent-Woodlab (www.woodlab.be) we have been working towards the use of X-ray Computed Tomography (CT) scanning to obtain large datasets. Virtual increment cores are saved as multipage TIFF files, metadata is stored as well (minimally location and wood species) and can be processed using dedicated software. Pith-to-bark density profiles and ring widths can be obtained simultaneously, allowing for accurate biomass stock estimations, as well as productivity throughout the lifespan of a tree. Currently, more than 5000 cores (actually curated at the Tervuren xylarium - http://xylarium.africamuseum.be) have been scanned, most of them at a resolution of 110 micron. An overview of the metadata and the sample locations is given on http://www.dendrochronomics.ugent.be. Software routines such as density-based crossdating, annotations such as ring indications are tied to the images and archived such that future researchers have all information available, including the indicated ring boundaries. Efforts are being made for an online platform, and machine learning techniques are being developed to treat such large datasets.

MI-3p Introducing the Individualistic Growth Response network (IGR) (Ryszard J. Kaczka)

Individualistic growth response - i.e. the individual-specific and partly differing response of neighbouring trees to environmental conditions - is gaining more and more attention. Within this context, recent studies are of interest since they have shown the expression of climate-growth relationships to depend on soil conditions (Lévesque et al., 2013, Rehschuh et al., 2017) as well as distance to the forest edge (Buras et al., 2017) which may help to better understand the mechanisms driving trees individualistic responses. However, the aforementioned studies represent rather local to regional spatial scales and do not encompass broad-leaved tree species. Thus, additional insights from other species and over larger scales are desirable - ideally following a systematic and uniform approach.
Here, we present the international Individualistic Growth Response network (IGR) which aims at deepening our understanding of individual-specific tree growth by including several species and sites

to represent a wide range of ecological conditions. A central principle of IGR is to apply a standardized dendroecological approach across the network, which allows for lowering investigator-specific biases and thus addressing general questions systematically. Currently, the network comprises data from 14 countries (ranging from Canada to China, but with a special emphasis on Europe) representing eight coniferous and three broad-leaved species. The poster presents initial research questions along with corresponding results obtained at an international workshop that takes place at Wageningen University and Research in February 2018.
IGR is a steadily growing network and we invite everybody to participate since this will further strengthen our expressiveness. A meet and greet at our poster will provide a good opportunity to discuss further research avenues and clarify open questions related to network-participation. We are looking forward to see you there!

MI-4p Pilot study of density structures using high resolution CT-scanning (Øyvind Paasche, Alexander Stine, Eivind William, and Nagel Støren)

High-resolution CT imaging of timber core samples has the potential to permit interrogation of the full three-dimensional density structure of tree growth while increasing the rapidity with which interannual density variability can be sampled. In this pilot study, samples from trees were collected from a high-altitude, continental area in central south Norway known as Rondane. Samples of near 200-year old *Pinus sylvestris* were collected close to the local tree line at 700 m altitude (N61.78, E9.72) and a ca 100-year old *Larix decidua* taken from the valley at 275 m altitude (N61.78, E9.54). Visualization of the selected tree ring samples was run in axial scan mode in a ProCon Alpha CT Core CT scanner at EARTHLAB, University of Bergen. Tube voltage was set to 58kV, current to 700mA and exposure time at 667ms. A total of 800 projections were made of the rotating sample, producing 16-bit imagery (65 000 grey values) with a voxel (volume pixel) size of 20 microns. The 3D volume image was reconstructed using Volex software, and visualized in Avizo Fire 9.4 (FEI). High-resolution 3D-images indicate that interannual variability in earlywood and latewood density can easily be distinguished as well as other structures. We compare the variability in interannual density variability inferred from individual density profiles subsampled from individual cores and quantify the potential for error reduction by taking advantage of the full three-dimensional density structure. Next steps in this study involves collecting and analysing a larger number of samples that cut across environmental gradients running from the Valley floor and up to the local tree line.

