Tree Rings in Archaeology, Climatology and Ecology

TRACE 2014

Aviemore, Scotland
6-10 May 2014

We have great pleasure in welcoming you to the 2014 Tree Rings in Archaeology, Climatology and Ecology Conference in Aviemore. It is particularly fitting that TRACE be held here in Scotland, as a significant portion of research has been undertaken on the nearby Rothiemurchus Estate by the University of St Andrews' Scottish Pine Project (http://www.st-andrews.ac.uk/~rjsw/ScottishPine/) over the past several years. We therefore welcome you to this beautiful area, home to some of the most extensive pristine remnant patches of natural and semi-natural Scots pine woodland in the country.

We have an excellent scientific programme to offer you spread across three days, in both oral and poster formats. TRACE 2014 seeks to strengthen the network and scientific exchange of scientists and students involved in the study of tree-rings. It aims at presenting and discussing new discoveries and approaches in wide field of tree-ring science; the scope of the meeting includes all fields of dendrochronology, such as tree-rings in archaeology, climate, geomorphology, glaciology, fire history, forest dynamics, hydrology, physiology, and stable isotopes. This annual meeting has the reputation as a friendly, sociable and intimate gathering that promotes the visibility of postgraduate and early career researchers, and we are looking forward to continuing that tradition. In addition to the scientific programme, we have a conference dinner and ceilidh lined up – hope you brought your kilts and other national costumes!

We would like to thank various organisations and companies for their sponsorship of the conference.

Rob Wilson, Chair - University of St Andrews (UK)
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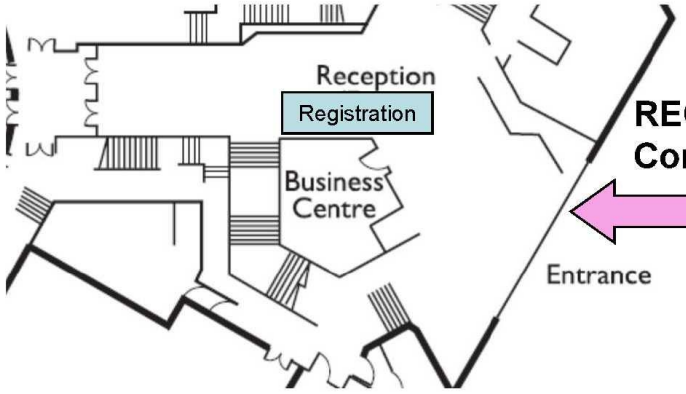

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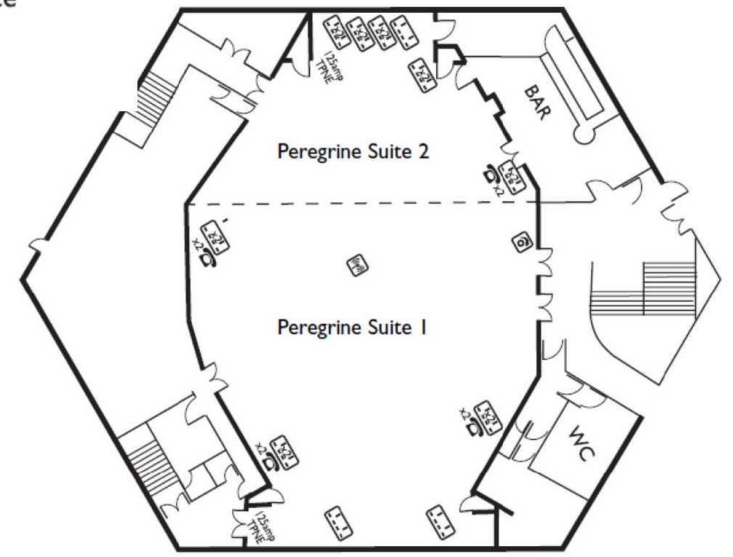

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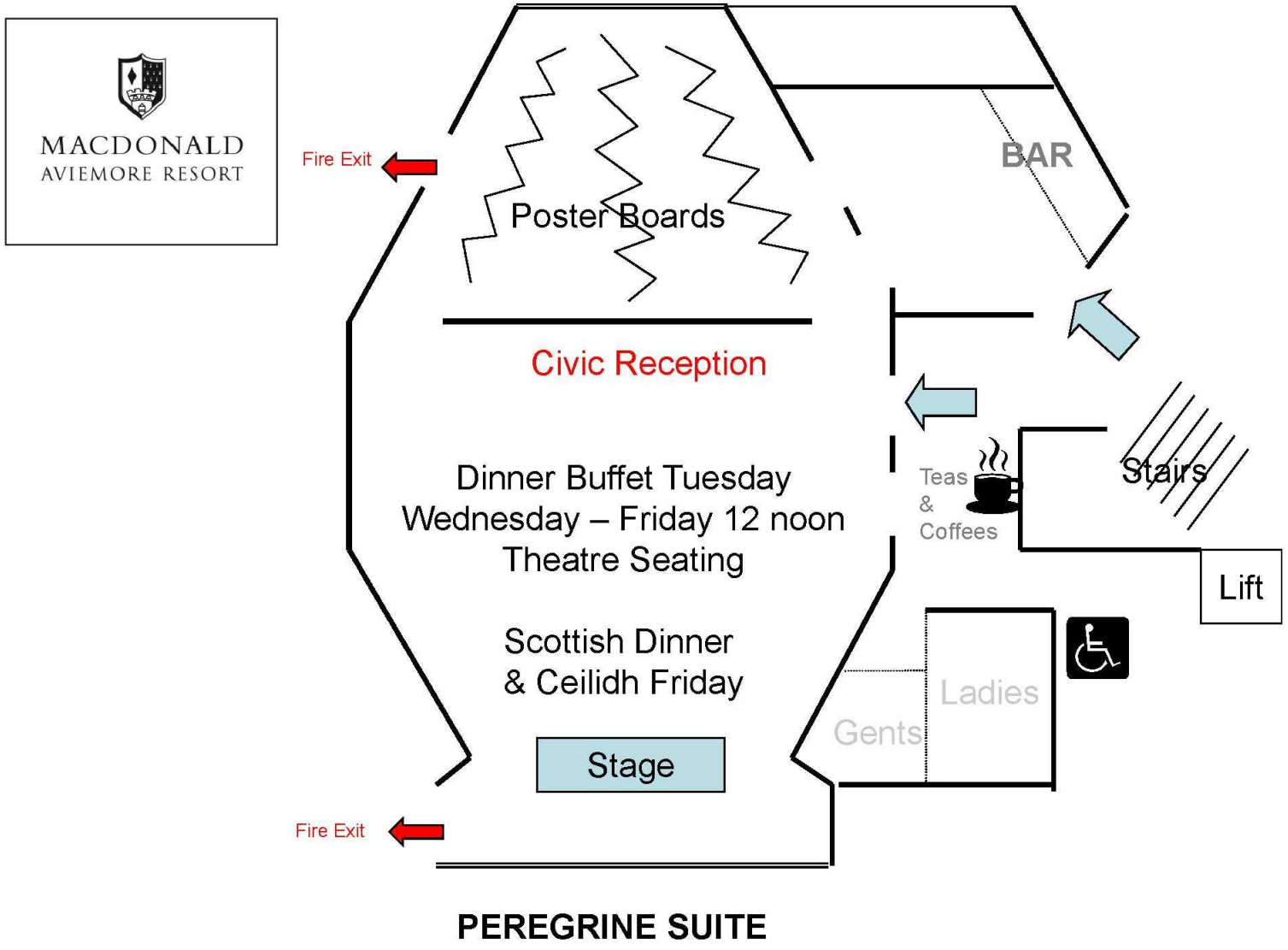
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AVIEMORE RESORT
Fire Exit
Poster Boards
BAR
Civic Reception
Dinner Buffet Tuesday
Wednesday – Friday 12 noon
Theatre Seating
Scottish Dinner
& Ceilidh Friday
Stage
Teas
&
Coffees
Stairs
Lift
Ladies
Gents
Fire Exit
PEREGRINE SUITE

	Day 1 - Arrival Tuesday May 6th	Day 2 Wednesday May 7th	Day 3 Thursday May 8th	Day 4 Friday May 9th
8.15 - 9.00		Registration		
9.00-10.45		Climate I	Isotopes	Tree-Response II
10.45-11.15		coffee	coffee	coffee
11.15-13.00		Ecology I	Wood Anatomy II	Climate II
13.00-14.00		Lunch	Lunch	Lunch
14.00-15.30		Historical	Ecology II	Field Excursion (2-6pm)
15.30-16.00		coffee	coffee	
16.00-17.30	Registration (4-7pm)	Wood Anatomy I	Tree-Response I	
17.30-19.00		Poster Session (5.30 - 7pm)	Poster Session (5.30 - 6.30pm) ATR Meeting (6.30 - 7.30pm)	
19.00 onwards	Civic reception, ice-break and buffet meal (7 - 11pm)	Dinner: Hotel or elsewhere in Aviemore	Dinner: Hotel or elsewhere in Aviemore	Conference Banquet and Ceilidh Dance (7pm onwards)

Session	Start	Name	Organisation	Title
Registration: Tuesday 6 May 16:00 - 19:00 (foyer in main venue opposite reception)				
Civic Reception, Icebreaker and Buffet Meal: Tuesday 6 May 19:00-23:00 (late bar available in main hotel)				
Registration: Wednesday 7 May 8:15 - 9:00				
Introduction: Wednesday 7 May 9:00 - 9:15	09:00:00	R. Wilson	University of St Andrews	
Climate 1: Wednesday 7 May 9:15 - 10:45	00:09:15	J. Esper	Johannes Gutenberg University	**KEYNOTE**: Volcanic Fingerprints in tree-rings
	00:09:45	K. Janecka	University of Silesia	Stone pine tree rings as a record of volcanic activity during the last ~280 years. Multiproxy approach.
	00:10:00	E. Rocha	Gothenburg University Laboratory for Dendrochronology	June-July summer temperature reconstruction in central Scandinavia over the past two millennia, inferred from Norwegian spruce tree-ring width chronology
	00:10:15	L. Schneider	Johannes Gutenberg University	Temperature signals in Hemispheric tree-ring density data
	00:10:30	M. Rydval	University of St Andrews	Spatiotemporal reconstruction of Scottish summer temperatures
10:45 - 11:15 Morning Tea				
Ecology 1: Wednesday 7 May 11:15 - 13:00	00:11:15	P. Cherubini	WSL Swiss Federal Research Institute	**KEYNOTE**: The use of tree rings in ecology and the need of rethinking sampling strategies
	00:11:45	S. Klesse	Swiss Federal Institute for Forest, Snow and Landscape Research WSL	Annually resolved forest growth: research opportunities and carbon-cycle consequences from a large snow breakage event in the Swiss Alps
	00:12:00	M. Vanoni	ETH Zürich	Tree-ring based mortality patterns of four species in Swiss natural forest reserves

Session	Start	Name	Organisation	Title
	00:12:15	A. Buchwal	Adam Mickiewicz University	Dendroecological records of shrubs annual growth in high & low Arctic sites (central Spitsbergen, W Greenland)
	00:12:30	V. Trotsiuk	Czech University of Life Sciences Prague	The role of the disturbances on the individual tree and stand biomass accumulation in the natural montane spruce forest
	00:12:45	J. Speer	Indiana State University	Dendrochronology at Indiana State University: From archaeology to disturbance ecology
13:00 - 14:00 Lunch				
Historical: Wednesday 7 May 14:00 - 15:30	00:14:00	C. Mills	University of St Andrews	**KEYNOTE**: A millenium of change: Dendrochronology in Scotland's built heritage and cultural landscapes
	00:14:30	M. Bridge	Oxford Dendrochronology Laboratory	The impact of dendrochronological dating on the interpretation of vernacular architecture in Wales
	00:14:45	T. Kolář	Mendel University	Updating the millennial-long oak tree-ring composite chronology from the Czech Republic
	00:15:00	L. Hellmann	Swiss Federal Research Institute WSL	Arctic driftwood is dominated by 20th Century central Siberian timber logging
	00:15:15	A. Hansson	Lund University	Early Holocene landscape and Baltic Sea development based on dendrochronological studies of submarine forest remains
Wood Anatomy 1: Wednesday 7 May 16:00 - 17:50	00:16:00	P. Owczarek	University of Wrocław	Dwarf shrubs and geomorphology - a review
	00:16:15	B. Li	Wageningen University	A story of the secondary growth of deciduous shrub
	00:16:30	T. de Mil	Ghent University	High-resolution dendro-proxies as climate indicators in the tropics
	00:16:45	D. Bretting	Technische Universität München	Response of stem and root growth of *Pinus radiata* on environmental conditions in the Western Cape province of South Africa

Session	Start	Name	Organisation	Title
	00:17:00	M. Opała	University of Silesia	Influence of climatic and topographic factors on downy birch tree-ring variations (Norwegian low Arctic)
	00:17:15	K. Giagli	Mendel University	Influence of environmental factors to secondary xylem growth in *Fagus sylvatica* L.
Poster Session: Wednesday 7 May 17:30 - 19:00 (bar available)				
Isotopes: Thursday 8 May 9:00 - 10:45	00:09:00	A. Bräuning	University of Erlangen-Nuremberg	What do spatial variations of stable oxygen isotope patterns tell us? An example from the Tibetan plateau
	00:09:15	J. Wernicke	Friedrich Alexander University Erlangen-Nuremberg	Hydroclimate variability from Southeast Tibet inferred from stable oxygen isotopes in tree-ring cellulose
	00:09:30	A. Gebrekirstos	World Agroforestry Centre (ICRAF)	Stable carbon and oxygen isotopes in tree-rings reveal drought events and possible ground water fluctuations in sub-Saharan Africa
	00:09:45	F. Slotta	Freie Universität Berlin	Dendro-ecophysiology of baobabs: Towards a better understanding via dendrometre and stable isotope studies
	00:10:00	C. Sargeant	University of St Andrews	Isotopic ecohydrology: Insights into water partitioning and availability to riparian forests along the Rhône River, France
	00:10:15	C. Hartl-Meier	Johannes Gutenberg University	Climate signals in stable isotopes from temperate forests: Species and site effects
	00:10:30	G. Tomlinson	Swiss Federal Research Institute WSL	Using environmental data to understand species-specific differences between tree-ring and foliar $\delta^{15}N$ and $\delta^{13}C$
10:45 - 11:15 Morning Tea				
Wood Anatomy 2: Thursday 8 May 11:15 - 13:00	00:11:15	H. Cuny	Institut national de la recherche agronomique (INRA)	Model of tracheid development explains conifer tree-ring structure

Session	Start	Name	Organisation	Title
	00:11:30	M. Klisz	Forest Research Institute	Different types of intra-annual density fluctuations in European larch as a genetic adaptation under stressful growth conditions
	00:11:45	G. Guada	Universidade Santiago de Compostela	Earlywood vessel size combined with ring width disentangle microclimatic effects of a river bank in an Atlantic oak forest in northwestern Spain
	00:12:00	A. Bast	Swiss Federal Research Institute WSL	Soil eco-engineering (1): Root growth and soil aggregation influenced by a mycorrhizal inoculum? Results from a three-year field experiment
	00:12:15	D. Kink	Swiss Federal Research Institute WSL	Soil eco-engineering (2): Wood anatomical variations in roots and their influence on root tensile strength
	00:12:30	J. Vieira	Universidade de Coimbra	Xylogenesis of *Pinus pinaster* under a Mediterranean climate
12:45 - 14:00 Lunch				
Ecology 2: Thursday 8 May 14:00 - 15:30	00:14:00	S. Poljanšek	Slovenian Forestry Institute	Pronounced height and radial growth decline of *Pinus sylvestris* as a result of massive needle shed
	00:14:15	M. Godek	University of Wrocław	Dendrochronological signal of atmospheric pollutant deposition via fog to montane spruce forest stands in Poland
	00:14:30	D. Stangler	Albert-Ludwigs University Freiburg	Growth phenology and productivity of sugar maple and yellow birch under the influence of forest management and environmental stress
	00:14:45	D. Druckenbrod	Rider University	Detecting and detrending canopy disturbance events in Scots pine forests
	00:15:00	P. Groenendijk	Wageningen University	Tree-ring analysis to detect centennial-scale growth changes in tropical tree species

Session	Start	Name	Organisation	Title
	00:15:15	P. Zuidema	Wageningen University	Long-term growth variation among tropical trees: Patterns, causes and consequences
15:30 - 16:00 Afternoon Tea				
Tree Response 1: Thursday 8 May 16:00 - 17:30	00:16:00	G. Jetschke	University of Jena	Climate response of four tree species from the east-German low rainfall area
	00:16:15	O. Konter	Johannes Gutenberg-University	Spatial and temporal climate signal variations in the Tatra
	00:16:30	T. Levanič	Slovenian Forestry Institute	Climate signal and potential of Bosnian pine (*Pinus heldreichii* Christ) for climate reconstruction in the central W Balkan region
	00:16:45	G. Pérez-de-Lis	Universidade Santiago de Compostela	Climate drivers of *Quercus robur* and *Quercus pyrenaica* radial growth along a water availability gradient in NW Spain
	00:17:00	R. Seiler	Swiss Federal Institute for Forest, Snow and Landscape Research WSL	Increased tree-ring growth close to eruptive fissures prior to volcanic flank eruptions on Mount Etna (Sicily, Italy)
	00:17:15	R. Sanchez-Salguero	Swiss Federal Research Institute WSL	Drivers of contrasting growth response of Scots pine to climate along an elevational gradient near the species' southern limit
Poster Session: Thursday 8 May 17:30 - 18:30 (bar available)				
ATR Meeting: Thursday 8 May 18:30 - 19:30				

Tree Response 2: Friday 9 May 9:00 - 10:45	00:09:00	R. Brienen	University of Leeds	Detecting evidence for CO_2 fertilization from tree-ring studies: The potential role of sampling biases

Session	Start	Name	Organisation	Title
	00:09:15	S-H. Chen	National Cheng-Kung University	Increasing drought stress and climate variability in high mountain ecosystems in Taiwan
	00:09:30	N. D. Singh	Manipur University	Dendroclimatic evaluation of climate-growth relationship of *Pinus kesiya* Royle ex Gordon growing in subtropical forests of Manipur, North East India
	00:09:45	W. Ashiq	University of Guelph	Range shift potential of red pine in eastern North America
	00:10:00	M. Isaac-Renton	University of Alberta	Growth and pysiological responses of lodgepole pine populations under drought: Studying climate change adaptation strategies from tree-rings
	00:10:15	J. Housset	Université du Québec à Montréal	Unexpected recent warming-induced growth decline in *Thuja occidentalis* at its northern limit in North America
	00:10:30	M. Girardin	Laurentian Forestry Centre	Heterogeneous influences of climatic changes on productivity of black spruce forests across Canada
10:45 - 11:15 Morning Tea				
Climate 2: Friday 9 May 11:15 - 13:00	00:11:15	D. Brown	Queen's University Belfast	Hydroclimatic changes during the 8.2 ka event revealed by Irish pines
	00:11:30	C. Leland	Lamont-Doherty Earth Observatory	Climatic convergence? Recent synchronicity among tree-ring records across Mongolia
	00:11:45	E. Düthorn	Johannes Gutenberg University	Comparing millennial scale MXD and stable carbon isotope data from northern Fennoscandia
	00:12:00	M. Saurer	Paul Sherrer Institute	A 1200-year drought reconstruction for the European alpine region based on tree-ring carbon isotopes

Session	start	Name	Organisation	Title
	00:12:15	C. Mathaux	Université d'Aix-Marseille	*Juniperus phoenicea* growing on cliffs: Dendrochronology and wiggle-matching applied to the oldest trees in France
	00:12:30	P. Hochreuther	University of Erlangen-Nuremberg	Tree stands on lateral and terminal Little Ice Age moraines of four glaciers in southeast Tibet – a comparison
	00:12:45	M. Ramírez-Ollé	University of Edinburgh	The fictions of dendroclimatology
13:00 - 14:00 Lunch				
Field Excursion: Friday 9 May 14:00 - 18:00				
Conference Banquet and Ceilidh: Friday 9 May 18:30 - 23:00				

ABSTRACTS IN THESE PROCEEDINGS ARE ORDERED ALPHABETICALLY. SUBMITTING AUTHOR IS UNDERLINED.

CLIMATE SENSITIVITY OF *FAGUS SYLVATICA* L. BASED ON TREE RING ANALYSES IN PHERIPHERAL POPULATIONS IN SPAIN

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Keywords: *Fagus sylvatica*, pheripheral populations, Iberian Peninsula, drought

Climate change projections for Europe suggest a further temperature increase of up to 4 - 5° C for the 21st Century. Global warming trends will definitely affect temperate tree species, especially those populations growing at their tolerance limits. In this context, peripheral populations are more prone to be imperiled by external factors than more central or continuous populations. European beech (*Fagus sylvatica* L.) forests at the Iberian Peninsula are a clear example of a temperate species at the rear edge of a large distribution area, with several geographically isolated populations. In addition to their value for conservation purposes, increased knowledge on the response of such peripheral forests to climate change is important for predicting future distribution of the European beech and choosing adequate forest management measures. Some pioneer studies on the well-known European beech forest of Montseny (Barcelona) revealed that tree growth is strongly limited by drought and that this beech forest is being progressively replaced by Mediterranean holm oak forest (Peñuelas et al. 2007). In order to gain deeper knowledge on the response of marginal European beech populations to climate change, we analyse four isolated forests at the Iberian Peninsula: two in the central part (Montejo and Tejera Negra) and another other two at the northeast (Montseny and Els Ports). Three out of the four sites are unexplored in terms of tree-growth and the work presented here represents the first assessment of the climate-growth relationships at these forests.

Summer precipitation and temperature were unequivocally identified as the main limiting factors for tree-growth in the beech forests of Montejo and Els Ports. While these relationships were stable, a decline in tree sensitivity to climate was detected for the beech forest at Montseny. The results from Tejera Negra are inconclusive since a clear response to climate could not be detected.

References:

Peñuelas, J. et al. (2007). Migration, invasion and decline: changes in recruitment and forest structure in a warming-linked shift of European beech forest in Catalonia (NE Spain). *Ecography.* 30: 829– 837.

DENDROCLIMATOLOGY OF *PINUS NIGRA* IN EASTERN GERMANY

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Keywords: *Pinus nigra*, dendroclimatology, climate correlation, response function

Many dendrochronological studies were carried out on black pine (*Pinus nigra*) to study the impact of climatic factors on tree-ring growth (Amodie et al. 2013, Leal et al 2008, Martín-Benito et al 2010). In this study we focus on this species in eastern Germany with a semi-natural occurrence on calcareous soils far north of its natural distribution area. A 140-year chronology was constructed based on annual ring-width measurements standardised with cubic splines. Daily climate data were available for the whole period. We found that precipitation as a single climatic factor could explain a very large portion (> 50%) of the growth variability. The highest influence had the overall precipitation of March to July with a Pearson correlation coefficient r around 0.65 (at some sites even r > 0.7), while rainfall in August did not matter at all. Precipitation of the previous September also contributed significantly. Temperature played a minor role and was not significant in a multiple linear regression. Results were cross-checked using the R packages dplR and bootRes. Correlation co-efficients for a moving 30-year interval were not constant, but showed some abrupt changes changes if the target year passed through the 1990 - 2000 period, indicating some local or global climatic changes. More details about relevant periods were obtained by moving windows of different length based on the CLIMTREG software (Beck et al 2013). PDSI as a combination of rainfall and temperature was significantly negatively correlated (r slightly larger than 0.4). The correlation with SPEI as an accumulated balance between precipitation and potential evapotranspiration was positive: increased with an increasing time interval of up to 24 months, but never exceeded values of 0.4.

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Amodei, T. et al. (2013). Relationships between climate and radial growth in black pine (*Pinus nigra* Arnold ssp. salzmannii (Dunal) Franco) from the south of France. *Ann. Forest Sci*. 70:41-47.

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Leal, S. et al. (2008). Tree rings of *Pinus nigra* from the Vienna basin region (Austria) show evidence of change in climatic sensitivity in the late 20th century. *Can. J. For. Res*. 38:744-759.

Martín-Benito, et al. (2010). Black pine (*Pinus nigra* Arn.) growth divergence along a latitudinal gradient in Western Mediterranean mountains. *Ann. For. Sci*. 67: 401-413.

RANGE SHIFT POTENTIAL OF RED PINE IN EASTERN NORTH AMERICA

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Keywords: red pine, climate change, range shift, dendrochronology

Species distributions are generally determined by some optimal climatic conditions favourable for their growth and establishment. Such favourable conditions diminish towards their range limits resulting in declined growth. Investigating growth and establishment along the range limit thus give insights about climate change impacts on species range shifts (Zhu et al., 2011). Typical decline in growth rates at northern limit (Schenk, 1996) is generally attributed to low temperatures (Woodward et al., 1990). Therefore with climate change induced warming, species survival and establishment is expected to increase at their northern range limits (Reich & Oleksyn, 2008). Though there is not enough empirical evidence to support this hypothesis, it is generally used to model species dynamics under climate change scenarios. Red pine (*Pinus resinosa* Ait) is a key species in Great Lakes – St. Lawrence forests in eastern North America that is predicted to move northward due to climate change. In this study we investigated the potential of red pine to move northward using tree ring data from the leading edge populations in Northern Ontario, Canada. We used 20th Century climate data to study red pine growth – climate relationships. Our analyses reveal that its historic growth response to increasing temperature is negative. We also observed that growth is positively related to preceding year's summer precipitation. Combined effects of temperature and precipitation suggest that drought is a dominant factor in red pine historical growth dynamics. Our results don't support: (i) the hypothesis of increased growth at northern range limit due to warming, and (ii) the predicted range shift of red pine. Projected increase in drought events during 21st Century will further limit red pine growth in northern Ontario. Results of this study provide useful information for the sustainable adaptive management of these forests.

References

Reich, P. B. & Oleksyn, J. (2008). Climate warming will reduce growth and survival of Scots pine except in the far North. *Ecology Letters*. 11:588-597.

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SOIL ECO-ENGINEERING (1): ROOT GROWTH AND SOIL AGGREGATION INFLUENCED BY A MYCORRHIZAL INOCULUM? - RESULTS FROM A THREE-YEAR FIELD EXPERIMENT

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Keywords: slope stabilisation, root length, root diametre, Swiss Alps

In mountain environments many slopes are covered by coarse grained substrate. These slopes show a high geomorphic activity, are susceptible to erosional processes, and cause a high hazard potential. Regarding hazard prevention, soil eco-engineering measures gained in importance.

Using plants for sustainable erosion control demands a stable seedbed, providing appropriate water and nutrient supply. However, degraded alpine slopes are often unstable and the coarse-grained material shows a low retention capacity of water and nutrients. This hampers a fast and sustainable development of a protecting vegetation cover. Thus, the question arises- what needs to be done to give planted saplings within eco-engineering projects maximum support developing their above- and below-ground structures to promote slope stabilisation. Laboratory experiments have shown a positive impact of mycorrhizal fungi inoculation on plant development and soil structure. Based on this, we intended to apply this approach in a field-experiment.

For this, we established two eco-engineered research plots (with/without inoculum) located in the eastern Swiss Alps. There we quantified fine-root development and soil aggregation at the end of three consecutive vegetation periods.

After the first vegetation period, at the mycorrhizal inoculated site, fine roots did indeed show a lower root length density compared to the non-mycorrhizal treated site, but the proportion of roots with thicker diametres tended to be higher. Contrary to expectations, aggregate stability was highest at the non-mycorrhizal treated site. At the end of the third vegetation period this pattern changed. Aggregate stability is then highest at the inoculated site and root length density increased. The tendency to thicker root diametres at the mycorrhizal treated site can be confirmed.

Since inoculation influences root growth, and root systems provide the stable anchorage for slope and soil stability, the investigation of the wood anatomical structure is inevitable for further understanding (*see Kink et al., this conference*).

THE CHRONOLOGY OF WOOD ANOMALIES OF NORWAY SPRUCE IN TATRAS

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Keywords: light ring, frost rings, Norway spruce, timberline, Tatras

Wood anatomical features, such as pale and frost rings, have proven to be useful in dendrochronology, offering linkages to environmental parameters not provided by other parameters (Wimmer 2002). Light rings have a low number of latewood cells, reduced latewood cell wall thickness, and therefore reduced density (Tardif et al., 2011). Frost rings were characterised by the presence of collapsed cells and broken cell walls (Payette et al., 2010). This study aims at: i) identifying all occurrences of wood anomalies: pale and frost rings, in Norway spruce (*Picea Abies* L. Karst) from timberline, ii) building the chronology of both wood anomalies, and iii) assessing the relationship between the wood anomalies and climate condition during growth season.

The sampling was carried out at four sites located within the timberline ecotone (1400 – 1500m a.s.l.) in the Tatra Mountains (Carpathians). Together more than 240 samples were collected and treated employing the standard dendrochronological methods. The site chronologies were established and ~30 samples per site were selected for analyses of wood anatomy. The designated samples have to correlate well with the site chronologies and exhibit a clear view of the whole ring (no missing ring, decayed or compression wood). The visual analyses were performed and pale and frost rings were identified. The preparation of wood samples was crucial in recognising the anomalies under the binocular microscope. The 350-year long chronologies (with 682 pale and 80 frost rings) were established. The chronologies were compared to temperature data (1966 - 2012) of daily and monthly resolution from two meteostations (Zakopane 850m a.s.l. and Kasprowy Wierch 2000m a.s.l.). Based on case studies of the years 1966 and 1977, the frost rings occur when both mean and minimum temperatures over 8 - 14 consecutive days drop below zero, reaching - 7.5^{o}C. The pale rings are the result of abnormally cold August and September. The example of 1976 (the highest repetition of pale rings), 1978 and 1980 shows that the temperature in the period of 1st August – 14th September was 2.4^{o}C, 2.3^{o}C, and 1.2^{o}C lower than average, respectively.

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WHAT DO SPATIAL VARIATIONS OF STABLE OXYGEN ISOTOPE PATTERNS TELL US? AN EXAMPLE FROM THE TIBETAN PLATEAU

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Keywords: Tibetan plateau, oxygen isotopes, spatial analyses, climate variability

The spatial pattern of stable oxygen composition in current precipitation on the Tibetan plateau mirrors the influence of three main factors, including the pathways of air masses from the surrounding oceans into the continent, the amount of rainfall during the summer monsoon season, and the increasing altitude (Liu et al. 2008; Yao et al. 2013). We hypothesise that oxygen isotope composition in wood cellulose reflects the isotope source value of soil water. To test this, we established a network of 21 stable oxygen isotope chronologies from trees covering the complete eastern Tibetan plateau to analyse the spatial variations of isotope composition of precipitation during the past thirty years. We found very consistent spatial patterns of general levels of stable isotope discrimination which can be explained by a combination of latitude, altitude, and topography-related evaporation. Plant oxygen isotope discrimination is strongly increasing with continentality and increasing dryness and is thus not reflecting isotope source values of source water, as hypothesised. However, short-term temporal variations in the spatial distribution pattern of isotope levels reflect the impact of climate variations on trees and can be used as palaeoclimate proxies (Grießinger et al. 2011) and as indicators of vegetation response to changes in hydroclimate (Liu et al. 2014; Yang et al. 2011).

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RESPONSE OF STEM AND ROOT GROWTH OF *PINUS RADIATA* ON ENVIRONMENTAL CONDITIONS IN THE WESTERN CAPE PROVINCE OF SOUTH AFRICA

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Keywords: drought events, stand density, tree ring analysis, root-shoot allometry

Due to predicted climate changes it is important to know to what extent trees and forests will be impacted by chronic and episodic drought stress. The trees' root-shoot reaction pattern and allocation principle is relevant for, e.g. assessment of tree stability, above/below carbon storage, resistance and resilience to drought stress and productivity. The genus *Pinus* plays an important role in South African forestry. We therefore chose Monterey pine (*Pinus radiata*) plantations at the Western Cape Province for analysing the root-shoot dynamics in dependence on environmental conditions. The selected plantations show a high variability in soil types, precipitation and supply of mineral nutrients. In order to study effects of climate trends and events on root-shoot allometry and how the growth dynamics develop along a local gradient, we sampled trees along an ecological gradient from moist to dry sites. The sampling provided increment cores from three main roots and the stem at DBH per tree. The combined root-shoot increment coring methodology used in this study is successfully tested in different pilot studies (Nikolova et al 2012, Pretzsch et al 2011 & 2012). Here we apply it to reveal how growth reactions on drought are modified by stand density. On each site 30 trees were chosen and classified in 3 density classes using multiple competition indices on an individual tree level. Tree-ring analyses revealed how the allometric root-shoot relationship varies with site conditions and stand density. Methods and results are discussed concerning their relevance for both plant ecology and forest practice.

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THE IMPACT OF DENDROCHRONOLOGICAL DATING ON THE INTERPRETATION OF VERNACUALR ARCHITECTURE IN WALES

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Keywords: dating, standing buildings, oak, Wales

Over the last eighteen years there has been a lot of effort expended on dating standing buildings in Wales, an area once regarded as 'difficult' and still with discrete areas in which dating seems to be more difficult than elsewhere. This has been funded largely by the RCAHMW (a public body) and more recently by a charity, now known as the Dating Old Welsh Houses Group. To date over 170 buildings have been dated, with more samples collected still to be analysed. The findings have had a profound impact on the interpretation and understanding of the development of vernacular architecture in Wales, which will be discussed. The distribution of dates obtained is quite different to that found in neighbouring England, reflecting cultural and historical variations.

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DETECTING EVIDENCE FOR CO_2 FERTILISATION FROM TREE RING STUDIES: THE POTENTIAL ROLE OF SAMPLING BIASES

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Keywords: ring analysis, growth rates, big tree selection bias

Tree ring analysis allows reconstructing historical growth rates over long periods. Several studies have reported an increasing trend in ring widths, often attributed to growth stimulation by increasing atmospheric CO_2 concentration. However, these trends may also have been caused by sampling biases. Here we describe two biases and evaluate their magnitude: (1) the *slow-grower survivorship bias* is caused by differences in tree longevity of fast- and slow-growing trees within a population. If fast-growing trees live shorter, they are under-represented in the ancient portion of the tree-ring dataset. As a result, reconstructed growth rates in the distant past are biased towards slower growth; (2) the *big-tree selection bias* is caused by sampling only the biggest trees in a population. As a result, slow-growing small trees are under-represented in recent times as they did not reach the minimum sample diametre.

We constructed stochastic models to simulate growth trajectories based on a hypothetical species with lifetime constant growth rates and on observed tree-ring data from the tropical tree *Cedrela odorata*. Tree growth rates used as input in our models were kept constant over time. By mimicking a standard tree ring sampling approach and selecting only big living trees, we show that both biases lead to apparent increases in historical growth rates. Increases for the slow-grower survivorship bias were relatively small and depended strongly on assumptions about tree mortality. The big-tree selection bias resulted in strong historical increases, with a doubling in growth rates over recent decades.

A literature review suggests that historical growth increases reported in many tree-ring studies may have been partially due to the big-tree sampling bias. We call for great caution in the interpretation of historical growth trends from tree-ring analyses and recommend that such studies include individuals of all sizes.

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HYDROCLIMATIC CHANGES DURING THE 8.2 KA EVENT REVEALED BY IRISH PINES

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Keywords: dendrochronology, pines, synchronicity, 8.2 ka event, hydrological

A pivotal cold event, deduced from the Greenland ice cores, took place between 8200 and 8000 cal. BP. Modelling of this climatic episode suggests that higher northern latitudes would have also experienced substantial reduction in rainfall and that Ireland would have observed a notable decline. No well-dated proxy record exists from the British Isles to test the model results. We present significant independent data for a phase of increased Scots pine initiation on Irish bogs at around 8150 cal. BP. Dendrochronological dating of sub-fossil Scots pine trees from three locations reveals synchronicity in germination across the area, indicative of a regional forcing, and allows for high-precision radiocarbon based dates. The starting rings of 40% of all samples from the north of Ireland dating to the period 8500-7500 cal. BP fall within a period of 25 years. The present colonisation model of Scots pine on peatland is interpreted as increasing drier conditions in the region and provides the first meaningful proxy data in support of a significant hydrological change in the north of Ireland accompanying the 8.2 ka event. The dating uncertainties associated with the Irish Scots pine record and the Greenland Ice Core Chronology 2005 (GICC05) do not allow for any overlap between the two. The results indicate that the discrepancy could be a result of dating inaccuracy that could have affected analysis of prior proxy alignments.

DENDROECOLOGICAL RECORDS OF SHRUBS ANNUAL GROWTH IN HIGH & LOW ARCTIC SITES (CENTRAL SPITSBERGEN, W GREENLAND)

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Keywords: Arctic, shrubs, serial sectioning, missing rings

Recent warming is expected to dramatically modify the arctic terrestrial ecosystem and woody plants growth in the polar regions. Dendrochronology and wood anatomical analyses might significantly contribute to investigations on how intra-plant growth respond to climatic variables across the Arctic biome.

In the following study tree-rings series of selected species from High and Low Arctic shrubs were investigated within the above-ground and below-ground parts. Serial sectioning method (Kolishchuck, 1990) was applied to dwarf shrub *Salix polaris* from central Spitsbergen and *Betula nana* from western Greenland. Annual radial growth was visually inspected on digital images of the full cross-section along two to four radii to account for the common wedging rings. Cross-dating was visually performed by first comparing the section of the same plant, then between plants, which allowed the detection of numerous partially and completely missing rings (Buchwal et al., 2013).

The obtained *Betula nana* and *Salix polaris* chronology spans over 120 years each. Climate-growth correlations between air temperature and ring width indicates that both species positively respond to summer temperature. Furthermore, a strong positive correlation was found between *Betula nana* growth and winter air temperature, i.e. with previous December and current January, and also with spring soil temperature.

Correlations with winter and spring thermal conditions have been rarely described so far for Arctic shrubs. Strong correlations with the dormant season conditions suggest that cambial activity in *Betula nana* is driven not only by growing season conditions, and might be under indirect influence of the heat cumulated in the soil.

Many studies dealing with Arctic shrubs growth responses to temperature usually base their estimations on biomass measurements of only the above-ground segments, neglecting the below-ground growth. In this context, the dendrochronological studies of shrub-rings can additionally provide a retrospective insight into intra-plant temperature responses and seasonal growth allocation.

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INCREASING DROUGHT STRESS AND CLIMATE VARIABILITY IN HIGH MOUNTAIN ECOSYSTEMS IN TAIWAN

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Keywords: *Abies kawakamii*, climate change, dendroclimatology, stable oxygen isotope

Increasing global temperature, frequent drought events, and changes of precipitation regimes may lead to high level of forest mortality and concerns rise over the vulnerability of mountain ecosystems (Allen *et al.* 2010). Palaeoclimate reconstruction is crucial to evaluate associated stress in the context of natural variability. Tree-ring widths and stable isotopes have been widely adapted in dendroclimatology and the latter may yield better climatic signals (McCarroll and Loader, 2004). We developed the first tree-ring $\delta^{18}O$ chronology in Taiwan using Taiwan fir (*Abies kawakamii*) in Mt. Hehuan (3090m a.s.l.). We collected and cross-dated 144 tree cores and selected 9 cores to obtain $\delta^{18}O$ chronology. Climate data were from mountain weather stations and Taiwan Climate Change Projection and Information Platform (TCCIP). We applied stationary bootstrap to resample climate and $\delta^{18}O$ data to estimate mean and standard deviation at each data point. Ring width and $\delta^{18}O$ reflect pre-growing and growing season climates respectively. Ring widths were significantly correlated with March-May sunshine duration ($r = 0.421$, $p < 0.05$) and precipitation ($r = -0.461$, $p < 0.01$). We applied tree-ring $\delta^{18}O$ chronology to reconstruct a 232-year climate (AD 1780-2011). The $\delta^{18}O$ chronology accounts for 33.1% of variance of growing season (May to October) temperature ($r = 0.575$), 38.4% of standard deviation of precipitation ($r = 0.620$), 22.9% of precipitation ($r = -0.479$) and 36.7% of Palmer Drought Severity Index ($r = -0.606$). The climate reconstruction shows high variability in the past two centuries but clear trends toward decreasing precipitation, elevated temperature, increasing variability of precipitation and frequency of drought events were observed into the 20th Century. The mountain ecosystem in Taiwan may undergo severe drought stress with global climate change.

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THE USE OF TREE RINGS IN ECOLOGY AND THE NEED OF RETHINKING SAMPLING STRATEGIES

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Keywords: dendroecology, review, state of the art, future research needs, future perspectives

Dendroecology is the science that applies dendrochronological methods in ecology. Tree-rings, as the biological, physical and chemical result of the influence on environmental factors on tree physiogical processes, can be used for the reconstruction of past environmental conditions. Dendroecological methods have been used to understand the role of fire as an ecological factor, e.g., in the southwest of North America, and of the impact of air and soil pollutants on forest ecosystems, e.g. in the red spruce decline in the Apalachian Mountains of the eastern U.S. and in the Waldsterben in central Europe. Classical dendroecological studies have enabled the reconstruction of past occurrence of natural disturbances, suggesting how to apply a close-to-nature silviculture. Wood chemical analyses have demonstrated the potential of tree-rings as indicators of air quality. Recently, wood anatomical features have been increasingly used to detect the impact of climatic extreme events on tree growth and physiology, showing their enormous potential.

In this talk, I review past significant achievements in dendroecology, suggesting possible future research avenues. In the future, I predict a more intensive use of tree-rings in different ecological fields to detect the impact of land-use changes on human societies. Of utmost importance will be providing an estimate of biomass produced by forests under different climatic and land-use management scenarios. However, it is still difficult to use tree-rings to assess forest stand biomass, because of sampling bias and a lack of adequate sampling strategies. An appropriate sampling design has yet to be developed, and represents a major challenge for dendroecology.

Tree-rings as indicators of tree response to environmental changes can and will be applied in several different, diverse, fields of ecology. The future of dendroecology is promising, and challenging. We only need to fully discover the tremendous potential of tree-rings.