Isotopes and Tree-rings

IT-1p Effects of sample preparation on stable isotope measurements of tree rings (Joshua Braun-Wimmer Annika Oertel, Loic Schneider, Hans-Peter Kahle, and Kerstin Treydte)

Sample preparation for stable carbon and oxygen isotope measurements of tree rings involves many different steps from taking increment cores in the field, surface preparation of the cores for increasing the visibility of tree ring boundaries for accurate crossdating, cutting of individual tree rings, homogenization of wood or cellulose, and cellulose extraction. Although many of these procedures are standardized between laboratories, there still exist uncertainties regarding potential contamination risks. We examined the possible influence of five widely used treatments: i) WD-40 as often applied for cleaning of the increment corers, ii) sanding of the core surface, and iii) chalk, both applied for increasing the visibility of tree-ring boundaries, iv) pencil powder used for marking tree rings for crossdating and v) glue used for mounting of tree cores on core holders. We tested the influence of these five treatments on both carbon and oxygen isotope values of whole wood and cellulose of *Fraxinus excelsior*, a ring porous tree species and compared them with the isotope values of untreated reference material from the same tree. Our results indicate no contamination risk for WD-40 and sanding. Chalk and pencil powder slightly affected the whole wood carbon isotopic

signature but had no effect on oxygen isotope values. Glue can have a significant effect on both carbon and oxygen isotope values of whole wood and cellulose and, hence, its utilization has to be avoided for stable isotope analysis.

IT-2p Long-term effects of drought on tree-ring growth and carbon isotope variability of Scots pine in a dry environment (Galina Timofeeva, Kerstin Treydte, Harald Bugmann, Andreas Rigling, Marcus Schaub, Rolf Siegwolf, and Matthias Saurer)

Drought frequency and intensity are increasing in many parts of the globe, enhancing tree decline and mortality. However, the underlying physiological mechanisms are still poorly understood, particularly regarding the chronic effects of long-term drought. Here, we combined analyses of radial growth and stable carbon isotopes in tree rings ($d^{13}C$) in a mature Scots pine (*Pinus sylvestris* L.) forest over the 20th century to elucidate causes of observed tree mortality in one of the driest parts of the European Alps (Pfynwald, Valais, Switzerland). Additionally, we investigated the effects of a 10-year irrigation experiment in the same forest stand, where annual precipitation was doubled. We found a sustained growth increase and immediate decrease of $d^{13}C$ values for irrigated trees, indicat- ing higher stomatal conductance and thus showing that water is a key limiting factor indeed. Growth of now-dead trees started declining in the mid-1980s, when both mean temperature and vapor pressure deficit (VPD) strongly increased. Growth of these trees was reduced to some extent already several decades earlier, while intrinsic water- use efficiency derived from $d^{13}C$ values was higher, indicating a very conservative water-use strategy, possibly at the cost of insufficient carbon uptake. The climate correlation analysis further showed that radial growth of the now-dead trees was highly sensitive to spring and summer mean temperatures as well as VPD. We conclude that the recent increase in atmospheric moisture demand in combination with insufficient soil water supply was the main trigger for tree decline and mortality of already weakened trees in Pfynwald.

IT-3p Oxygen isotopes in tree rings of Canary Pine as recorders of fog interception on La Palma (Jose Carlos Miranda, Giovanna Battipaglia, Simona Altieri, Kerstin Treydte, and Luis Gil)

Climatic variations in the transition zone from temperate to tropical regions determine the fate of local ecosystems. In some of these regions, the lack of climate records limits predictions of future climate conditions. The Canary Archipelago is such a transition zone, where atmospheric stratification caused by the Azores High and humid trade wind influence causes distinct altitudinal gradients in vegetation. A stratocumulus cloud layer ("sea of clouds" as locally named) is formed under atmospheric stability conditions, leading to increased and isotopically heavier water supply for vegetation due to fog water droplets interception, compared to precipitation occurring under atmospheric instability conditions. Thus, the altitude, thickness and annual frequency of the sea of clouds determines the amount of local water input on the islands. These specific climatic conditions are, however, only scarcely recorded due to the lack of climatic stations in general and the absence of instruments for quantification of water interception in particular. In order to obtain a long-term register of the influence of the sea of clouds on vegetation, we combine dendrochronology and stable oxygen isotope analysis in plant tissues of *Pinus canariensis*. This species is endemic on the Canary islands and dominates vegetation between 200 and 2000 m asl, particularly on the island of La Palma. Trees damaged during volcanic eruption allowed us to obtain past oxygen isotope signatures on different recovery stages from crownless to fully crown recovered trees and to compare them to pre-eruptive tree-ring values. Four pine trees from 1780 to 1915 m asl damaged by an eruption in 1949 were felled and 5 slices were taken from each tree. Dendrochronological measurements were performed following standard procedures. Oxygen isotope ratios were analysed in tree-ring cellulose extracted from pools of 5 tree rings. Trees damaged by volcanic eruption showed high $\delta 18O$ values, ranging from 36.29 to 40.27 per mil. The first tree rings formed after the volcanic damages showed, however, significantly lower isotope values compared to pre-eruptive rings and the following post eruptive rings. High $\delta^{18}O$ values may be related to the uptake of

isotopically enriched water from fog interception. Fog interception by vegetation is dependent on leave surface, thus interception in our studied trees was minimum after volcanic damages, and increased with recovery of the foliar surface. Therefore, lower oxygen values of the first post-eruptive formed rings corresponded with a lower fog intercepted water input. Besides tree-ring width indices were positively correlated with $\delta^{18}O$ values, i.e. heavier isotope values were related to wider rings, as higher quantities of fog water may have been intercepted, increasing the water availability for pine that is its limiting resource at this altitude.

IT-4p Linking strip-bark morphology, ring widths, and stable isotopes in Siberian pine trees from Mongolia (Caroline Leland, Laia Andreu-Hayles, Edward R. Cook, Kevin J. Anchukaitis, Amy Hessl, Neil Pederson, Kevin Griffin, Oyunsanaa Byambasuren, and Baatarbileg Nachin)

Many long-lived trees growing on ancient lava flows of central Mongolia have developed 'strip-bark morphology' which is defined by partial cambial dieback along the tree stem. These old trees are highly sensitive to moisture and their ring widths have been valuable for placing recent hydroclimatic extremes into a historical context of over two millennia. On the Khorgo lava field, previous studies indicate that trees with strip-bark morphology show more positive long-term ring-width trends relative to whole-bark (no dieback) trees over the past two centuries. To elucidate what might contribute to these divergent growth trends and to better understand the physiology of these trees, we measured stable carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotopes in tree rings of three strip-bark (SB) and three whole-bark (WB) Siberian pine trees from 1830-2011. Using a dual isotope approach, we find that interannual variations of both $\delta^{13}C$ and $\delta^{18}O$ are strongly linked to growing season moisture conditions, and we interpret $\delta^{13}C$ variability as being primarily regulated by stomatal conductance. Regarding long-term trends, $\delta^{13}C$ of SB trees, after being corrected for the industrial-period changes of atmospheric CO2, show significant increases over the 1830-1995 period of analysis whereas there is no clear trend in WB trees. While WB trees appear to keep relatively constant discrimination against the heavy isotope (^{13}C) over time, SB trees have an overall decreasing trend in discrimination and higher increases in intrinsic Water Use Efficiency (iWUE) compared to WB trees. This suggests that these SB trees might have developed more stomatal control and conservative water-use strategies compared to the analysed whole-bark trees over the past two centuries. However, the distinct physiological behaviour between SB and WB trees was diminished during severe drought conditions around the turn of the 21st century. These results provide novel insights on the physiology of ancient trees and suggest that trees with stem dieback may have differing carbon-water relations.

IT-5p $\delta^{13}C$ and $\delta^{18}O$ of Fagus sylvatica, Pinus sylvestris and Quercus petraea as climate proxies: a methodological investigation (Valérie Daux, Alice Michelot-Antalik, Aliénor Lavergne, Nathalie Bréda, and Claire Damesin)

Climate reconstructions in temperate Europe have been widely based on oak species. However, other co-occurring species, largely distributed in Europe, may be used for recording climate variability. Here, we documented the inter-trees and inter-species variations over 1960-2007 of oxygen and carbon isotopic compositions in ring cellulose of *F. sylvatica, P. sylvestris* and Q*. petraea* co-occurring in the Fontainebleau forest (France). Our results indicated that large levels of series replication (11 trees on average) were required to generate isotopic mean series representative of the populations and to develop robust paleoclimate reconstructions. For both carbon and oxygen isotopes, the standard value of 4 trees is too low.
In the Fontainebleau forest, the isotopic chronologies of the three co-occurring species showed different mean levels, although they varied in a coherent way with time. The $\delta^{13}C$ and $\delta^{18}O$ were higher in the gymnosperm than in the deciduous angiosperms. A lower stomatal conductance, a higher rainfall loss and a longer growing season may be responsible for the inter-species isotopic differences. A lower rate of isotopic exchanges with xylem water may also concur to the higher

δ18O in pine.
The $\delta^{18}O$ and $\delta^{13}C$ chronologies were significantly correlated to one another in the three species and responded primarily to air moisture (VPD, RH, PET) and maximum temperature, which indicated that stomatal conductance was an important driver of changes in both types of records. The correlations were strong with the May to July climate variables in *F. sylvatica*, and with the July and August ones in *Q. petraea* and *P. sylvestris*. The oxygen isotopic records were systematically more coherent to one another than the carbon records (at the inter-individual and inter-species scales), which may encourage using $\delta^{18}O$ rather than $\delta^{13}C$ for future reconstructions of past hydroclimatic variations in Europe. The three studied species have a good potential for achieving this aim.