Paolo Cherubini's research interests lie within physiology, ecology, and evolution, with relevance to the knowledge and sustainable management of natural resources and nature conservation. He strives to understand the key processes behind tree growth, to gain a thorough understanding of the influence of environmental stress on tree physiological processes, with particular focus on intra- and inter-annual cambial activity and wood formation. Dr. Paolo Cherubini is Italian, grew up in Pisa, Italy, and was educated in forest sciences at the Università di Firenze (Italy), and in dendrochronology at the Universität Basel (Switzerland) where he obtained his PhD in 1996. In 1992 he moved from Italy to the ETH Zurich in Switzerland, and since 1993 he is with the WSL Swiss Federal Research Institute at Birmensdorf (Zürich, Switzerland).

Dr. Cherubini is currently Senior Scientist at the WSL, in the Research Group "Dendroecology". He is Adjunct Research Scientist at the Lamont-Doherty Earth Observatory of Columbia University, New York City (U.S.A.), Adjunct Faculty at the University of Nebraska-Lincoln (U.S.A.), Guest Professor at the Institute of Earth Environment of the Chinese Academy of Sciences (CAS) in Xian, China, and Lecturer at the Department of Geography of the University of Zurich (Switzerland). He is editorially very active: he serves currently as Editor in Chief of the journal *Dendrochronologia,* he served 2002-2011 as Associate Editor of *Tree-Ring Research*, and is Associate Editor of the *Canadian Journal of Forest Research*, Editor of *iForest* and *Forest@*, member of the Editorial Board of *Geochronometria* and of the *Journal of Vegetation Science*.

LINKING CLIMATE, FOREST ECOLOGY, AND LAKE CATCHMENT CHARACTERISTICS IN THE MIDDLE ATLAS MOUNTAINS, MOROCCO: A DENDROCHRONOLOGICAL PERSPECTIVE

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Keywords: dendrochronology, Holocene climate, forest ecology, *Cedrus atlantica*, Morocco

Northwest Africa is uniquely situated at the interface between temperate and arid climate zones, where rapid climate changes and shifting vegetation patterns throughout the Holocene are documented in multiple proxies (Lamb et al., 1999; Esper et al. 2010; Fletcher and Zielhofer, 2011). Dendroclimatological investigations show that the native *Cedrus atlantica* (Atlas cedar) is a valuable indicator of drought severity in the Atlas Mountains of Morocco (Esper et al., 2010; Linares et al., 2011). Dendroecological research has revealed that *Cedrus atlantica* forests are subject to extensive anthropogenic threats that may have altered their structure and composition over time (Linares et al., 2011; Navarro-Cerrillo et al., 2013). This research aims to explore the localised effects of climate changes and anthropogenic impacts on *Cedrus atlantica*-dominated forests near Lake Sidi Ali, in the Middle Atlas, Morocco using dendroclimatological and dendroecological methods. Lake Sidi Ali is the focus of ongoing palaeolimnological and palaeoecological investigations into Holocence environmental change, thus offering the possibility to compare complementary pollen- and tree-ring-based archives at the lake catchment scale. Here, we present the methodology and preliminary results of the first dendrochronology field season at Lake Sidi Ali, incorporating samples of *Cedrus atlantica* and *Quercus ilex* (Holm oak) to compare and contrast the dendrochronology record from two competing species. A representative site chronology will test for the local impacts of wider regional climatic trends and variability, including a recent drying trend from the late 1900s (Esper et al., 2010), preceded by 500 years of humid conditions, characteristic of broader trends in the western Mediterranean and Northern Hemisphere (Esper et al., 2010; Fletcher and Zielhofer 2011). We anticipate this study, in conjunction with insights from palaeoecology of the Sidi Ali lake sediments, will provide a more detailed understanding of the importance of climatic impacts on terrestrial ecosystems in the Sidi Ali catchment.

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MODEL OF TRACHEID DEVELOPMENT EXPLAINS CONIFER TREE-RING STRUCTURE

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Keywords: conifers, kinetics of tracheid development, tree-ring structure, wood density, xylogenesis

In general, conifer tree rings are composed by light earlywood with large thin-walled cells followed by dense latewood with small thick-walled cells. Yet, how wood formation processes (cell enlargement and cell-wall deposition) and associated kinetics create this universal pattern remains poorly understood. Here, we quantify the duration and rate of xylogenesis by weekly monitoring tree-ring formation over 3 years (2007–2009) in 45 trees of three conifer species (*Abies alba* Mill., *Picea abies* (L.) Karst., *Pinus sylvestris* L.) in France. These data were used to investigate xylogenesis kinetics, and to attribute the relative importance of rate and duration of cell enlargement and wall deposition on tree-ring structure. Cell enlargement duration contributed to 75% of changes in cell diameter along the tree-rings, while the rate and duration of cell-wall deposition contributed equally to changes in cell wall material. Remarkably, the amount of wall material per cell was constant along most of the rings. Consequently, in contrast to conventional wisdom, changes in cell-wall thickness were not principally attributed to the kinetics of wall deposition (33%), but rather to the changes in cell size (67%). The duration of enlargement, as the main driver of cell size and wall thickness, contributed to 56% of wood density variation along the rings. This study unravels how kinetics of tracheid development shapes conifer tree-ring structure. This mechanistic framework now forms the basis for unravelling how environmental stresses trigger deviations (e.g. false rings) from the universal tree-ring structure.

THREE CENTURIES OF MONSOON CLIMATE VARIABILITY IN MYANMAR AND VICINITY INFERRED FROM TEAK TREE RINGS

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Keywords: dendrochronology, teak, Myanmar, climate, monsoon

Asian monsoon extremes critically impact much of the globe's population. Key gaps in our understanding of monsoon climate remain due to sparse coverage of palaeoclimatic information, despite intensified recent efforts (Cook et al. 2010). We describe a ring-width chronology of teak (*Tectona grandis*), one of the first high-resolution proxy records for the nation of Myanmar (Burma). Based on 29 samples from 20 living trees and spanning from 1613-2009, this record, from the Maingtha Forest Reserve north of Mandalay, helps fill a substantial gap in spatial coverage of palaeoclimatic records for monsoon Asia (D'Arrigo et al. 2011). Myanmar teak growth correlates significantly with rainfall and drought indices during and prior to the local monsoon season, and with larger-scale climate indices such as core India monsoon rainfall, an important index of the Asian monsoon and with the El Niño-Southern Oscillation (ENSO). The teak ring width value following the so-called 1997–98 El Niño of the Century suggests that this was one of the most severe droughts in the past 300 years in Myanmar. This teak series also shows evidence for the influence of the Pacific Decadal Oscillation (PDO) on the monsoonal hydroclimate of Myanmar and adjacent southeast Asia (D'Arrigo and Ummenhofer, conditionally accepted, *I J Clim.*). Evidence for past dry conditions inferred for Myanmar is consistent with tree-ring records of decadal megadroughts developed for Thailand and Vietnam (Buckley et al. 2007, 2010). These results confirm the climate signature related to monsoon rainfall in the Myanmar teak record and the considerable potential for future development of climatically-sensitive chronologies from Myanmar and broader monsoon Asia.

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HIGH-RESOLUTION DENDRO-PROXIES AS CLIMATE INDICATORS IN THE TROPICS

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Keywords: tropical dendrochronology, X-ray computed tomography, high-resolution proxies, quantitative wood anatomy

There is a lack of information on plant-environment interactions in Africa (Gebrekirstos et al. 2009) and especially in Central Africa. Environmental records are archived in tree rings and dendrochronology is possible in the tropics, although additional tree ring features should be investigated as well (Worbes 2002). We present a combined approach of retrospective methods to describe Central African tropical tree growth and its relation with climate. Our study area is the Luki Reserve (05°30'S-05°45'S, 13°07'E-13°15'E) located in a semi-deciduous forest that is part of the southernmost edge of the Mayombe forest (Democratic Republic of the Congo). Canopy (brevi-) deciduous tree species with proven annual growth rings (De Ridder 2012, Couralet et al. 2010) were sampled and analysed. In essence, tree-ring data are enriched with high-resolution proxy data obtained from nondestructive 3D X-ray Computed Tomography (XCT) and Quantitative Wood Anatomy (QWA). Via 3D XCT analysis we are able to construct pith-to-bark microdensitometry profiles of intact drilling cores. These profiles were corrected for ring and fibre deviations (van den Bulcke et al. 2013) and contain subtle inter- and intra-annual environmental signals along the growth trajectory of a tree. QWA traits are derived via processing and analysis of reflected/transmitted light microscopy images. Size and distribution of vessel lumina of the selected tree species are semi-automatically measured, corrected for ring deviations and mapped with their corresponding ring-corrected X and Y co-ordinates. These traits are synchronised to the density profiles and ring boundaries to create a matrix with tree response variables. A multi-trait approach for climate response of tropical trees is proposed, where climate-sensitivity of each variable is assessed. Eventually, the presented methodology could enable analysis of tropical trees which do not form clear visual annual rings, but which have a recurring pattern of other anatomical traits.

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GROWTH TRENDS AND VARIABILITY AT EUROPEAN BEECH MARGINAL POPULATIONS IN THE MEDITERRANEAN BASIN

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Keywords: *Fagus sylvatica,* growth trends, marginal sites, Mediterranean

Any change in climate bears implications for forest growth and species persistence. Selection pressure generally increases towards the edges of the species' geographical distribution areas / niches, rendering those populations especially sensitive to variations in the climatic conditions. The study of the dynamics of those populations at the margins has gained increasing interest, especially of the ones located at the so-called “rear edge”, where plant growth is constrained by drought. The response of rear-edge populations to water deficit may help to estimate tolerance limits and adaptation of species to forthcoming climate change (Hampe and Petit 2005).The Mediterranean basin (MB) represents a mayor ecotonal limit in Europe, where several boreal and temperate species meet their rear distribution limits in Europe. European beech (*Fagus sylvatica* L.) is a clear example of a temperate species meeting the rear edge of its distribution at the MB. Previous studies concerned with tree-growth of marginal European beech populations at the MB have reported a wide variety of site-dependent and species-specific trends, including both positive (Tegel et al. 2013) and negative (Peñuelas and Boada 2003; Jump et al. 2006; Linares et al. 2011) physiological responses. From such a variety of results stands out that the assessment of drought impacts on European beech forests requires an increasing number of local sites since resilience to drought depends not only on the vegetation type, but also on the characteristic of the drought spell, plant-growth rates and ecological conditions of the site (Vicente Serrano et al. 2012). In order to gain more knowledge on European beech growth at marginal sites, we analyse growth trends and variability at 13 marginal European beech populations sampled across the MB.

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DETECTING AND DETRENDING CANOPY DISTURBANCE EVENTS IN SCOTS PINE FORESTS

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Keywords: dendroecology, disturbance chronology, growth curve, time series analysis, Scots pine

Canopy disturbance events often abruptly increase the growth rate of surviving, subdominant forest trees. Their elevated growth rates may be transient, if canopy cover returns, or prolonged, if a tree attains a dominant canopy position. Druckenbrod et al. (2013) introduced a time series method to detect and detrend canopy disturbance events using examples from forests in eastern North America; however, the resulting growth patterns are likely characteristic of closed canopy forests in other biogeographic regions as well. This presentation tests this hypothesis by applying this method to Scots pine (*Pinus sylvestris* L.) forests near the Cairngorms in Scotland. While Scots pine has been present in Scotland for 8,000 years, extant stands older than 250 years are rare due to the intensive historical use of timber as a resource in this region (Wilson et al. 2011) and Scots pines of this age have not shown evidence of incipient mortality spirals (Fish et al 2010). Focusing only on growth releases in this application of the method, Scots pines are detrended using a combined linear trend and a flexible growth curve from Warren (1980). This new, combined trend and curve intervention is capable of capturing transient and prolonged growth responses. Disturbance events from these extant pine forests are compared with historical documentary sources and tree recruitment intervals to reconstruct the characteristics of past forest management in this region. A stand-alone version of this method is also introduced that operates using the freely available MATLAB Compiler Runtime. This stand-alone version does not require expertise in MATLAB to analyse tree-ring collections.

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DEVELOPING 500-YEAR CHRONOLOGIES OF STABLE CARBON AND OXYGEN ISOTOPES, FROM *PINUS SYLVESTRIS* L. IN THE JOTUNHEIMEN REGION OF SOUTHERN NORWAY

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Keywords: stable isotopes, dendroclimatology, Summer North Atlantic Oscillation, Fennoscandia, *Pinus sylvestris* L.

The aim of this research is to explore the climatic signal contained within the stable carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotopes of the annual rings of *Pinus sylvestris* L. (Scots pine) from the Jotunheimen region of southern, central Norway to examine possible links to the Summer North Atlantic Oscillation (SNAO). Previous research in this region has shown that ring-width measurements from Scots pine contain only a moderate climate signal (r = 0.36-0.62, P ≤0.01) (Blackmore, 2006). It is hypothesised that stable isotopes from tree-rings in this region will contain a stronger climate signal at both high- and low-frequencies. An annually pooled chronology of c. 10 trees will be constructed from AD 1500 to present. Isotopic analysis will be conducted on α-cellulose by high-temperature pyrolysis, producing simultaneous measurements of $\delta^{13}C$ and $\delta^{18}O$.

Preliminary isotope results from an annual pool (ranging n = 7 to n = 10 trees) for the period AD 1700 to 2003 shows strong and significant correlation between tree-ring $\delta^{13}C$ and summer (June to August) mean temperatures measured at Dombås (c. 70km to the east) (r = 0.64; P <0.001). To examine the spatial extent and coherency of the climate signal recorded in the Jotunheimen isotope record data were also compared to the CRU TS3.1 gridded temperate dataset using KNMI Climate Explorer (van Oldenborgh et al., 2009), this shows that a strong summer temperature signal from the $\delta^{13}C$ extends well throughout central and southern Fennoscandia.

This research is conducted as part of a Swedish VR funded project led by Prof Hans Linderholm at Gothenburg University entitled “The Character, Teleconnections and predictability of the Summer North Atlantic Oscillation”.

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COMPARING MILLENNIAL SCALE MXD AND STABLE CARBON ISOTOPE DATA FROM NORTHERN FENNOSCANDIA

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Keywords: climate reconstructions, dendrochronology, summer temperature, cloud cover

Tree-ring maximum latewood density (MXD) chronologies are the most suitable proxy to estimate late Holocene summer temperature variations at annual resolution. The two longest MXD chronologies have been developed in northern Europe reaching back to the 2nd Century BC and the 5th Century AD (Melvin et al. 2013; Esper et al. 2012). Here, we show these two independent records represent similar temperature fields and may be combined to produce an integrated summer temperature reconstruction extending back to 17 BC. This new reconstruction is compared with long-term $\delta^{13}C$ records from northern Scandinavia (McCarroll et al. 2013; Loader et al. 2013; Gagen et al. 2011); their similarities and differences are discussed. We focus on inter- and intra-proxy correlations, and on low- and high-frequency associations.

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VOLCANIC FINGERPRINTS IN TREE-RINGS

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Keywords: dendroclimatology, maximum latewood density, sulphate aerosol, surface cooling

Tree-rings contain valuable information on past extreme events. Among these are large-scale cooling events caused by explosive volcanic eruptions injecting sulphate aerosols into the stratosphere. The aerosols scatter incoming solar radiation and thereby cool the Earth surface. The precise magnitude and persistence of post-volcanic cooling is not known, though it is hypothesised that clustered eruptions contributed to longer-term temperature changes such as at the transition from the Medieval Warm Period into the Little Ice Age. While a number of studies revealed the importance of dendrochronological records to evaluate post-volcanic cooling events, recent work comparing reconstructed and simulated (from general circulation models) temperatures suggested the proxy to be substantially biased. Tree-ring chronologies ought to be miss-dated and the cooling signal smeared. The presentation will emphasise the importance of tree-ring data as key proxy for evaluating post-volcanic cooling events. Differences between ring width and maximum latewood density records will be addressed, and some results of regional and larger scale analysis discussed.

Professor Jan Esper is the Head of the Institute of Geography at Johannes Gutenberg-Universität Mainz. He acted as Head of the Dendro Sciences Division, WSL ETH Domain, Birmensdorf, Switzerland between 2006 and 2009, after 5 years as a Research Scientist at the same institution. Jan was a postdoc at the Lamont Doherty Earth Observatory of Columbia University from 2000 – 2001, having completed a one-year stint as an Associate Researcher for the Department of Geography at the University of Bonn between 1999 – 2000. He obtained his Diploma in Geography in 1995 and his PhD in 1999, both from the University of Bonn. Jan also completed a Habilitation in Geography, University of Bern, in 2005.

Professor Esper's research research interests include global climate change, paleoclimatology and vegetation dynamics.

MONITORING THE FORMATION OF XYLEM AND PHLOEM OF SCOTS PINE (*PINUS SYLVESTRIS* L.) AT THE CELLULAR LEVEL IN RESPONSE TO ARTIFICIALLY INDUCED STRESS

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Keywords: Scots pine, xylem, phloem, cell, artificial stress

This research focuses on microscopic analyses of xylem and phloem of Scots pine (*Pinus sylvestris* L.) when being exposed to an artificial stress factor. In summer the trees observed were artificially stressed using the method of girdling- a bark strip is removed from the circumference of the trunk at a height of 130cm. The aims of this research are to analyse the growth progress of trees with an interrupted transport of growth hormones as the dividing function of lateral meristem was artificially inhibited; further, to evaluate the time of the cambial activity as well as the radial increment in connection to the vitality of the trees. Within the growing season, the dynamics of the radial growth of xylem and phloem in response to the stress induced was evaluated. The number and morphological parameters of the cells formed were continuously monitored using regular micro-core sampling (Trephor tool) from the trunks. The cells formed reflect the tree growth response in a temporal series. Six healthy reference sample trees and six stressed trees were selected for the research. The micro-core samples were collected at weekly intervals from places above the injury and below the injury.

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STABLE CARBON AND OXYGEN ISOTOPES IN TREE RINGS REVEAL DROUGHT EVENTS AND POSSIBLE GROUND WATER FLUCTUATIONS IN SUB-SAHARAN AFRICA

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Keywords: stable isotopes, Africa, dendrochronology, *Faidherbia albida*, climate change

Tree-rings are important proxies for palaeoclimate studies because they contain continuous historical records of inter-annual and intra-annual time resolutions, which range over hundreds of years. This study uses stable carbon and oxygen isotopes in tree rings to understand the drivers and impacts of climate change in sub-Saharan Africa and their ability to reconstruct past regional climate variability and climatic trends. Our approach considers large scale climate gradients and different temporal scales (inter-annual and intra-annual variations) and combines multi- parameter measurements (carbon and oxygen isotopes, whole wood and cellulose measurements). The study species are *Faidherbia albida* and *Sclerocarya birrea* from south and West Africa, respectively. Both are very important deciduous trees, and widely distributed in sub-Saharan Africa. Particularly, *F. albida* has a distinctive phenology; it bears leaves and flowers during the dry season and sheds its leaves during the rainy season. Stable carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) mean values showed similar inter-annual patterns. In general, both $\delta^{13}C$ and $\delta^{18}O$ show negative correlations with rainfall, humidity and PDSI. On the contrary, they are positively correlated with sunshine hours, maximum temperature and evaporation. The reverse phenology of *Faidherbia* and intra-seasonal resolution measurements reveals seasonal ground water fluctuations. Both carbon and oxygen stable isotopes showed strong climatic signals including the long Sahel drought events and climatic recovery phases.

INFLUENCE OF ENVIRONMENTAL FACTORS TO SECONDARY XYLEM GROWTH IN *FAGUS SYLVATICA* L.

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Keywords: European beech, cambium, growth ring formation, temperature, soil moisture content

Analysing cambial activity dynamics and wood cell development renders it possible to recognise various environmental factors, registered as signals in growth rings, during the formation phases. European beech (*Fagus sylvatica* L.) wood is considered to be optimal for indicating the impact of internal or external factors on cambial activity. This study aims to compare seasonal cambium dynamics and differentiation phases, between two successive growing seasons (2010–2011), in European beech trees, located at Rajec-Domanka site in the Czech Republic and thereafter, to infer the influence of three climatic parameters dominating during growing period. Air and soil temperature, as well as moisture content data were measured directly at the research plot and six sound European beech trees were selected for microcoring by using Trephor tool, at weekly intervals during 2010 and 2011 growing seasons. According to this research, a significant decrease of soil moisture content during 2011 growing season was recorded (13.0 ± 4% and 9.8 ± 3 % for 2010 and 2011 respectively), air temperature was found significantly different between two years (14.7 ± 5.6^{o}C and 15.2 ± 5^{o}C respectively), while soil temperature displayed a similar range (11.8 ± 2.2^{o}C and 11.1 ± 2.1^{o}C respectively). The cambial activity onset timing was found statistically different between two years. However, averaged air temperature was similar when onset eventually occurred (9.6 ± 1.6°C and 9.9 ± 4.0°C respectively), as well as during the beginning of each formation phase. Furthermore, at approximately 14 days, a significantly different timing shift of the wood-formation phases occurring between 2010 and 2011 growing periods, was also observed. Conclusively, it is assumed that the critical factor for wood formation in the case of Rajec-Domanka site is probably soil moisture content rather than air temperature.

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HETEROGENEOUS INFLUENCES OF CLIMATIC CHANGES ON PRODUCTIVITY OF BLACK SPRUCE FORESTS ACROSS CANADA

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Keywords: dendroclimatology, ecophysiology, boreal, black spruce, process-based model 3PG

The 20th Century was a pivotal period at high northern latitudes as it marked the onset of a rapid climatic warming brought on by major anthropogenic changes in global atmospheric composition. These environmental changes interact strongly with land ecosystems in North America. Evidence of improving vegetation productivity in the coastal Arctic tundra initiated by climatic warming during the late 20th to early 21st Centuries are cumulating in analyses of satellite data and *in situ* field measurements. In contrast, areas of declining vegetation productivity were documented in the southern adjacent boreal ecosystems across a belt stretching from Interior Alaska to northwestern Quebec. Scattered within this heterogeneity are, nonetheless, diverging local trends in relation to species traits and local site factors and disturbance history. Here, remote sensing, tree-ring data, process-based modelling and long-term proxy/historical records are used to provide an integrated perspective on climatic, physical and ecosystem changes in Canadian black spruce (*Picea mariana*) forests during the late 20th to early 21st Centuries. Analyses of tree-ring data collected from 724 dominant and co-dominant trees in eastern Canada emphasise locally diverging responses of forests to recent climatic changes. The divergence at the local scale is primarily due to demographic and species traits that mediate temperature and water stress constraints on radiation, water and carbon use efficiency. At the country-wide scale, modelling with a canopy gas exchange model show large variability in productivity responses to recent climatic changes, with many areas across the western boreal showing a decrease of productivity and others from the northeast showing an increase. Analyses of the drivers for these changes point to complex sets of climatic drivers. The results highlight the high sensitivity of these forests to relatively modest changes in temperature.

DENDROCHRONOLOGICAL SIGNAL OF ATMOSPHERIC POLLUTANT DEPOSITION VIA FOG TO MONTANE SPRUCE FOREST STANDS IN POLAND

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Keywords: fog deposition, acid pollution, Norway spruce, subalpine forest, growth reduction

Since the 1970s Norway spruce (*Picea abies*) forests in middle-size mountains of southwestern Poland had been affected by large-scale dieback caused mainly by air pollution deposition (Błaś and Sobik, 2003). In the upper part of the Central European hercynian mountains orographic fog tends to be the main pathway of acid pollutant deposition, even more important than acid rain. Moreover fog deposition is much more spatially variable than wet deposition carried by precipitation only (Błaś et al., 2002). The most intense forest destruction was observed at the sites with effective fog deposition: upper parts of western to northwestern slopes (windward to prevailing airflow) and at forested mountain summits. Further deforestation was stopped in the mid-1990s, after substantial reduction of anthropogenic emission, mainly from neighboring large power plants.

The goal of this study is to examine how the annual rate of tree rings growth responds to spatial and temporal variability of atmospheric pollutant deposition with particular emphasis to fog deposition. There were twelve sampling sites located in different altitudinal zones (from 600 to 1300m a.s.l.) and divided into five mountain ranges along NW-SE transect. The health status of the drilled trees is closely correlated with the spatial variability of fog deposition, showing only slight growth reductions at foothill reference sites where fog deposition is negligible. The ratio of annual growth in 1980s to 1950 is as low as 0.2-0.3 at the windward subalpine sites. In the subalpine spruce forests at leeward, eastern slopes growth reduction is significantly smaller, reaching 0.5-0.6 of the 1950s' value. It is also interesting that for the last two decades a significant regeneration of conifers has been observed.

Concluding, dendrochronological methods appear to be decisive for testing the hypothetical role of fog deposition for the health status of montane Norway spruce stands.

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TREE-RING ANALYSIS TO DETECT CENTENNIAL-SCALE GROWTH CHANGES IN TROPICAL TREE SPECIES

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Keywords: dendroecology, tropical forests, growth changes

Contrasting evidence for increasing and decreasing biomass in intact tropical forests has been found from permanent plot studies. These results suggest tropical forests acted either as carbon sinks or sources. However, the limited length of these studies restrains analyses to decadal scales. It is thus unclear whether growth changes occurred at longer time scales.

Tree-ring analysis provides long-term growth data, allowing for extension of growth change analysis to centennial scales. Detecting these changes, however, requires disentangling ontogeny from long-term growth changes and several methods have been developed to do so. However, consistency in output and sensitivity to detect trends of these methods have hardly been compared. Here we compare output consistency and detection sensitivity of four commonly used trend-detection methods: traditional detrending, basal area transformation, regional curve standardisation and size-class isolation. To compare method consistencies, we applied the four methods on measured tree-ring data. Detection sensitivity of each method was assessed by modelling growth data with imposed (positive and negative) trends and quantifying whether trends were correctly detected. Finally, we applied the two best methods on tree-ring data of 14 tropical species (~1400 trees) from three sites (Bolivia, Cameroon and Thailand) to analyse long-term growth changes.

All methods except traditional detrending showed consistent results and good sensitivity. However, with basal area transformation often detected erroneous growth-trends. Method choice may thus influence trend detection and we recommend using regional curve standardisation and size-class isolation to detect growth trends.

When applying these two methods on the 14 species, we found no evidence for consistent growth changes. Increasing trends were found – for some species and in particular size categories – whereas decreasing trends were also noted. Although these results were obtained for a subset of species from only three sites, they do suggest growth increases at decadal scale cannot be extrapolated to longer time scales.

EARLYWOOD VESSEL SIZE COMBINED WITH RING WIDTH DISENTANGLE MICROCLIMATIC EFFECTS OF A RIVER BANK IN AN ATLANTIC OAK FOREST IN NORTHWESTERN SPAIN

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Keywords: oak, vessel area, dendrochronology, sea level, river influences

The use of vessel area of ring-porous species as a climate proxy is becoming widely used in dendrochronology to complement the environmental information provided by ring-width studies. This can be useful to understand the effect of climatic factors at different micro-environmental locations.

We investigated the effect of prolonged water excess in an Atlantic rainforest close to the sea level. We selected two groups of 13 oak trees (*Quercus robur* L.*)* in order to investigate the variation of ring-width and earlywood anatomy. The groups were located nearby, but under contrasting hydrological conditions. The first group was along the river bank and the second on the slope.

Out of two core samples per tree, we measured earlywood, latewood and total ring-width, as well as the lumen area of all large earlywood vessels that was correlated to monthly values of precipitation and temperature.

We found distinct differences between both groups. Total and latewood width of trees growing on the slope were positively correlated to rainfall in June, and also negatively correlated to temperature in July, suggesting that water availability at the beginning of latewood formation is important to ensure sustained growth. Furthermore, earlywood vessel size was highly correlated to temperature during the dormant season, mainly during the previous December.

These relationships were weak, absent or even opposite for the trees along the river bank, suggesting that the proximity of the river smoothed the climatic influence. This is probably due to the higher water availability during summer, and the constant saturation of soil water table every year during winter as a result of the Atlantic river regime.

These results confirm the importance of climatic conditions during the dormant period for oaks under Atlantic climate, and also the high sensitivity of earlywood vessel features, rendering this proxy a valuable complement for dendrochronology studies.

ON THE CORRELATION PATTERNS BETWEEN NORTHERN SCANDINAVIAN LATEWOOD DENSITY AND NORTH ATLANTIC CLIMATE VARIABILITY OVER THE PAST 150 YEARS

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Keywords: maximum latewood density, Scots pine, sea surface temperature, Fennoscandia

Large-scale circulation patterns such as the North Atlantic Oscillation (NAO) and the Atlantic Multidecadal Oscillation (AMO) are closely linked with climate variability over Fennoscandia today (Jones and Mann 2004), but likely their impacts and spatial influences have varied through time. Natural climatic changes originating from the North Atlantic Ocean have recently been shown to drive multi-decadal variations in Europe over the past centuries (e.g. Sutton and Hodson, 2005; Linderholm et al., 2010). A composite chronology of Maximum Latewood Density (MXD) from 7 sites in northern Scandinavia was used to investigate their relationship with North Atlantic sea surface temperature (SST) and atmospheric/ocean circulation in 1870 – 2005, with the aim of identifying influences of local to regional patterns on regional summer temperatures. The sites included in the composite represent latitudinal and altitudinal tree-line pine growth in Fennoscandia. The mean MXD chronology correlates strongly with mean (JAS) temperature averaged over Fennoscandia ($r > 0.7$), but it is weakly correlated ($r = 0.32$) with July to September (JAS) NAO/AO observed indices, and even weaker with the AMO. Correlations with gridded SST extend beyond northern Fennoscandia, being locally strong ($r > 0.5$). Positive correlations of the same magnitude are also found in the western North Atlantic (the sub-tropical gyre) and negative correlations in the mid-latitude gyre. The negative correlations occur only during the AMJ and JAS seasons, when the ocean mixed layer is shallow in the North Atlantic. This tripolar pattern, similar to that of Rodwell and Folland (2003), suggests that North Atlantic SST influences summer temperature variability in northern Fennoscandia, illustrating the potential for using tree-rings to reconstruct the thermohaline circulation and the heat transport towards the North Atlantic region back in time.

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X-RAY DENSITOMETRIC ANALYSIS OF SESSILE OAK - METHOD AND APPLICATION IN DENDROCHRONOLOGY

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Keywords: sessile oak, x-ray densitometry, anatomy

In the past decades, X-ray densitometrically determined wood density distributions within the annual rings of conifer wood served as indicators for temperature and precipitation. Due to its prevalence and longevity as well as its specific rhythm of developing annual rings, sessile oak (*Quercus petraea* [Matt.] Liebl.) is also of interest for dendroecological and dendroclimatological investigations. Yet, its more complex cell structures as compared to conifer wood prevent the employment of high-resolution X-ray densitometry.

Therefore, the goal of the present work was to clarify how characteristics of wood anatomy are represented in the intra-annual X-ray densitometric profiles of differently structured annual rings of oak wood, thereby enabling the application of X-ray densitometry for density analysis of sessile oak wood.

Overall, 19 stem discs and 80 increment cores from 53 trees were prepared for radiodensitometrical examination. For the x-rayed samples micro-sections of the cross sections were produced. Based on digital photomicrographs anatomical characteristics for every annual ring were quantified and described by means of image analysis.

Ten different annual ring parameters could be deduced from the present X-ray-densitometric profiles. The obtained density profiles were found reproducible. It has shown that the deduced annual ring parameters represent the wood anatomical structure of the annual rings to a high degree. Within the framework of climate-growth-analyses, seven out of ten of the deduced parameters have shown to possess a dendroclimatological relevance. Furthermore, it became clear that particularly the mean latewood density within the annual ring correlates significantly with the mean precipitation of the current month of August.

As the result of the investigations, it was possible to obtain reproducible and wood anatomically verifiable intra-annual density parameters in climate sensitive late wood of the annual rings of sessile oak.

EARLY HOLOCENE LANDSCAPE AND BALTIC SEA DEVELOPMENT BASED ON DENDROCHRONOLOGICAL STUDIES OF SUBMARINE FOREST REMAINS

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Keywords: submerged forest, dendrochronology, Baltic Sea

A submerged forest landscape with rooted pine remains and organic deposits is situated at a depth down to about 20m in the Hanö Bay outside southeastern Sweden, in the Baltic Sea. It is hypothesised that two land phases characterise the area, the first around 11,700-10,500 years ago, corresponding to the Yoldia Sea and early Ancylus Lake phases, and the second around 9,800-8,000 years ago, the initial Littorina Sea phase (Björck 1995). The organic deposits found throughout the area are indicative of a small river running through the former landscape as well as lagoonal basins and/or oxbow lakes along the former coastline with pine trees growing along the sandy coastline.

The two major aims of the project are to increase the understanding of the early Holocene coastal landscape and ecosystems in the area, and on a regional scale to connect this to the Baltic Sea development. This project will use several methods to study the former landscape: dendrochronology and dendroclimatology, radiocarbon dating, sediment analysis, multi-proxy analyses of lake sediments and high resolution bathymetry data. Collaboration with archaeologists from Södertörn University will extend this project to include the development of the early Mesolithic cultures in southern Sweden.

The pine remains found *in situ* at the bottom are often complete with bark and fallen trunks of several metres can be found. Other samples are just consisting of the roots and the base of the trunk. By sampling these well-preserved submerged pine remains at different depths we hope to build floating chronologies that can help us understand the speed of the water level changes in the dynamic early Baltic Sea. The tree-ring chronologies will also be used to interpret the local climatic and substrate conditions. Diving and sampling of these trees will take place in the summer of 2014.

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CLIMATE SIGNALS IN STABLE ISOTOPES FROM TEMPERATE FORESTS: SPECIES AND SITE EFFECTS

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Keywords: dendroclimatology, tree physiology, moist mid-latitudes, drought, $\delta^{13}C$ and $\delta^{18}O$

Temperate forests in the mid-latitudes are of great importance, since these ecosystems make up a large fraction of utilised forests. In such environments, stable isotopes are typically used for tree physiological investigations, in particular for studying drought stress. However, the climate signals of stable isotopes from temperate forests are not fully understood. Here, we present a tree-ring study from a montane mountain forest in the moist mid-latitudes and assess the response of $\delta^{13}C$, $\delta^{18}O$ and tree-ring width to climate variables, considering site and species effects. Our sites differ in moisture conditions including a dry, medium, and moist site, and comprise Norway spruce, common beech and European larch. The general response to sunshine duration, temperature, moisture index, precipitation and cloud cover, as well as the response to extreme drought events are analysed for each tree-ring parameter, site and species. While the climate signals inherent to $\delta^{13}C$ and $\delta^{18}O$ are distinct, and independent of site and species, the signals inherent to the ring-width data are weak, and appear dependent on species and site. During drought events, $\delta^{18}O$ variations show minor site-specific dependencies, while the drought response of $\delta^{13}C$ is overall strong with no species- or site-specific effects. Because of the species- and site-transcending response patterns, stable isotope studies from the moist mid-latitudes indicate good potential for deriving long-term climate patterns.

ARCTIC DRIFTWOOD IS DOMINATED BY 20TH CENTURY CENTRAL SIBERIAN TIMBER LOGGING

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Keywords: Arctic, driftwood, pine, Siberia, Boreal rivers

Spatiotemporal patterns of Arctic driftwood composition affect our understanding of past ocean current dynamics and source region characteristics. Recent findings suggest Arctic driftwood to be composed of spruce from North America and larch from Siberia, dating throughout most of the Holocene. However, a site location within the permanent sea ice extent and a low sample replication might impede the representativity for the entire Arctic. Here, we present a wood-anatomically analysed compilation of 2,557 driftwood samples from Greenland, Iceland, Svalbard, and the Faroe Islands. Tree-ring widths of *Pinus sylvestris* as the overall dominating species (37.9%) were measured. Eurasian boreal reference chronologies allowed us to crossdate 498 out of 969 samples. The central Siberian rivers Yenisei and Angara are source regions for 47% of all material, which dates between AD 1631 and 1999. Considerably less wood is delivered by the western (Northern Dvina and Pechora Rivers) and eastern (Lena River) Siberian river systems. Mid-20th Century timber logging and floating activities at the Yenisei and Angara, as well as their accumulated discharge rates, explain the vast quantity and the main peak between 1930 and 1980 of material from this region. Our results, based on sites beyond the Arctic sea ice extent, not only contradict the assumption of absent driftwood pine, but also highlight the Eurasian origin and young age of the material. Nevertheless, consideration of even more samples and other species, together with longer reference chronologies, appears indispensable for developing a reliable cross-disciplinary archive at the interface of marine and terrestrial environments.

SHORT-TERM GROWTH, WOOD DENSITY AND CHEMICAL FLUCTUATIONS IN SHORT ROTATION PLANTATIONS OF *EUCALYPTUS NITENS* (DEANE & MAIDEN) MAIDEN IN NORTHWEST SPAIN

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Keywords: X-ray densitometry**,** ITRAX, *Eucalyptus nitens*, wood density, dendroecology, dendrochemistry, short rotation forestry, biomass

Wood density and chemical components are some of the most important determinant of wood properties and therefore a critical factor in short rotation forestry (Wimmer et al. 2002). It is the strongest predictor for paper properties, biomass and mechanical strength of sawn timber. However, wood density can be changed by silvicultural practices, genetic manipulation and climate conditions. This study aims to use Energy dispersive X-ray fluorescence (ITRAX Multiscanner) (Cox, Analytical Systems, Molndal, Sweden), which provides highly sensitive and precise spatial resolution of cation content, wood density in individual annual tree growth (Smith et al. 2014). Seasonal radial growth of *E. nitens* trees for bioenergy purposes was estimated on 105 trees from 40 experimental plots installed in a range of site conditions under 5,600 and 2,300 trees·ha^{-1} stocking in northwest Spain. In the age range between 2 and 5 years, discs from felled trees were extracted at several stem heights, and 0.5m height cross-sections were processed for high-resolution wood density and chemical properties using the new ITRAX multiscanner in a long north-south diametric direction. In general, lower density was formed early in the growing season, and higher wood density later. Relationships between wood density and seasonal growth increment, and climate were analysed. Furthermore, correlations among wood chemical components and the growth fluctuations with climate and soil nutrients were carried out in this study. The presented approach opens new opportunities for wood properties, silviculture and environmental interaction studies of short rotation plantations, which is of particular importance in forestry (Smith et al. 2014).

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TREE STANDS ON LATERAL AND TERMINAL LITTLE ICE AGE MORAINES OF FOUR GLACIERS IN SOUTHEAST TIBET – A COMPARISON

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Keywords: southeast Tibet, glacier history, Little Ice Age, dendroclimatology

The glaciers of the Tibetan Plateau, origins of most of the major rivers in south and east Asia, are undergoing a vast shrinkage during the recent decades. Recent glacier history in adjacent high mountain areas (Karakorum, Pamir, Tien Shan, Himalayas) has been covered widely via remote sensing (e.g. Bolch et al. 2012). However, the coverage of the heavily glaciated southeastern Plateau is comparatively low and the resulting time series too short for recognition of long-term trends. This demands the application of other methods.

We used trees from the lateral and terminal Little Ice Age (LIA) moraines and from recently exposed glacier forefields of four monsoonal temperate glaciers. Samples of the species *Larix griffithii* and *Picea likiangensis*, among which larches are the pioneers, were collected during three field campaigns in 2011-2013. Maximum tree ages vary between 257 and 272 years, indicating a regional retreat since approximately 1740 AD, with local variations mainly due to exposition and altitude. Apparently, tree germination occurred 20 years earlier than in previous studies (Bräuning 2006, Zhu 2012). This may be explained by differences in local climate, or underestimation of ecesis time lag. Terminal moraine stands on all visited glaciers are of much younger age than those on the lateral moraines. The reason for this is still unclear and demands further analyses. Shrub ages from inside LIA moraines, as well as our well-replicated ring width chronologies, point towards strong geomorphological activity due to a fast mass loss and small readvances during the last decades, in combination with formation of dead-ice bodies. Tree growth on all sites is strongly temperature-controlled, and ring-width chronologies of *Larix* correlate well on a regional level.

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UNEXPECTED RECENT WARMING-INDUCED GROWTH DECLINE IN *THUJA OCCIDENTALIS* AT ITS NORTHERN LIMIT IN NORTH AMERICA

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Keywords: Boreal forest, Canada, climate change, distribution limit, tree growth

Available evidence indicates that northern boreal forests and tundras are exposed to greater warming than most other terrestrial biomes. At the cold margins of the boreal zone, continuing warming will permit a longer seasonal vegetation period and favour growth and northward shifts of species distributions. In warmer and drier areas, warming-induced processes affecting plant growth and reproduction could cause many species to see a reduction of their distribution. The presence of northern marginal populations isolated from the continuous distribution could accelerate species migration, assuming that such populations have a good fitness with their future local climatic conditions. Considering annual radial growth as a proxy for tree fitness with climate, we hypothesised that a growth increase of northern marginal populations should be observed subsequently to global warming. To test our hypothesis, we investigated radial growth by tree-ring measurements in dominant and co-dominant eastern white cedar (*Thuja occidentalis* L.; n = 723) distributed across a latitudinal gradient from its northern margin to the heart of its distribution areas. Unexpectedly, a growth decline was observed in marginal sites. Dendroclimatic analysis revealed that radial growth was limited by short growing seasons but also by summer moisture availability in the marginal zone. Sites with larger trees and receiving less precipitation were the most sensitive to summer droughts. Growth was also limited by an excess of water before or after the growing season in some part of the gradient, especially in poorly drained soils. White cedar marginal populations might already have reached the threshold of optimum temperature. Their response to future climate change will highly depend on the seasonality and magnitude of variations in precipitation regimes.

COMPARISON OF EARLYWOOD VESSEL AREAS ON THE CROSS-SECTION OF *QUERCUS ROBUR* L. TRUNK FROM DIFFERENT SITES

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Keywords: oak, earlywood vessels, environmental conditions

Environmental conditions have an essential effect on the formation of earlywood vessels in *Quercus robur* L. The studies published so far have focused on the effect of precipitation and air temperature. It has been proved that the area of earlywood vessels increases with an increasing temperature and precipitation sums. Besides the mentioned climatic parameters, soil properties are significant for tree vitality and growth. The main aim of this study was to expand the existing knowledge by research into the effects of site conditions, especially groundwater availability, on earlywood vessel area in a trunk of *Quercus robur* L. For this purpose, two sites with abundant groundwater and two sites with normal groundwater levels were selected. Cores were taken on each site by an increment borer from five sample trees at maximum. The earlywood vessel area was measured on a worked cross-section of the cores. The mean values of earlywood vessel area on particular sites were compared with each other. The analysis results show that the differences in macrovessel area on typologically different sites are statistically significant. The difference between typologically the same sites (groundwater abundant) was not proved. It is expected that the research will be extended for comparison with climate data for these site in the future.

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GROWTH AND PHYSIOLOGICAL RESPONSES OF LODGEPOLE PINE POPULATIONS UNDER DROUGHT: STUDYING CLIMATE CHANGE ADAPTATION STRATEGIES FROM TREE RINGS

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Keywords: Growth response, climate change adaptation, drought stress physiology, water use efficiency, stable isotopes

It is essential to select tree populations for reforestation that are both productive and drought tolerant, especially given projected increases in drought frequency and severity. Tree-ring analysis has emerged as a promising method to test adaptation of trees to changing climates. We combine this retrospective approach with a genetic experimental design that can provide insight into adaptation strategies for projected climates.

These genetic field experiments, also known as provenance trials, involve testing various seeds sources across multiple environments to determine the best genotypes for planting in a region; because a southward movement of seeds essentially represents a climate regime shift, the observed responses to drought in these experiments can help us target the most suitable populations for planting for future climates.

We sample from a large-scale, long-term provenance trial of lodgepole pine (*Pinus contorta*), one of western Canada's most important tree species. We collected stem disks, height increment and diametre data from 550 trees that represent British Columbia's northern, central interior and southern interior regions. We analyse the primary and secondary growth response of these populations to drought events occurring in 1998 and 2003, and further analyse the isotopic signatures archived in tree rings to indicate physiological responses.

We expect southern sources will show better growth or faster recovery of growth during drought periods in the field trial, and be better suited for planting in central regions under a warming climate. Since millions of lodgepole pine seedlings are planted every year for reforestation, there is the opportunity to immediately implement our recommendations to maintain forest health and productivity.

STONE PINE TREE RINGS AS A RECORD OF VOLCANIC ACTIVITY DURING THE LAST ~280 YEARS. MULTIPROXY APPROACH

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Keywords: stone pine, Tatras, volcanoes, pale rings, climate

Stone pine, *Pinus cembra* L., is the tree species which grows in the highest elevation within and above the ecotone of timberline in the Tatras, Western Carpathians (Bednarz 1992). Its growth is strongly influenced by climate, especially summer temperature; therefore tree rings are a reliable proxy of past weather. The long chronologies are archives of both long-term and abrupt changes of the high-mountain climate. Volcanic eruptions are one of the most important factors responsible for such short-lasting but significant fluctuations of climate. The study aims at: i) assessing the main climate events recorded in several tree-ring proxies, ii) identifying the records of the volcanic activity in studied features of tree rings, and iii) defining the volcano-climate-tree link responsible for tree rings features. The research was carried out in several sites located in the Polish Tatra Mountains. More than 400 samples were collected and used to develop tree-rings chronologies of: tree ring width (TRW), wood density anomalies (WDA) (Filion 1986), blue intensity (BI) and wood density (MXD) (Briffa et al. 1998). These were compared with information about volcanic activity (VEI, DVI, IVI) (Robock 2000) for the period between 1730 and 2013. The short volcanic coolings weren't registered by TRW (TRW chronology and pointer years). Only the largest events, such as Tambora (1815) and Katmai (1912), were captured by this proxy. The features related to wood density (pale rings, BI, MXD) register a wider spectrum of volcanic events. The visual analyses of pale rings confirmed by wood density measurements reveal most of the main stratovolcano eruptions from the southern and northern hemispheres (Tambora 1815, Katmai 1912, Augustine 1976, Pinatubo 1991) (Schneider et al. 2009).

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GENETIC VARIATION AND RADIAL GROWTH PATTERN OF NORWAY SPRUCE PROVENANCES IN POLAND

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Keywords: *Picea abies*, natural range, climatic response, molecular markers

We selected four provenances of the Norway spruce from the north of Poland, which were growing within the experimental area in Wyszków. The selected provenances represent 2 populations from the northern (natural) range of spruce - Górowo Iławieckie and Augustów, and 2 from the "spruceless" zone – Kartuzy and Mestwinowo. From among 192 trees (48 trees from each selected provenance) we collected increment cores and materials for DNA extraction. We measured the ring-width and created individual chronologies for each tree (using the WinDENDRO^{TM} software). We verified the individual chronologies (COFECHA) and created the actual, standard and residual chronologies (ARSTAN). We included the following climate parameters: average monthly air temperature, and monthly sums of precipitation. Pointer years were indicated using the WEISER software. We also analysed 4 microsatellite loci (SpAG - D1, SpA- G2, SpAG - C1 and SpAC1 - H8) [Pfeiffer et al. 1997; Yazdani et al. 2003].

Analyses showed a strong conformity of the growth curves, both in individual sequences representing particular provenances and in the chronology of the provenances. Response function analysis did not demonstrate any significant relations between climate and growth. Ten pointer years, common for all provenances, were selected. The analysis of distances confirmed the difference between the Mestowinowo population and the other studied populations. All four populations were characterised by strong polymorphism. Genetic analysis showed a low level of differentiation between the populations. All loci - apart from one - showed a shortage of heterozygotes. Among the analysed populations of the spruce the highest variability was observed in the population from Górowo Iławeckie. That population was also characterised by a lower heterozygosity. Opposite results were obtained for the Mestwinowo populaton - the best in terms of growth properties. For each inspected population pair, on the basis of a genetic distance, the genetic similarity was calculated. Genetic analysis showed a low level of differentiation between the populations (Fst=0.0222). This means that 2.2% of the entire genetic variability is associated with differences between the populations. This confirms the clinal nature of variability in this species and raises doubts as to the post-glacial spruce migration hypothesis. Obtained results do not confirm the impact of genetic variability (between the populations) on the differences in the growth patterns in the analysed provenances. However, the genetic influence on the processes of adaptation of spruce stands to variable environmental conditions cannot be excluded in the context of observed climate changes.

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CLIMATE RESPONSE OF FOUR TREE SPECIES FROM THE EAST-GERMAN LOW RAINFALL AREA

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Keywords: climate response, drought, black pine, ash, beech, oak

Climate response has been investigated for four tree species in the East German low rainfall area in Thuringia where average annual precipitation falls below 600mm. Black pine (*Pinus nigra*) has large semi-natural stands on calcareous soils far north of its natural distribution, common ash (*Fraxinus excelsior*) reaches its physiological limit along calcareous slopes. European beech (*Fagus sylvatica*) loses its competitive dominance and is gradually replaced by pedunculate oak (*Quercus petraea*) on warm and drier sites.

All chronologies have been constructed with samples from several sites. Detrending was done by cubic smoothing splines to eliminate possible effects of management. In general all species responded strongly to precipitation; the whole growth period (March to July) gave the strongest correlations (r = 0.6 ... 0.7). Temperature was of minor influence (negatively correlated, r = -0.3, to June and previous September). Response to a combination of rainfall and temperature through SPDI as well as SPEI (with variable time lag) always lead to lower correlation coefficients.

Although precipitation was the strongest factor, differences between species could be detected: black pine and beech responded strongest to rainfall in July, ash and oak strongest to June rainfall. For oak and ash negative influence of temperature was narrowly peaked at June, while for black pine and beech June and July contributed as well. The co-efficients of response function showed a similar behaviour. For ash the response co-efficient to precipitation became higher when the trees were stressed by increasing drought along the slope. Oak and beech had temporally rather constant correlations to rainfall (30y sliding window), while ash showed a gradual decline in response co-efficient (as a possible age effect?) and black pine indicated some (climatic?) transition from June to July precipitation as the most dominant factor.

Our findings extend results of García-Suárez et al. (2009) from higher rainfall area.

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THE TREE RING STUDY OF DOWNY BIRCH IN ICELAND AND NORWAY

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Keywords: Iceland, Norway, downy birch, missing rings, dendroclimatology

Downy birch (*Betula pubescens* Ehrh.) is one of the main native tree species in Scandinavia; it grows from Iceland to Finland and further east into northern Russia. Although various birch species are very common in Eurasia, downy birch is more associated with exposed habitats such as mountains and high latitudes. In Iceland the growth of downy birch is driven by summer temperature (Eggertsson 2008) whereas there is little known about a relationship between the populations from Scandinavia and Asia. The aim of this study has been: i) to test the teleconnection between downy birch sites located in Iceland and S Norway, and ii) to define whether the climate similarly influences on their growth.

In southern Iceland two sites, 100km distant from each other, were investigated, one on the slopes of Búrfell Mountain (669m a.s.l.), part of the Hekla ridge, and the second in Vatnshornsskógur. Fifty trees per site were sampled; due to frequent occurrence of irregularities of rings two cores per tree were taken. In Norway one site, Tjonnsviksvatnet (820m a.s.l.) (Telemark Region), was sampled in an identical manner. Standard dendrochronological methods were used to produce and test time series of TRW. The character of the wood and abundance of missing rings create challenges related to the preparation, measuring and analysis. The visual cross-dating was essential to assemble the coherent sets of TRW series. Trees from both regions were relatively young (~ 110 – 130 years) and to enhance the climatic signal different techniques of chronology computing were tested employing ARSTAN. The dendroclimatic analyses were performed using instrumental and CRU grid data of temperature and precipitation. The pointer years and longer lasting growth changes were calculated to identify the short climatic events and influence of insect outbreaks (mainly *Epinotia solandriana*) (Halldorsson, Sverrisson 1997, Halldorsson et al. 2001).

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SOIL ECO-ENGINEERING (2): WOOD ANATOMICAL VARIATIONS IN ROOTS AND THEIR INFLUENCE ON ROOT TENSILE STRENGTH

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Keywords: slope stabilisation, *Alnus incana* (L.) MOENCH, *Acer pseudoplatanus* (L.), Swiss Alps

Steep vegetation free slopes are prone to erosional processes. The resulting risk potential is likely to increase with the predicted change in the spatiotemporal distribution of precipitation events. For stabilising these slopes, soil eco-engineering is a very promising and sustainable approach.

The establishment of a close and dense vegetation cover is a central task in soil eco-engineering. Root systems support plant growth and soil stability, and they modify near subsurface parameters like aggregation, (bulk)density or soil moisture. Induced by constant rain or torrential rainfalls, saturated soil exerts downhill pressure to plants. As long as the root system supports anchorage, the respective slope area remains stable. Here, the tensile strength of the roots is a critical measure, because it is more likely that the single supporting roots break than the entire root system being pulled out of the soil completely. As a consequence, root tensile strength is an important parameter in characterising the soil stabilisation potential of trees and shrubs.

Tree roots show a high variability in their anatomical structure. Therefore, we assume that these structural changes affect the tensile strength of every single root. To confirm this assumption, the root systems of three alder (*Alnus incana* (L.) MOENCH*)* and four maple (*Acer pseudoplatanus* L.) trees were excavated on an eco-engineered slope in the Swiss Alps, which was stabilised in 1997.

The excavated root systems were cut into > 500 samples to determine their tensile strength. In addition their age, diametre, and root moisture was measured. Two micro-sections were prepared from root samples, which were successfully tested for tensile strength. The microscopic analysis focused on anatomical parameters as number and size of vessels, fibre size and cell wall thickness. The results for the final correlation between the anatomical characteristics and the root's tensile strength are presented for both tree species.

ANNUALLY RESOLVED FOREST GROWTH: RESEARCH OPPORTUNITIES AND CARBON-CYCLE CONSEQUENCES FROM A LARGE SNOW BREAKAGE EVENT IN THE SWISS ALPS

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Keywords: dendroecology, forest growth, biomass reconstruction

In 2012 a winter storm caused severe damage in a *Pinus Sylvestris* forest of a permanent monitoring plot in the Valais, Switzerland. This extreme event created an opportunity for dendrochronological research; we collected disks at 1.30m from 273 patchy-randomly distributed trees (representative of ~10% of the population) to investigate annually resolved absolute biomass increment.

We scanned each disk and measured tree-ring widths of 4 radii (two slope-parallel and two along the slope) to calculate basal area increment (BAI), which is strongly limited by drought conditions of the water year ($SPEI_{pSep\text{-}Aug}$, r=0.66, period: 1940- 2011). The averaged basal areas (BA) derived from those 4 radii match the scanned inside-bark BA nearly 1:1 (R^2=0.99), and the inventory derived outside-bark BA equal the measured inside-bark BA by a linear conversion factor of 1.34 (R^2= 0.98). These robust statistics allowed us to reconstruct and upscale annual aboveground biomass increment (ABI) for the whole 2ha plot. Since 1940 (15 years after the last large management activities) the mean ABI was 1840 kg/ha with an annual variability of ±30%. The snow-breakage induced biomass loss on this plot exceeded ~32 t. Under the same environmental conditions, we estimate the remaining living trees (n=2194) would require approximately 9.5 years to make up for the living biomass lost in this extreme climate event. We propose that well replicated, representative tree-ring datasets close to or from within monitoring plots have a huge potential to complement the rather short-term and low-resolution forest inventory monitoring data to gain knowledge about annual changes in forest productivity even before monitoring started.

DIFFERENT TYPES OF INTRA-ANNUAL DENSITY FLUCTUATIONS OF EUROPEAN LARCH AS A GENETIC ADAPTATION UNDER STRESSFUL GROWTH CONDITIONS

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Keywords: European larch, IADF, stress conditions, G × E

The phenomen of producing tracheids similar to latewood cells within the earlywood zones and tracheids similar to earlywood cells within the latewood zones determines the occurrence of intra-annual density fluctuation (IADF). The majority of publications about the fluctuation of wood density refers to four types of anomalies in the anatomical structure of an annual ring: latewood cells in the earlywood zone (E), latewood cells in the transition zone earlywood-latewood (E+), earlywood cells in the latewood zone (L), and earlywood cells in the border zone between previous and present annual ring (L+) [Rigling et al. 2001]. Environmental factors determining the occurrence of density fluctuations may include: droughts, frost, defoliation, air pollution, or seasonal flooding. Gaps in the knowledge on the genetic background of interaction between radial growth and stress encouraged us making an attempt to verify the following theory: The flexibility of response to stress factors visible in the anomalies in radial growth is based on genetics.

The studies covered the offspring of eight parent trees of European larch (families) from two seedling seed orchards (trails) in the Młynary and Zaporowo Forest Districts. The identification of different types of fluctuation was based on X-ray density profiles. The impact of environmental (trail, year) and genetic (family) factors on the frequency of occurrence of IADF's was analysed using the generalised linear model (GzLM) which includes the explanatory variables: trail, family, year and the interaction family x trail [Liang & Zeger 1986]. In the analysis the repeatability of the measurements in years was taken into account, using the GENMOD procedure, SAS 9.3. For the frequency of occurrence of the E-type fluctuation the family and year factors determined to be significant, while for the E+, L and L+ fluctuations the family, year and also the trail x family interaction were crucial. The frequency of occurrence of different types of density fluctuations depends on the environmental and genetic factors, as well as on their interaction. The occurrence of wood density fluctuation may be interpreted as the epigenetic-driven (expression of genes) ability of trees to adapt to stressful environmental conditions

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TESTING PARAMETERS ON BASIS OF EARLYWOOD VESSELS FOR SIGNAL QUALITY AND APPLICABILITY

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Keywords: *Quercus*, ring-porous, ROXAS, dendroecology

Measurements of wood anatomical features (vessel size, vessel density, etc.) have been used to obtain valuable ecological information in recent years. In this study we applied the software ROXAS (Fonti et al. 2009) to analyse the earlywood vessel dimensions of 16 trees of *Quercus petraea* on two different sites for 110 years. Chronologies of 15 distinct parameters on basis of earlywood vessels were built and tested for their signal strength, representativeness, and applicability.

The EPS was used as a criterion to assess signal strength and quality of the different chronologies. Twelve parameters showed sufficient quality. The correlation between the two cores of the same tree indicated representativeness of only a few parameters (i.a. total vessel area in % of ring area, vessel density). Applying a principal component analysis revealed a high correspondence among some of the parameters (i.e. maximum 3, 5 or 25% vessels) and the necessity of splitting parameters because of intermixed signals (e.g. Mean Vessel Area, MVA of the first row of vessels, MVA of remaining vessels). Similar results were obtained calculating the inter-correlation between the parameters.

A range of parameters can be obtained from earlywood vessels, but only a few meet the requirements of a dendroecological analysis. Important is the splitting of the earlywood vessels into vessels of the first row and the following earlywood vessels (García-González & Fonti, 2008), especially for parameters like mean vessel area and total vessel area. Otherwise an intermixed signal due to the different time span of vessel formation is analysed. The remaining parameters enable deeper understanding of ecological adaptation strategies on different sites. In conclusion, we recommend testing desired parameters for each study ahead.

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UPDATING THE MILLENNIAL-LONG OAK TREE-RING COMPOSITE CHRONOLOGY FROM THE CZECH REPUBLIC

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Keywords: oak, tree-ring chronology, Czech Republic

Over the past decades, we developed a continuous tree-ring chronology that includes material from nearly 2000 archaeological, historical and subfossil oaks. This compilation, representing most of the Czech Republic and covering almost the entire Late Holocene, was, however, characterised by low replication during the past two centuries. Here, we present a modern update of the millennial-long Czech composite record, consisting of disc and core samples from 1036 oaks (475 from Bohemia and 561 samples from Moravia/Silesia), which span the period 1750-2012 AD. All modern wood was randomly sampled at numerous sawmills, lumberyards and living trees from the same regions where the historical data derived. This sampling strategy was chosen so that the artificial signal-degradation was as low as it is for the historical subset. Although our study implies a significant improvement of the Czech oak chronology, a problem with lower replication still remains for the first half of the 19th Century. Therefore, next steps will focus on the collection of data from this period. The resulting very strong chronology will be used for analyses of climatic extremes in the past and for reconstructions of drought periods in the last millennium.

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SPATIAL AND TEMPORAL CLIMATE SIGNAL VARIATIONS IN THE TATRA

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Keywords: dendroclimatology, calibration, elevation, *Larix decidua*, Eastern Europe

Understanding past climate variations is crucial for the assessment of the peculiarity of recent warming. Only few millennial temperature reconstructions, mainly from northern Scandinavia and the Alps, have been developed for the European continent (e.g. Esper et al., 2012; Büntgen et al., 2011). In eastern Europe dendroclimatological studies extending to medieval times are restricted to a single record, consisting of tree-ring width (TRW) data from historic timbers and living individuals of *Larix decidua* Mill. (Büntgen et al., 2012). Since the provenance of the historical material could not clearly be identified, additional calibration trials, considering TRW data from high- and low-elevation larch sites in the Tatra Mountains area, have been completed. Variations in climate-growth response as a function of altitude are a well-known feature in alpine settings (Hartl-Meier et al., 2014) and also reported for various species in the Tatra Mountains (Büntgen et al., 2007).

Here we analyse the differences of site-specific climate signals of *Larix decidua* L. emphasising altitudinal and temporal aspects. Recently sampled material was added to existing chronologies, spanning the periods from 1634-2012 and 1657-2012, in low- and high-elevation sites respectively. TRW data were calibrated against temperature, precipitation and a drought index (scPDSI) over the extended 1901- 2009 period. The high-elevation sites confirm a robust early summer temperature signal (r_{MJJ}=0.56, p<0.001) (Büntgen et al., 2012, 2007). Tree growth at lower elevations tends to be controlled by a mixed external forcing; March temperatures ($r_{1955\text{-}2009}$=0.32, p<0.01), May-July precipitation ($r_{1901\text{-}2009}$=0.20, p<0.05) and March-July scPDSI ($r_{1901\text{-}2009}$=0.21, p<0.05) reveal significant positive coherence. However, none of these climate-growth relationships remain stable throughout the 20th Century. Our results thereby demonstrate that the inclusion of low-elevation TRW data in a millennial scale reconstruction complicates the calibrational process and is potentially biasing such long-term records.

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A 375 YEAR LONG CLIMATE RECORD IN JUNIPER TREES, SONORA PASS, CALIFORNIA

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Keywords: junipers, $\delta^{13}C$, $\delta^{18}O$, Sonora Pass, PDO

In the south-western USA the western juniper tree species *J. Occidentalis* has been investigated sparingly over the years with regard to use as a climate proxy. The aim of this project is to add to and update current western juniper ring-width chronologies, as well as comparing and cross-dating with previous studies to consider the reliability of the results. In addition, $\delta^{13}C$ and $\delta^{18}O$ isotopic ratios are analysed and correlated with climate trends.

Samples were taken from nine individual juniper trees at Sonora Pass in California using a 10mm diameter increment borer, with a total of eight cores suitable for analysis. All cores were taken within 2534m and 2709m elevation. From this, a ring-width chronology was compiled using TSAP-Win. The finalised chronology (SON2011) was then cross-dated with an already existing chronology (Miles and Worthington, 1998) with excellent results, supporting the validity of SON2011.

Ring-widths for SON2011 correlated well with precipitation (0.50) on a 10-year average, indicating longer term responses to water source; higher precipitation over 10-20 years links to increased tree growth over the same period – this longer term trend may be due to the root system of western junipers which can extend into the ground up to five times the height of the tree itself. Therefore the decadal trend may relate to water table fluctuations.

The annual $\delta^{13}C$ and $\delta^{18}O$ records from SON2011 were combined from three individual trees, over 1877AD - 2011AD. These chronologies were then compared with local records from the online resource KNMI Climate. $\delta^{18}O$, while showing little correlation with annual changes, was found to have an excellent inverse correlation with the Pacific Decadal Oscillation (PDO) index on a ten-year average (-0.58). With a positive PDO value precipitation in the area normally increases. The inverse relation to these changes seen in SON2011 $\delta^{18}O$ continues to be investigated.

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CLIMATIC CONVERGENCE? RECENT SYNCHRONICITY AMONG TREE-RING RECORDS ACROSS MONGOLIA

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Keywords: coherence, hydroclimate, Mongolia, regions, tree-ring network

Mongolia has experienced a significant range of hydroclimatic conditions over the past three centuries that vary in severity, duration, and spatial extent. Little is understood about the atmospheric drivers behind extreme hydroclimatic events in the past, nor the climatology of Mongolia in general. However, a network analysis of 20 tree-ring records describes spatial characteristics of historical moisture variability. central Mongolia is defined by four hydroclimatic regions during the 19th and 20th Centuries. These regions are generally similar in terms of moisture variability, but also characterised by periods of distinct hydroclimatic differences. In particular, when considering the period 1717-1996, the moisture variability of the Khangaii Mountain region (central Mongolia), and eastern Mongolia are generally out-of-phase. Interestingly, these regions gradually become in-phase starting around the turn of the 20th Century. The convergence occurs on annual ($r=-0.105$ ($p>0.05$) from 1717-1749; $r=0.443$ ($p<0.05$) from 1950-1996) and multidecadal time scales. Additionally, the two regions share strong common spectral power equivalent to time scales of ~25-years in the most recent century. Gridded self-calibrated PDSI data are positively correlated across the study region during the mid-to-late 20th Century as well, and therefore corroborate spatial synchronicity across the network of tree-ring data during this time. The recent hydroclimatic convergence, which is also evident across larger spatial scales in central Asia (Fang et al., (2010), Seim et al., (in prep)), could provide invaluable information for understanding regional resource availability.

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DENDROGEOMOPHOLOGICAL STUDY ON SNOW AVALANCHE IN TATRA MOUNTAINS

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Keywords: snow avalanche, Tatras, dendrogeomorphology

Snow avalanches are the major natural hazard influencing natural environment, touristic infrastructure and also endangering humane life in the Tatras. Activity of snow avalanches affects landscape, especially forest landscape, by controlling the course of timberline. Avalanches are the main geomorphic processes limiting warming-related upslope advance of the subalpine forest. The aim of this study was to: i) identify and analyse the main areas influenced by avalanches, and ii) reconstruct the spatiotemporal dynamic of the process in Biały Żleb gully as a case study. The standard dendrogeomorphological and GIS techniques were used to date and assess the range of the events. A detailed map of avalanche catchment was prepared based on the records of past events, historical maps, aerial photos and LIDAR digital terrain model. More than 600 of the injured and decapitated trees growing along the avalanche paths were sampled and dated. All existing historical maps and aerial photos spanning from 1938 to 2012 were investigated, revealing the relatively stable position of the timberline. The results of tree-ring analyses were coupled with GIS data to bring additional information about the spatiotemporal dynamic of events. The result of tree-ring analyses complemented this data and allowed us to extend the event chronology by up to 200 years.

Ackowledgements
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CLIMATE SIGNAL AND POTENTIAL OF BOSNIAN PINE (*PINUS HELDREICHII* CHRIST) FOR CLIMATE RECONSTRUCTION IN CENTRAL W BALKAN REGION

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Keywords: long chronologies, Bosnia and Herzegovina, temperature, precipitation

Bosnian pine (*Pinus heldreichii* Christ) - PIHE, is a species native to mountainous areas of the Balkans and southern Italy. PIHE is a tree species of the upper tree line in the Dinaric mountains and as such a promising source of valuable climate information. Due to its longevity it might have a good potential for long climate reconstructions based solely on living trees. The aim of our study was to investigate potential of PIHE: (1) for construction of long PIHE chronologies for the region of the central W Balkan, and (2) for long climate reconstructions based mostly on cores from living trees.

Preliminary PIHE chronology is 437-years (1573-2009) long and has a sufficient sample depth for EPS>0.85 from 1659 onwards. Comparison with climate data show specific response of PIHE to climate – trees respond positively to above average temperature in March (Mt) and negatively to above average temperature in June and July (JJt). We found weak positive response to June and July precipitation (JJp). This is somehow expected since precipitation is abundant along the Dinaric mountain ridge and are not factor in minima. Running window statistics reveal a significant temporal change in the identified signals – JJt and JJp signals were significant before 1965 and Mt after 1965; both temperature and precipitation loose signal after 1965.

Although already quite long, PIHE chronology can be extended by adding additional old trees from the studied region. Climate signal in tree-rings is somehow specific compared to other trees species in the region (e.g. *Pinus nigra*). JJt and JJp seems to play an important role in the formation of tree-rings (see also Seim et al. 2012), however a clear positive March temperature signal in PIHE tree-rings after 1965 and almost complete disappearance of the JJt and JJp signal after 1965 deserves attention as well. The reasons for that are yet to be investigated.

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A STORY OF THE SECONDARY GROWTH OF DECIDUOUS SHRUB

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Keywords: *Betula nana*, early summer, temperature, precipitation, radial growth

The recent climate change is believed to drive an obvious terrestrial vegetation switch in the high latitude region of the Northern Hemisphere (ACIA 2004). Nevertheless, in the northeastern Siberian tundra the change of the local abiotic influence, especially climate, and its effect on the deciduous shrub species is still largely unknown. In this study we used dendrochronological methods to fill this gap. The species we focused on is the dwarf shrub *Betula nana*, the dominant deciduous shrub species in this region. The results indicated: (1) the light stress is likely the most vital abiotic factor during the early life stage of *Betula nana* shrubs; (2) summer temperature (second half of June to late July) was the most important climatic factor that influenced *Betula nana* growth in the eastern Siberian tundra; and, (3) the one-year time lag between the previous year's summer precipitation (mainly June) and its effect on the radial growth of *Betula nana* was largely related to the soil nutrient availability of the growing season before the ring-growth year. It further implies that the temperature and precipitation in early summer largely determines the radial growth of *Betula nana*.

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PRELIMINARY RESULTS OF XYLEM HYDRAULIC ADJUSTMENT OF SESSILE OAK AT ITS SOUTHERN DISTRIBUTION LIMITS

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Keywords: *Quercus petraea,* forest dieback, quantitative wood anatomy, drought, rear edges

Increasing forest dieback during recent decades has been largely documented in all continents by different authors (Allen et al., 2010). Climate change and especially drought impacts seem to play a determinant role on the recent expansion of tree death across the globe. In such conditions, trees need to adapt their physiology in order to counteract drought effects that could lead to tree death (e.g., by xylem embolism; McDowell, 2011). The characterisation of the plants' responses to environmental variations related to climate change is essential to predict their morphological and physiological adaptation strategy, which will determine their survival capacity. Among the tree features susceptible to climate change, waterconducting cells on tree-rings may encode valuable information related to hydrological conditions during the growing season (Fonti et al., 2010). We examine how sessile oak (*Quercus petraea*) modifies its xylem traits as a response to changes in climate variability during the last half century. Samples were taken with increment borers from five marginal sessile oak sites at the rear edges of the species distribution limits (Spain, Italy, Slovenia, Bulgaria and Romania) where climatic effects are supposed to be the most restrictive. The core surfaces from 10 trees per site were prepared using a sliding microtome. Samples were scanned and WinCell image analysis software was used to perform the quantitative wood anatomical measurements (QWA), mean vessel area (MVA), and theoretical xylem hydraulic conductivity (KH). We will show the first results on the relations of QWA in sessile oak trees and climate and how these responses vary across southern Europe during the last half century.

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JUNIPERUS PHOENICEA GROWING ON CLIFFS: DENDROCHRONOLOGY AND WIGGLE-MATCHING APPLIED TO THE OLDEST TREES IN FRANCE

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Keywords: *Juniperus phoenicea*, cliffs, wiggle matching, missing rings

In the French Mediterranean region, the tree populations growing on exposed calcareous cliffs benefit from inaccessibility and absence of fires, grazing and competition by more aggressive level-ground vegetation. In such habitats, trees are probably the oldest ones of the region. In this highly constrained environment trees have developed a variety of original adaptations. Among the species encountered, *Juniperus phoenicea* can obtain ages in excess of 1500 years thus providing very long tree-ring series. However, both false and partially missing rings are visible under the microscope to such an extent that uncertainty remains about the periodicity of ring formation thus making crossdating very difficult. Thus it was decided to apply the «wiggle-match dating» technique to check whether dendrochronological detection of tree-rings coincides with the age provided by ^{14}C dating. The technique was applied on 4 trees from cliffs of the Ardèche valley on which from 652 up to 1235 rings were counted. Results show that the difference between the number of counted tree-rings and ^{14}C dates is small. Consequently, the uncertainty of our counting is limited. The gap seems triggered by totally missing rings but their frequency seems rather low. Therefore it seems possible to cross-date the samples and build up a long chronology from this long-lived species.

HOW HIGH ONE CAN GO? THE TREE GROWTH ABOVE THE TIMBERLINE AT BABIA GORA MOUNTAIN (NORTHERN CARPATHIANS)

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Keywords: Norway spruce, Carpathians, timberline, spatial analyses, age structure

The research concerned an area located above the timberline at Babia Gora Mountain in the northern part of the Carpathian Arc. The studies were based on comparison of Norway spruce *Picea abies* L. Karst condition in three habitats: a) a patch of forest located just below the main mountain ridge, above the timberline; b) single trees growing on the clearing and mountain pine zone; and, c) spruce forest within the timberline ecoton. The aim of the study was to determine the condition of trees growing above the timberline as the function of location and history of particular habitats.

Standard dendrochronological techniques were used. We took and analysed samples from spruces growing at and above timberline: 52 samples from trees growing individually, 104 from an isolated patch of the forest and successively 68 and 66 trees from sites at the timberline on northern and southern slopes of the massif. Each tree was localised by high-resolution GPS. The analysis was based on the age structure of the sites, average tree-ring width of the trees, number of missing rings and sites' chronologies.

The analysis of age structure showed that the youngest are the solitary spruces (the majority of tress were aged 30 – 40 years), while the oldest trees were located within the timberline ecoton on the northern slopes (majority of trees in 130 – 140 age range, maximum age 296 years). The highest number of missing rings was observed in spruces growing in the patch of isolated forest (16 trees), and the lowest (recorded only for one tree) for that growing as a solitary tree on a clearing. Based on the spatial analysis (conducted using GIS tools) we concluded that within the patch of forest the conditions for growth of the trees are deteriorating with altitude, as evidenced by analysed average width of tree-rings. While the young, solitary trees and their good condition (low number of the missing tree-rings) probably prove the recovery of environmental conditions since the end of the 1970s.

A MILLENNIUM OF CHANGE: DENDROCHRONOLOGY IN SCOTLAND'S BUILT HERITAGE AND CULTURAL LANDSCAPES

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Keywords: dendrochronology, Scotland, heritage, buildings, landscape

This presentation reviews the dendrochronological evidence from Scottish historic buildings, archaeological sites and cultural landscapes, using tree-ring data which cover a 1000 year period, developed by several analysts over the last 40 years or so (e.g. Baillie 1977; Pilcher & Baillie 1980; Mills & Crone 2012; Crone & Mills 2013; Wilson et al 2012). This evidence records a millennium of enormous change in the timber supply and the woodland resource in Scotland. Prior to about AD 1450, native oak timber dominates the record, much of it long-lived material. From the mid 15th Century, at a time when the state recognises the degradation of the Scottish woodlands, there is an enormous shift in much of the country to imported oak timber, which persists until the 17th Century. At this time Norway, one of the key exporters, cuts off its oak supplies and imported pine becomes predominant thereafter in Scottish buildings, although its provenance shifts through time. The reasons for the late-medieval demise of native oak timber supplies are considered in the context of possible inadequacies in resource management in the face of a worsening climate.

However, recent work indicates a probable under-recognition of native timber in post-medieval Scottish buildings, which is being tackled by the development of more regional chronologies for oak, pine and other native species used in construction. Our oldest surviving woodlands, usually relict cultural landscapes, become key sampling sites for this purpose. The tree-ring evidence for the exploitation of the native Caledonian pinewoods is briefly considered, with historic native pine timber as yet relatively little explored compared to oak and now being investigated further under the Scottish Pine 'SCOT2K' Project, at the University of St Andrews, which has both climate reconstruction and cultural heritage objectives.

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Coralie Mills is a dendrochronologist and environmental archaeologist who lives and works in Scotland. Coralie grew up in Dorset in SW England, took a first degree in Environmental Plant Geography at Reading University followed by a Masters in Environmental Archaeology at Sheffield University, where she remained to undertake a PhD on the Dendrochronology of Exeter Cathedral & Environs, training within the English Heritage Dendrochronology Laboratory in Sheffield. Moving to Scotland in 1988, Coralie worked first for Historic Scotland's Central Excavation Unit as its environmental archaeologist then for AOC Archaeology Group, for many years as a director, before forming her own consultancy *Dendrochronicle* in 2009. Themes from her university training have continued through her Scottish work and publications, in particular on how tree-ring analysis and other complementary approaches can provide insight into the intertwined history of our native woodlands, our cultural wooded landscapes and our built heritage.

Coralie is now a Post-Doctoral Research Fellow at the University of St Andrews working (part-time) on the built heritage aspects of the NERC-funded SCOT2K native pine dendrochronology project, led by Dr Rob Wilson. SCOT2K aims to build a 2000 year native pine tree-ring record for Scotland, for multiple objectives including climate reconstruction and cultural heritage applications. In the rest of her time, Coralie continues her work within *Dendrochronicle* as an independent dendrochronologist and environmental archaeologist. Coralie's love of native woodland history is reflected in her voluntary role as Chair of the Native Woodlands Discussion Group, a society which encourages interest in native woods, their ecology, management and history, in Northern Britain. Coralie is also editor of the NWDG's annual Scottish Woodland History Conference proceedings. A strong advocate of social media in promoting public interest and participation, Coralie publishes the *Dendrochronicle* web-site and runs *Dendrochronicle* accounts on Facebook and Twitter.

HISTORIC TIMBER: AUGMENTING SCOTLAND'S NATIVE PINE CHRONOLOGIES

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Keywords: pine, dendrochronology, Scotland, historic, timber

Scotland's native pinewoods have a long history of use, thus historic pine timber has an important role in developing Scotland's pine chronologies. Within the Scottish Pine Project, the SCOT2K element (2013-2016) aims to establish a continuous native pine record for the last 2000 years for both climate reconstruction and cultural heritage objectives.

Historically, native pine was used extensively for construction, especially in areas within easy reach of the Caledonian pinewoods. These Highland areas relied less on imported timber which supplied many other parts of Scotland from the mid-15th Century. While use was mostly local, native pine was sometimes transported longer distances within Scotland, down rivers and around the coast. Such transported timber outside the Highlands could prove particularly important in obtaining medieval native pine for chronology building, in the period before imports became dominant. The potential for native pine to survive in early Scottish buildings outside the pine heartlands is being tested.

The main priority, however, is to analyse timbers from areas where natural pine dendrochronology records have been developed. This poster will focus on samples taken from Upper Speyside and other buildings in the Cairngorms area: sampled structures range from cruck-frame cottages to castles. Other parties have kindly loaned material to widen the range of sites covered, including project partner Anne Crone at AOC Archaeology.

The objective is to augment the native pine tree-ring record for periods where the natural living tree and sub-fossil record is thin or disturbed, often a consequence of past phases of exploitation. In upper Speyside, 18th Century disturbance is especially evident, when exploitation of Scotland's native pinewoods was intensifying.

Alongside orthodox ring-width cross-dating methods, the new Blue Intensity method is used to: (a) facilitate dating of historic pine timbers, and (b) allow the historic material to be used for dendroclimatic reconstruction.

COMPARISON OF CARBON CONTENT, $\delta^{13}C$ WHOLE WOOD AND LIGNIN METHOXYL GROUPS FROM SUB-FOSSIL *PINUS SYLVESTRIS* L. TREES IN NORTHERN SCANDINAVIA - A NEW CLMATE PROXY?

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Keywords: carbon content, carbon isotopes, lignin methoxyl groups, subfossil trees, whole wood

Stable carbon isotopes from tree-rings are used in dendroclimatological studies to reconstruct past temperature or precipitation variability (Loader et al., 2003; Battipaglia et al., 2008). It is assumed that whole wood and cellulose samples from recent and sub-fossil tree rings are isotopically invariable. Sub-fossil wood retained in boreal lakes is usually not in its primary textural condition due to microbial and fungal decay. For dendroclimatological studies, it would be beneficial to evaluate the influence of such degradation processes on stable carbon isotopes.

We sampled eight stem discs of *Pinus sylvestris* L. from three shallow lakes in northern Scandinavia, with different degrees of wood textural preservation, covering the period AD 1082-1453. Our main objectives are to evaluate: (1) the carbon content as a measure for degradation of the sub-fossil wood, and (2) to assess the reliability of sub-fossil $\delta^{13}C$ from whole wood and lignin methoxyl groups for dendroclimatological studies in northern Scandinavia.

The carbon content in whole wood, obtained from 1360 tree rings, ranges from 46%-54%, and the difference between $\delta^{13}C$ from whole wood and methoxyl groups is 2.12 ‰ (SD=0.87‰). We have visually identified two classes of wood texture in our sub-fossil samples considering the carbon content: well preserved wood (%C=49.5%; SD=1.1%) and degraded wood (%C=49.5%; SD=1.7%) While well-preserved segments of the inner part are characterised by constant $\delta^{13}C$ values ($\delta^{13}Cww$=-26.18‰; SD=0.89‰ and $\delta^{13}Cmg$=-24.06‰; SD=1.30‰), degraded outer parts of the stem discs are characterised by degraded $\delta^{13}C$ values ($\delta^{13}Cww$=-25.91‰; SD=1.17‰ and $\delta^{13}Cmg$=-23.88‰; SD=1.33‰).

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SURVEY OF THE WOOD FEATURES OF NORWAY SPRUCE (*PICEA ABIES)* RELATED TO THE ATMOSPHERIC POLLUTION AND FOG DEPOSITION

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Keywords: atmospheric pollution, fog, tracheids, cell width, cell lumen

Sub-alpine mountains of south-western Poland were exposed to high levels of atmospheric pollution in the decade 1980-1990. As a result of acid deposition, the majority of forest areas were damaged (Błaś et al., 2002). Previous dendrochronological analyses of remaining trees showed the reduction of the width of annual rings, especially in areas with frequent highly acidic orographic fog (Schweingruber, 2007). Therefore the aim of the research was to analyse the possible changes in wood anatomy related to the decrease of annual ring-width. We compared the wood structure of trees growing in: 1) polluted areas with high deposition of fog; 2) polluted areas without fog deposition; and, 3) unpolluted areas. The radial wood cores, extracted at breast height from fifteen trunks of Norway spruce, were used for the anatomical analyses. The width of each annual ring was measured as well as the width and the lumen of chosen tracheids from early- and latewood. Based on the measurements, the cell-wall thickness was calculated.

The most significant changes in the wood structure occurred in trees growing in polluted areas with intense fog deposition. There, the annual rings in years 1980-1990 were extremely narrow with only 5-16 cells in a radial row, whereas in unaffected rings of years 1950-1960, above 100 cells typically were present. Additionally, the thickness of the cell-wall of latewood tracheids decreased as well as the ratio of the tracheids width and lumen between earlywood and latewood. Interestingly, in trees coming from the polluted area devoid of fog deposition, the tracheids' parameters appeared to be similar to controlled trees (from unpolluted stands).

It is postulated that the high level of pollution mediated by the intense fog deposition affects the cambial activity, which in turn determines the processes of cell divisions and differentiation in developing secondary wood.

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A QUESTION OF TIME: EXTENSION OF THE EASTERN ALPINE CONIFER CHRONOLOGY BACK TO 10 071 B2K

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Keywords: chronology, *Pinus cembra*, *Larix decidua*, Alps, Holocene

The Eastern-Alpine Conifer Chronology (EACC) was established on the basis of samples from treeline or treeline-near sites mainly in the eastern Alps (Nicolussi et al., 2009). It has continuously covered the last ca. 9100 years up to the present day. However, there have been two additional but only radiocarbon-dated multi-centennial chronologies with similar environmental settings that drop into the 10th and 11th millennium b2k. Recently discovered and analysed samples from the site Schlatenkees in the Austrian Alps allows now the closing of the chronology gap around 9200 b2k and with that the extension of the EACC back to 10 071 b2k (8072 BC).

The first millennium of the extended EACC shows a distinct different tree-species composition related to the younger EACC section; it is dominated by larch (*Larix decidua*) samples (74%) whereas the following nine millennia are mainly covered by cembran pine (Pinus cembra, 81%). This suggests different (drier) climatic conditions in relation to the following millennia.

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INFLUENCE OF CLIMATIC AND TOPOGRAPHIC FACTORS ON DOWNY BIRCH TREE-RING VARIATIONS (NORWEGIAN LOW ARCTIC)

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Keywords: downy birch, tree-ring width, dendroclimatology, Low Arctic

The Arctic is very sensitive to contemporary climate changes. Shrubs' expansion and changes of the northern tree line are clearly visible in this area. The aim of this study is to determine how downy birch (*Betula pubescens*) reacts on these changes in different topoclimatic conditions. Four research sites located in the northern part of the Scandinavian Peninsula (Troms Region) were chosen for detailed research. We collected 100 samples in: glacial valley, plateau, sea coast and narrow ridge. The life span of collected samples ranged from 91 to 193 years. The constructed local chronologies are characterised by high inter-correlation (0.53-0.76), sensitivity (0.40-0.53) and EPS (0.80-0.95) values. Climatic data from Tromsø spanning 1925-2013 were used. The NAO Index were also analysed. The differences between sites were visible in the course of the chronologies and their climatic response. The growth of birch responds to summer temperatures (rJJA=0.30-0.43, rJun=0.28-0.40, rJul=0.25-0.33 rAug=0.24). Dendroclimatic analysis has also shown high values of cross-correlation function between tree-rings and seasonal NAO index (MJJ). The plateau site, which is exposed to macroclimatic conditions due to lack of orographic barriers, has shown the highest correlation with temperature. The sea coast site, located on the relatively stable slope, is characterised by the least pronounced extreme years. In the U-shaped glacial valley the influence of climate is weakened by a number of local factors. The lowest influence of climate was recorded in the ridge site- a result of mass movement disturbances. The observed responses are not time stable; weakening of the correlation values in recent decades is observed. The results show that topoclimatic conditions modified the dendroclimatic signal, however the common growth pattern was observed. This study demonstrates that *B. pubescens* can be used as an indicator for summer temperature in the Low Arctic over the last centuries.

THE DENDROCLIMATIC POTENTIAL OF SHRUBS FROM WESTERN PAMIR-ALAY (TAJIKISTAN)

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Keywords: central Asia, high mountains, shrubs, dendroclimatology

Tree-rings are an excellent proxy data source in the areas where meteorological records are incomplete or rare. Traditionally, dendrochronological research has been limited to the forest areas. In recent years, interest has increased in dendrochronological studies of shrubs and dwarf shrubs, especially in regions where trees are not a dominant life form, e.g. high mountains and the Arctic. The high mountain systems of central Asia are very sensitive to climate variations and reflect global changes. There are only a few dendroclimatological reconstructions from this area. The presented research was carried out in the Pamir-Alay Mountains (Tajikistan). This area remains a significant gap in dendroclimatic reconstructions of the last millennium climate. The samples were collected on the altitude between 2200-2800m a.s.l. Different shrub species (*Juniperus seravschanica, Ephedra equisetina*, *Rosa lutea*, *Cerasus nana* and *Spiraea* sp.) were evaluated in terms of their potential for dendroclimatic reconstructions. Developed tree-ring width chronologies and climatic data from Iskanderkul station were used in the calculations. The results showed that the greatest potential exists for *Juniperus seravschanica,* which was clearly the oldest, reaching 900 years. The growth of juniper responds to summer precipitation (r=0.40). Interesting results were also obtained for *Ephedra equisetina* (max. 63 years old). Climate-growth response analysis for this species showed that July temperature was the main climatic factor limiting its growth (r=0.45). The presented preliminary results provide grounds for the further investigation on the long-term climate reconstruction of summer temperature and precipitation in the Pamir-Alay.

EXPLORING BLUE INTENSITY - COMPARISON OF BLUE INTENSITY AND MXD DATA FROM ALPINE SPRUCE TREES

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Keywords: blue intensity, maximum density, *Picea abies*, Alps

Blue intensity (BI) / blue reflectance has been recognised as a proxy to aquire wood density of conifers but in an easier way as with classical radiodensitometric analyses (McCaroll et al. 2002). We explore the potential of BI analysis results by comparing it with maximum density data (MXD, Esper et al. 2007) established on parallel cores from living spruce (*Picea abies*) trees of high-elevated sites (c. 1900m a.s.l.) in the eastern Alps. The period 1804 to 2003 is covered by 6 to 21 series.

BI analyses of the samples were carried out after resin extraction, preparing the surfaces utilising a WSL microtome, filling the tracheid lumens with chalk, establishing high-resolution pictures by microscope photography and establishing BI data for earlywood as well as latewood by using the software LignoVision. δBI series were established by subtracting earlywood BI (BI_{ew}) from maximum BI (BI_{max}) data.

A comparison of the software tools LignoVision and CooRecorder based on the same sample photos showed no significant differences in the BI_{max} data. The usage of chalk results in a clear differentiation of the BI_{ew} from the corresponding BI_{max} values. MXD as well as δBI / BI data show nearly normal distributions and largely linear relationships. Comparisons of the MXD mean series with the BI_{max} / δBI chronologies reveal high similarities and correlation results; raw data chronologies (sample depth >5), r 0.89 (BI_{max}) and 0.91 (δBI), first differenced series 0.95 and 0.94 (n=200).

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DWARF SHRUBS AND GEOMORPHOLOGY - A REVIEW

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Keywords: Arctic, high mountains, dwarf shrubs, chronology, geomorphic processes

The aim of the study is to present a ring-based anaylsis of dwarf shrubs as a tool to investigate modern geomorphological processes in Arctic and Alpine environments. Climate change and the increase of temperature and precipitation in these areas are evident and are not only influencing shrub expansion and growth-ring variations but also the activity of geomorphic processes. Dwarf shrubs produce well defined and countable growth rings. The ability to build ring chronologies of dwarf shrubs allows a precise dating of these processes. The age of *Salix polaris* was the base for reconstructing debris flow events in the High Arctic (Owczarek et al. 2013). Additionally, clearly visible scars and reaction wood in micro-sections supported and supplemented the dating of ground movements. Wood anatomical techniques were applied by Gärtner-Roer et al. (2013) to periglacial investigations in the Alpine environment. The results showed clear differences between the vessel sizes in roots of shrubs growing on active and inactive rockglaciers and thus provide new information about the dynamics of mass movements above treeline. The germination age and time of colonisation of dwarf shrubs can be used in large-scale analysis. This information has allowed reconstruction of glaciofluvial changes in two partially glaciated basins in Spitsbergen during the last 100 years (Owczarek et al. 2014). The results presented are promising for further geomorphological studies, but this method should be used carefully due to a series of problems, such as missing rings and applying serial sectioning for each individual.

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CLIMATE DRIVERS OF *QUERCUS ROBUR* AND *QUERCUS PYRENAICA* RADIAL GROWTH ALONG A WATER AVAILABILITY GRADIENT IN NW SPAIN

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Keywords: radial growth, drought gradient, NAO index, *Quercus robur*, *Quercus pyrenaica*

Several studies concerning growth responses to local and large-scale climatic variation have been recently performed in oak species from north-western Spain Rozas et al. (2009), Rozas & García-González (2012), Rozas & Sampedro (2013), GonzálezGonzález et al. (2014). The present study specifically assesses the effects of local climate and North Atlantic Oscillation (NAO) on the radial growth of *Quercus robur* and the more drought-tolerant *Quercus pyrenaica*. The study areas are located along a drought gradient in NW Spain where both species co-exist.

Wood cores of both species were taken from three sites: Bermui (wettest), Labio (intermediate), and Moreiras (driest). Earlywood (EW), latewood (LW) and total tree-ring (TR) widths were used to explore growth patterns using principal component and correlation analyses. Tree-ring responses to climate were evaluated through bootstrapped correlations for the period 1964-2009. We used monthly gridded time series of temperature, precipitation, and NAO index.

LW and TR revealed similar patterns at Bermui and Labio for both species, which greatly differed from those observed at Moreiras. EW patterns were highly correlated within each site except at Bermui. Climate sensitivity was stronger for LW and TR than for EW, and notably similar between species. NAO, precipitation and minimum temperature greatly influenced radial growth. EW was enhanced by high minimum temperatures in February at Bermui, and by wet conditions the previous December at Labio. Positive NAO indices resulting in an absence of rain the previous November and January negatively influenced EW formation, mainly at Moreiras. LW was inversely related to the NAO of autumn at Moreiras and of the previous winter at Bermui, though positively for the previous and current August at Labio. The results suggest that climatic drivers controlled radial growth in a similar way in both *Q. robur* and *Q. pyrenaica*, being NAO-related precipitation in autumn and winter a key factor for both species. Nonetheless, climate influence varies locally across the gradient.

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ANNUALLY RESOLVED STABLE ISOTOPE CHRONOLOGIES FROM LATEGLACIAL CENTRAL EUROPEAN TREE RINGS

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Keywords: Younger Dryas, tree-ring width, oxygen and carbon isotopes, *Pinus sylvestris* L.

To date ice cores and varved lake sediments possibly provide the best available proxy records for the Lateglacial period. This includes the so-called Younger Dryas interval (ca.12.700 - 11.600 cal BP), representing an abrupt return to glacial-like conditions interrupting the transition to the warmer climate conditions of the Holocene. Lateglacial tree-ring chronologies are rare, however, and they are of the utmost importance for determining the ^{14}C calibration curve. They may also contain valuable information about past environmental conditions at annual resolution. As the existing Lateglacial tree-ring material is characterised by rather short segment lengths (mean tree age 140 years), tree-ring width may not be the best parameter for assessing climate anomalies. Carbon and oxygen isotope composition of tree-ring cellulose has proven potential for climate reconstruction. Besides correction of short juvenile trends, isotope data can be used with only minor adjustments to their means- and sample depths of 4-5 trees are normally enough for a significant expressed population signal.

We are investigating a floating 758-year (13153 –12395 cal BP) dendrochronological record of Lateglacial chronologies of Scots pine (*Pinus sylvestris* L.) from subfossil tree remnants of central Europe, namely from Barbiers River (Moyenne Durance, southern French Alps) and three Swiss (Dättnau, Landikon and Gänziloh) sites. We will present and discuss our tree-ring stable isotope records ($\delta^{13}C$ and $\delta^{18}O$) in comparison to lake sediment and ice core data records.

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PRONOUNCED HEIGHT AND RADIAL GROWTH DECLINE OF *PINUS SYLVESTRIS* AS A RESULT OF MASSIVE NEEDLE SHED

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Keywords: needle trace method, tree-ring widths, dendrochronology, Balkan Peninsula, forest fire

An unknown event in 1929 caused radial growth decline of *Pinus nigra* Arn. (PN) trees on one of the sampled site in Bosnia and Herzegovina (Poljanšek et al., 2012). Needle trace method (NTM), which retrospectively examines the needle shedding through the life-time of the studied trees (Kurkela and Jalkanen, 1990), revealed sudden loss of all needle age classes on PN trees in the growing season of 1929 (Poljanšek et al., 2013). In the affected stand, PN grows together with *P. sylvestris* L. (PS) trees. To determine if PS trees, too, were affected in the 1929 event, our research was extended to PS trees.

The sampled PS trees were up to 180 years old and 18m high. On average, there were 3.5 needle sets on the main stem, while average age of needles at the time of their shed was 2.9 years. Radial and height growth decline in all PS trees was similar to growth decline of PN trees in 1929, but needle shed pattern is not that clear. Data on needle shed in 1929 is not complete due to the damage in main stems. Nonetheless, results confirmed needle loss of all age classes in all trees but the tallest PS tree. Needle shed of the other PS trees is consistent with results of PN trees.

NTM evidenced the abrupt needle shed on two pine species in one growing season, which resulted in growth decline. Possible reasons for such a massive loss of needles could be defoliation by fungi, insects or destruction of crown by wildfire. With consideration that needles of all age classes were affected in two different pine species and on trees of various heights, wildfire and/or extreme heat spell/drought-related-events should also be addressed as the main reason for needle shed and consequential growth decline.

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DATING OF WOODEN CONSTRUCTION ELEMENTS REINFORCING THE PONÁVKA STREAM BANKS

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Keywords: dating, tree rings, oak, archaeological research

In 2012 and 2013 rescue archaeological research was conducted in the area of Koliště street in the centre of Brno before a shopping mall and administrative centre called Edison was built there. During the research, 509 dendrological samples in the forms of log discs or wedges were taken for anatomical and dendrochronological analysis. The aim of the dendrochronological research was to clarify the development of the Ponávka river bank reinforcements in the past. Out of the total number of samples, 77 were selected for the dendro-analysis; 16 of them could be reliably dated. They came from the period between the first half of the 15th Century and the first half of the 16th Century. The reasons for the low number of samples dated include an insufficient number of tree-rings as timber of small dimensions was used for bank reinforcements, and the high extent of timber degradation. The results of the anatomical analysis showed that predominantly oak was used for the main bearing timber constructions. The auxiliary constructions, boards and woven fillings, were made of fir and alder; there were also limited amounts of spruce, poplar, ash and lime. Due to the low durability of the material used for the woven fillings and other elements, we assume that it was often necessary to replace them. The broad range of woody species identified indicates that these species were included in the natural composition of the surrounding environment.

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THE FICTIONS OF DENDROCLIMATOLOGY

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Keywords: fiction, trust, dendroclimatology, sociology, uncertainty

In this presentation the concept of 'fiction' will be used to refer to the beliefs and practices that a dendroclimatologist pretends to trust despite her awareness of the uncertainties associated with them. The creation of a climatic reconstruction is permeated with uncertainties, and the dendroclimatologist acts 'as-if' these unknowns were favourably resolved, thus maintaining a state of positive expectations. In this talk I will show different examples of these fictions and I will outline their basis. The dendroclimatologist knows full well that these uncertainties remain, but accepts them as an irreducible aspect of the climatic reconstruction on the basis of what her community of peers believes to be reasonable. Ultimately, the possibility of creating a tree-ring based climatic reconstruction relies on these fictions and only becomes possible because the dendroclimatologists act 'as-if' they were possible. The results presented in this talk are part of a doctoral investigation carried out by a sociologist of science interested in understanding the work of dendroclimatologists. In particular, the data have been generated over a period of two years of study of the members of the Tree-ring Laboratory at St. Andrews University (Scotland).
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JUNE-JULY SUMMER TEMPERATURE RECONSTRUCTION IN CENTRAL SCANDINAVIA OVER THE PAST TWO MILLENNIA INFERRED FROM NORWEGIAN SPRUCE TREE-RING WIDTH CHRONOLOGY

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Keywords: tree-ring, *Picea abeas* L. Karst, summer temperatures, central Scandinavia

This study presents the first two millennia-long Norway spruce (*Picea Abeas* L. Karst) tree-ring width chronology from Fennoscandia. The chronology was built from living and subfossil (lake) wood from the province of Jämtland, in the central Scandinavian Mountains and covers the period from BCE 114 to CE 2012. During two periods (CE 323 to 393 and CE 889 to 913), the sample replication is low and therefore the reliability is rather unsure. The expressed population signal is above the threshold (EPS~0,85) in most segments except the periods with few samples. Still more subfossil wood samples are needed to further improve the present chronology.

Previous studies from this region have focused on Scots pine (*Pinus sylvestris*), and by adding the information of an additional tree species, we hope to learn more about regional climate variability in the last 2000 years.

A signal-free age-dependent spline standardisation technique was used in order to enhance the climatic signal and remove non-climatic variability due to obvious stand dynamics characteristics of a closed-canopy forest. The standardised chronology was used to reconstruct June-July mean summer temperature, where the reconstruction model accounts for 45% of the total variance in the instrumental temperature record over the 1911-2008 period. Due to the short time-spans of the existing spruce chronologies in Scandinavia, general comparisons were made with three millennia-long pine tree-ring chronologies (Jämtland, Torneträsk and Finland) which have previously been used to reconstruct summer temperatures.

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SPECIES-SPECIFIC AND SITE-SPECIFIC RESPONSE OF OAK (*QUERCUS* SPP.) TO THE CLIMATE IN CHANGING CLIMATE CONDITIONS

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Keywords: central Europe, crown condition, precipitation, oak, temperature, tree-rings

The significance of species and site variability of oak response to climate conditions is growing with the changing climate. The changes in the dynamics of precipitation distribution in central Europe may be considerably reflected both in the radial growth and the health condition of the trees. How will the growth response to the climate differ in different oak species on the same or nearby sites? To what extent are these responses affected by the site conditions? Answers were sought in the site- and species-variable territory of the Czech Republic, exploring *Quercus robur*, *Quercus petraea*, *Quercus polycarpa* and *Quercus dalechampii*. Twenty samples were taken at each stand using a Pressler borer. PAST4, ARSTAN and DendroClim2002 were used for analyses. Negative pointer years were also examined. The mean tree-ring series of individual sites manifest a high resemblance. The years with low increments were confirmed by the analysis of negative pointer years. They can be explained by low amounts of precipitation and the relative saturation of soil by water (AWR). The significant correlations between the mean air temperature, global radiation and tree-ring width are predominantly negative. The significant correlations between precipitation, AWR and tree-ring width are mainly positive. The amount of water available in the soil is therefore clearly the main climate-dependent limiting factor of radial growth in this territory. The mean monthly temperatures increased and the amount of spring precipitation decreased after 1990 in comparison to the period of 1961–1990. In consequence, the significance of available spring water in the soil rose after 1990. The comparison of the four sites shows that the differences in site conditions proved to be of more importance than differences between oak species.

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SPATIOTEMPORAL RECONSTRUCTION OF SCOTTISH SUMMER TEMPERATURES

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Keywords: dendroclimatology, temperature, spatial reconstruction, Scots pine, Scotland

A detailed understanding of past temporal patterns and spatial expression of temperature variations is important to place recent anthropogenic climate change into a longer-term context. In order to fill the current gap in our understanding of northwest European climate dynamics and thus provide the context necessary to assess likely future changes of climate in this climatically important region, the limited spatial and temporal coverage of instrumental data must be extended using proxy data. Tree-rings provide one of the best proxy data sources for such an exercise. Until recently, the development of dendrochronological records in Scotland for climatological purposes has been limited. To help develop insight into the patterns of temperature variability in this region, multiple tree-ring parameters including ring-width (RW), maximum latewood density (MXD) and blue intensity (BI) from a network of 42 living Scots pine (*Pinus sylvestris* L.) sites distributed throughout the Scottish Highlands were utilised to reconstruct mean summer temperature with a grid resolution of 0.5°. Due to the considerable anthropogenic disturbance from logging events at some Scottish sites, RW data were assessed and corrected for disturbance-related pulse releases using Combined Curve and Trend Intervention Detection prior to their application in reconstruction development. In addition to the use of individual parameter site chronologies, corrected RW series were also combined with BI data to develop filtered high-frequency-BI / low-frequency-RW composite band-pass series. The results identified the timing, scale and duration of warmer and colder periods in the recent past, revealing the spatial patterns of temperature variability in this region over the past few centuries.

SHOULD WE HAVE THE BLUES? BLUE INTENSITY EXPERIMENTS FROM SCOTLAND

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Keywords: blue intensity, maximum latewood density, Scots pine, image analysis, Scotland

Blue intensity (BI) has the potential to provide information on past summer temperatures of a similar quality to maximum latewood density (MXD), but at a substantially reduced cost. We present BI data generated using a new, low cost BI measurement system: CooRecorder. Focusing on four sites in the Scottish Highlands from a wider network of 42 sites developed for the Scottish Pine Project, BI and MXD data from Scots pine *(Pinus sylvestris)* were used to facilitate a direct comparison between these parameters. A series of experiments aimed at identifying and addressing the limitations of BI suggest that while some potential limitations exist, these can be minimised by adhering to appropriate BI generation protocols. The comparison of BI results produced using different resin-extraction methods (acetone vs. ethanol) and measurement systems (CooRecorder vs. WinDendro) indicates that comparable results can be achieved. A comparison of BI with MXD, measured from the same trees, with instrumental climate data revealed that overall, BI performs as well, if not better than MXD, in reconstructing past summer temperatures. Although reconstructions developed even from species exhibiting a distinct heartwood-sapwood discolouration may seem to be robust, unlike MXD, such BI chronologies can be sensitive to the choice of detrending method, which may mask differences in the relative trends of non-detrended BI and MXD data. This suggests that the heartwood-sapwood colour difference is not entirely removed using either acetone or ethanol chemical treatment, which may ultimately pose a potential limitation for extracting centennial and longer timescale information**.** Additional research is required in order to develop new methods to overcome this potential limitation. However, the ease with which BI data can be produced should help justify and recognise the role of this parameter as a potential alternative to MXD, particularly when MXD generation may be impractical or unfeasible for financial or other reasons.

TOWARDS A 1150-YEAR TREE RING STABLE CARBON AND OXYGEN ISOTOPE CHRONOLOGY FOR THE CENTRAL SCANDINAVIAN MOUNTAINS

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Keywords: tree-rings, stable isotopes, climate change, central Scandinavian Mountains

Stable isotopes from tree-rings provide a valuable complement to the more often measured parameters of tree-ring width and density, as they can provide information about additional climate parameters such as sunshine/cloudiness and vapour pressure which are mechanistically related to isotope fractionation in trees (Seftigen et al., 2011; Young et al., 2012). In Fennoscandia, where the growth-based proxies have extensively been utilised to reconstruct historical temperature variability (Linderholm et al. 2010), the development of complementary stable isotope data for this region will enable a multi-parameter approach with which to explore the climate of the past.

In this study, we present the first 500 years of an 1150-year long stable carbon and oxygen isotope chronology (currently under construction) from the central Scandinavian Mountains. The objective is to analyse climate variability during the past millennia with a multi-proxy approach, allowing us to investigate the strength and character of several climatic parameters through time. Samples from Scots pine (*Pinus sylvestris* L.) were collected, and a total of 73 trees combined to develop an annually resolved stable isotope chronology spanning the period 862-2012 CE with a mean annual replication of 9 trees. Preliminary results suggest that cellulose $\delta^{13}C$ ratios at the site are directly controlled by summer sunshine (R^2=0.57; calibration period of instrumental data 1983-2006 CE), and that the temperature signal captured by carbon ratios, although highly correlated with sunshine (R^2=0.53; 1983-2008 CE), is less directly linked to $\delta^{13}C$. Cellulose $\delta^{18}O$ values show weaker associations with instrumental data, but initial analyses indicate that summer cloudiness and precipitation are important but less temporally stable controlling factors. The non-stationary relationship between $\delta^{18}O$ and climatic parameters, as well as the variations in the coupling of sunshine/temperature, may together provide a tool with which to explore shifts in the large-scale atmospheric circulation systems influencing the summer weather of central Scandinavian Mountains (e.g. Seftigen et al., 2011).

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DRIVERS OF CONTRASTING GROWTH RESPONSE OF SCOTS PINE TO CLIMATE ALONG AN ELEVATIONAL GRADIENT NEAR THE SPECIES' SOUTHERN LIMIT

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Keywords: climatic change, *Pinus sylvestris* elevation, drought, dendroecology, tree size, forest management

Drought-induced decline is driven by abiotic stressors such as water shortage, tree features (size, age), and the biotic neighbourhood around each tree, i.e. the competition intensity each tree experiences. The southernmost Scots pine (*Pinus sylvestris*) forests are among the most vulnerable areas to drought-induced growth decline in response to ongoing climate warming (Sánchez-Salguero et al., 2012). At the research sites, the current degree of competition is an outcome of the interaction among past historical forest management which decreased in the past decades (Linares et al., 2010) and long-term trends in climate-related growth stressors. Here, we compare the growth trends and climate-growth relationships of Scots pine stands located in three different elevations (1400, 1650 and 1900m a.s.l.) in central Spain, near the southernmost distribution limit of the species in Eurasia. First, we analysed long-term trends of climate variables (temperature, precipitation and a drought index). Then we investigated the influence of changing climatic factors along the elevation gradients, tree-to-tree competition and tree features (size, age) on radial growth at the stand and tree levels. In the study area there has been a temperature rise and a decrease in precipitation during the late 20th Century (since the 1980s) which led to increasing drought stress during the growing period (May to October). As a result, *P. sylvestris* showed growth decreases with increasing competition, particularly in the warmer low-elevation stand. Growth at the lowermost stands was mainly constrained by warming-related drought stress in spring and summer. In contrast, growth at the mid- and high-elevation sites responded positively to winter temperature. Our findings suggest that the growth of rear-edge low-elevation Scots pine populations is particularly sensitive to water availability during the growing season, while previous-winter temperature influences on growth are more important at higher elevation. However, our results also evidence that past forest management practices have a strong effect on current stand structure, modulating tree growth responses to climatic factors (Camarero et al., 2011). The increasing competition and growth reduction of drought-prone low-

elevation Scots pine populations will threaten their future persistence near the southernmost species limit under the forecasted warmer and drier conditions. Contrastingly, warmer winter conditions could enhance growth of high-elevation populations.

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ISOTOPIC ECOHYDROLOGY: INSIGHTS INTO WATER PARTITIONING AND AVAILABILITY TO RIPARIAN FORESTS ALONG THE RHÔNE RIVER, FRANCE

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Keywords: riparian, water partitioning, $\delta^{18}O$, tree-rings, climate

The hydrological partitioning within riparian zones is of key significance in determining overlying forest health, survival and composition. The details of water presence, movement and retention within floodplains remain poorly resolved, particularly in relation to the moisture availability to individual species in the forest stand (Alstad et al. 2008). Such short-comings enhance the vulnerability of floodplain forests to future climatic, hydrological and anthropogenic changes. These uncertainties preclude the development of detailed and robust theories of forest response, both at the individual and stand level, and regional hydrologic cycling with implications for the scientific and socio-economic spheres (Lindner et al. 2010).

This project aims to elucidate the ecohydrological processes occurring within floodplains along the Rhône River, France, through stable oxygen isotope analyses of streamflow, groundwater, soil water, tree-ring cellulose and annual growth measurements. We are learning that site-specific hydrology and floodplain characteristics act in conjunction with the individual species morphology and physiology to affect the water availability at the root zone, its accessibility to tree roots, uptake and preservation of the signature recorded within the growth-ring. We have utilised two riparian species: *Fraxinus excelsior* and *Populus nigra,* which have contrasting rooting characteristics and therefore act as integrators of distinct hydrological reservoirs within the floodplain (Singer, et al. 2013). Our work has demonstrated that substrate composition and topography (soil thickness and gravel elevation) are significant parameters in determining water availability whilst acting to impede the rooting extent of *F. excelsior*, whereas *P. nigra* accesses water from both phreatic and vadose zones. These characteristics modulate the impacts from fluctuations in climate and hydrology. The isotopic signals of a recent channel flow restoration (2000) were also discerned. These insights into the hydrological and topographic factors controlling forest response will generate more informative predictions of climatic and anthropogenic modifications on forest health and survival.

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A 1200-YEAR DROUGHT RECONSTRUCTION FOR THE EUROPEAN ALPINE REGION BASED ON TREE-RING CARBON ISOTOPES

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Keywords: carbon isotopes, drought, Medieval Climate Anomaly

Precipitation and drought reconstructions back to Medieval times are still rare for many regions, but would be of great importance for a better understanding of past climate variability. We showed that the carbon isotope ratio of tree-rings from Alpine larch (*Larix decidua*) is strongly correlated with July/August drought during the calibration period 1901-2004 (r^2=0.58; Kress et al. 2014). Split-period verification of the calibration indicated a reliable and stable relationship with high predictive skill. Based on historic material from buildings of the Lötschental and Simplon regions (Switzerland), combined with the chronology from the living trees, we constructed a 1200-year drought-sensitive, well-replicated carbon isotope chronology. Before merging, the individual series were standardised to avoid the production of artificial long-term trends, but variations up to the segment length of 350 to 400 years were retained. Our reconstruction revealed pronounced alterations of wet and dry periods, including a long absence of wet summers during the Little Ice Age (i.e. dry conditions) and relatively wet summers during the medieval climate anomaly (MCA). The warm-wet MCA contrasts strongly with the climate of the drought-prone warm phase of the recent decades, which indicates different forcing mechanism for these two warm periods. The results also point to beneficial conditions for agricultural-based societies during the MCA in this region.

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TEMPERATURE SIGNALS IN HEMISPHERIC TREE-RING DENSITY DATA

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Keywords: MXD, Northern Hemisphere, multi-centennial, reconstruction, volcanoes

While numerous reconstructions of hemispheric temperature variability over the last millennia have been published within the last two decades, their ability to robustly sample the full frequency spectrum of variability has been debated. Tree-ring width (TRW), the substantial proxy in all high-resolution records (Shi et al. 2013), is prone to memory effects that likely bias the high-frequency signal (Franke et al. 2012). Maximum latewood density (MXD) data store less previous-year information, expressed in lower auto-correlation and time-invariant responses to extreme events like volcanic induced cooling (Esper et al. 2013). Additionally, long regional MXD chronologies may preserve climatic trends on centennial to millennial time-scales (Esper et al. 2012). In hemispheric-scale reconstructions, however, MXD data have not been used as significant contributions to proxy networks.

Here we assess the potential of this temperature proxy on a larger scale by analysing the common signal in 15 multi-centennial MXD chronologies distributed over the Northern Hemisphere (NH). When combined to yield continental averages, coherent growth trends are revealed over the past 600 years. A weighted composite of the regional MXD records explains significant amounts of extra-tropical land temperature variation and June-August means are reconstructed back to 600 CE. The MXD reconstruction places the characteristic transition between warmer medieval temperatures and a cooler Little Ice Age into the late 15th Century. This is somewhat delayed compared to other TRW-based records and might be related to faster recovery from negative extremes caused by large volcanic eruptions.

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DENDROCHRONOLOGICAL ANALYSES AT A NEAR-NATURAL HIMALAYAN TREELINE: DETECTING THE RESPONSE TO CLIMATE CHANGE

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Keywords: treeline ecotone, interacting environmental factors, landscape scale, *Abies spectabilis*, *Betula utilis*

While at global scale low-temperature plant growth limitation determines the position of natural alpine treelines, factors and mechanisms influencing treeline position and dynamics at smaller scales are not well understood. The knowledge about interacting landscape scale and local scale abiotic and biotic factors and processes influencing the treeline and its response to climate is still deficient. Moreover, effects of natural processes often mix up with impacts of land use. In consequence, complex research approaches at smaller scales are needed.

The main objective of the project “Sensitivity and Response of the Treeline Ecotone in Rolwaling Himal, Nepal, to Climate Warming” (TREELINE) is to detect hitherto poorly understood driving forces for spatially differentiated treeline dynamics under climate warming. We implement an integrated landscape approach focusing on topography, climate, soils, and vegetation to study a near-natural treeline ecotone in Rolwaling, Nepal. Vegetation and dendrochronological analyses include the sampling of randomly selected forest stands along elevational transects (3100 - 4200m a.s.l.) across the treeline ecotone with regard to growth rates, age structures, tree physiognomy, stand densities, and tree recruitment. Moreover, we analyse site conditions and mechanisms (geomorphic controls, soil physical and chemical conditions, plant interactions) in order to detect how the region-wide climate warming input and finer-scale modulators interact to govern spatially non-uniform treeline response patterns.

Within this framework we collect tree-ring data from sample trees of all diametre and height classes in order to detect changes in age structures of stands and in radial increment of trees, focusing on *Abies spectabilis* and *Betula utilis*. For correlations of annual radial increment with climatic variations we use data from meteorological stations and from climate modelling.

We present first results of treeline response patterns. Consecutive analyses including more detailed environmental datasets will specify these preliminary results and enable further modelling approaches.

INCREASED TREE-RING GROWTH CLOSE TO ERUPTIVE FISSURES PRIOR TO VOLCANIC FLANK ERUPTIONS ON MOUNT ETNA (SICILY, ITALY)

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Keywords: tree-rings, volcanic flank eruptions, Mount Etna

Active volcanoes from all around the world are being investigated and studied for their effects on the environment, on global climate and on human life, by a variety of different disciplines. Increasing population and vulnerability of areas close to active volcanoes result in higher risks and hazard potential. Early indicators of volcanic activity could help in risk management and are urgently needed, but eruptions remain largely unpredictable. Here we show that tree growth in volcanic areas is not explainable using climate data only; tree-ring width is influenced by volcanic factors as well. Furthermore, we demonstrate to what extent tree growth prior to eruptions provides information usable to indicate time and location of flank eruptions. We analised 240 cores sampled at 8 sites along two eruptive fissures measuring tree-ring width. Cores revealed different growth rates at the different sites prior to the eruption. Higher growth rates of trees along the two eruptive fissures before the ensuing eruption were found. These results are in agreement with an increased vegetational index observed along one of the two eruptive fissures derived from satellite imagery (Houlié et al., 2006).

Further investigation on a larger number of trees and sample sites, including chemical analysis of the wood, combined with remote sensing techniques showing vegetational growth needs to be carried out. A better understanding of how trees grow in volcanically-active regions and on the influence of volcanic activity on tree physiological processes prior to eruptions needs to be gained because of its importance in early hazard-risk assessment, which could have huge impacts on the lives of millions of people.

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DENDROCLIMATOLOGICAL POTENTIAL OF THREE JUNIPER SPECIES FROM THE WESTERN TIEN SHAN, UZBEKISTAN

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Keywords: central Asia**,** dendroclimatology, juniper species, Uzbekistan, western Tien Shan

There is a lack of studies assessing the consequences of climate change on tree growth and vitality in central Asia from a long-term perspective. Although the genus *Juniperus* has been used in dendroclimatological studies in central Asia, so far little attention has been paid towards its specific site requirements.

Here we present the first dendrochronological study on three different juniper species co-existing in the Zaamin National Park in eastern Uzbekistan: *Juniper turkestanica* (JUTU), *Juniper seravschanika* (JUSE) and *Juniper semiglobosa* (JUSM). Ninety trees (140 series) were sampled at five sites at elevations ranging from 2100 to 2700m a.s.l. on west and south facing slopes, with gradients from 10 to 30°. Growth-climate responses was calculated using data from the closest meteorological station (Shahristanskii, Tadjikistan) and grid point data generated for a larger area covering the 38-41°E and 67-70°N region for the 1950-1992 period. In general, the results point towards drought stress during summer, whereas the studied species show different intensities in the response under similar site conditions. Ring width of JUSE growing at low to mid elevation is negatively influenced by summer drought (JJA temperature: $r = -0.38$, $p < 0.05$; JJA precipitation: $r = 0.41$, $p < 0.01$) while JUTU at higher elevation (2700m a.s.l.) is mainly controlled by early spring temperatures (April: $r = 0.40$, $p < 0.01$). The annual growth of JUSM is not significantly influenced by any climate variable, which is most likely related to micro-site conditions. The weaker results obtained with the CRU grid-point data also show the importance of representative instrumental data for this heterogeneous terrain.

Besides a careful site selection, the identification of the species in the field as well the access to representative climate data seems crucial for further investigations on juniper growth in Uzbekistan.

SISAK, CROATIA: DENDROARCHAEOLOGY AND ITS ECONOMIC IMPLICATIONS DURING ROMAN CONQUEST AND COLONISATION

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Keywords: dendroarchaeology, Pannonia, romanisation, Siscia

Wooden beams from various occupation phases at Sisak, Croatia were excavated throughout the 1990s and 2000s by the Aegean Dendrochronology Project and Prof. Dr. Aleksandar Durman and brought to the Cornell Tree-Ring Lab, which has assembled four separate chronologies from different occupation periods in the wide range of the 9th Century BCE to the 3rd Century CE. The chronology of focus for this poster is 363- years long and contains 31 securely cross-dated samples, and is radiocarbon wiggle-match dated to the Imperial Roman period (ending in c. 226 CE). The timbers are from a variety of buildings including a bath complex, an aqueduct, settlement houses, and various other riverine structures. Many do not have a specific building associated with their provenence, but come from the same river area in general. The buildings date to the 1st Century CE, with many dating to the century and a half after initial Roman conquest by the (future) emperor Augustus in 35 BCE.

The general understanding of Roman conquest is that it was a primarily military endeavour, though this dendrochronological material, when combined with the vast array of archaeological remains from the city, shows a different side of events during Roman conquest. There appear to be multiple buildings in place in the early 100s CE and somewhat earlier, pointing to a necessity to quickly build river structures which seem to relate to civic as well as military use. Archaeological material strongly solidifies this argument, as more than a thousand lead tags from textiles dating to this specific 1st Century BCE / 1st Century CE period found in the same river area imply significant civil economic exchange, with large numbers of women involved. Radiocarbon wiggle-match dating has aided significantly in working with the dendrochronological and archaeological analysis, as this chronology currently does not cross-date well with any absolute chronologies.

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DENDROCLIMATIC EVALUATION OF CLIMATE-GROWTH RELATIONSHIP OF *PINUS KESIYA* ROYLE EX GORDON GROWING IN SUBTROPICAL FOREST OF MANIPUR, NORTH EAST INDIA

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Keywords: *Pinus kesiya* Royle ex Gordon, northeast India, Manipur, dendroclimatic, photosynthate, climate change

Tree-ring chronologies have been established as a useful proxy for studying climate history (Stockton & Meko, 1975; Cook et al., 1999; Stahle et al., 2000). Climate - growth relationships of trees varies from region to region within the same tree species. In the present study, dendroclimatic evaluation of the relationship between the climatic factors and annual growth ring indices of *Pinus kesiya* Royle ex Gordon growing in subtropical forest of north east India was carried out in order to determine which climate factor is limiting the growth of this tree. The annual growth ring-widths were distinctly marked and are of datable nature. The statistical characteristics of the measured ring width series suggest its suitability for dendroclimatic studies. Mean sensitivity of 0.45 indicates the placement of the series on a scale from complacent to extreme changes in ring width growth on an annual basis (Fritts, 1976). An autocorrelation value of 0.22 revealed that there is less influence to the growth of the current year ring than the previous year (Grissino-Mayer, 2001). Good correlation among sampled trees revealed a common response to environmental factors. An express population signal value of 0.80 indicates the robustness of the chronology (Wigley et al., 1984). Response function analysis of the standard chronology to climate factors showed significant response to April-September mean temperature in the current year growth. Average monthly rainfall factor displayed a synergistic effect with temperature to the growth of the tree at the study site. Relative humidity does not show much effect for the growth of the tree as revealed in the present study. It is further concluded that tree-ring indices of *P. kesiya* would serve as a good source for studies on changing climate in northeast India.

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DENDRO-ECOPHYSIOLOGY OF BAOBABS: TOWARDS A BETTER UNDERSTANDING VIA DENDROMETER AND STABLE ISOTOPE STUDIES

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Keywords: climate response, dendrometer, stable isotopes

The African baobabs, *Adansonia digitata* and *Adansonia kilima*, are widely distributed throughout semi-arid Africa and were revealed by ^{14}C dating to reach ages up to 2000 years. Thus, they have great potential to become a new archive of trans-regional high-resolution climate information for the African continent. Their ecophysiology, however, remains not fully understood. In order to achieve a better comprehension we installed dendrometers on a rather small baobab in the Limpopo Valley, South Africa. The data cover both rainy and dry season and are completed with climate data (temperature, relative humidity) recorded by a nearby installed climate sensor. First results show that the tree started to bud and stem swelling was observed before the onset of the rainy season and was able to cease photosynthetic activity of the leaves during a prolonged dry phase without shedding them and becoming dormant. Increment cores were taken before and after the monitored seasons. Intra-annual stable isotope variations ($\delta^{13}C$, $\delta^{18}O$) were measured and will additionally enhance our understanding of the tree's reaction to sudden weather changes during the vegetation period. Further results will be presented and discussed.

DENDROCHRONOLOGY AT INDIANA STATE UNIVERSITY: FROM ARCHAEOLOGY TO DISTURBANCE ECOLOGY

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Keywords: disturbance ecology, archaeology, new frontiers

The Dendrochronology and Biogeography Laboratory at Indiana State University was established in 2001. In the last 13 years, we have had 3 PhD, 12 Masters, and 6 undergraduate students work on theses that involved dendrochronology. This work has been completed under the supervision of Dr. Jim Speer and Dr. Karla Hansen-Speer who worked as a lab manager at the lab for three years. Most of this work focuses on disturbance ecology, but we have also branched out to archaeology and climate response. The focus of this presentation will be our three most recent research projects which examined pandora moth outbreaks across their entire range using chronologies from the International Tree-Ring Databank, developing a chronology in a new tree species to dendrochronology (*Juniperus osteosperma)* to date the Bridger Antelope Trap archaeological site in Wyoming, and examining the effect of fire on sixteen arboreal species in the Eastern Deciduous Forest. Throughout his career as a dendrochronologist, Dr. Speer has developed a research agenda on exploring new tree species to dendrochronology and examining new ecological interactions such as invasive species response, root parasites effects on tree growth, fire effects in previously unexplored species, and examining different insect outbreak systems using dendrochronology. From this work on the frontiers in dendrochronology, we have found many new directions of investigation where dendrochronology can contribute to other fields such as ecology, archaeology, and climatology.

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GROWTH PHENOLOGY AND PRODUCTIVITY OF SUGAR MAPLE AND YELLOW BIRCH UNDER THE INFLUENCE OF FOREST MANAGEMENT AND ENVIRONMENTAL STRESS

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Keywords: dendrometer, productivity, global change, valuable wood

This study investigates interactions among silvicultural treatments and environmental stressors to develop species-specific adaptation strategies to climate change for two valuable broadleaves in eastern Canada, sugar maple (*Acer saccharum* Marsh.) and yellow birch (*Betula alleghaniensis* Britt.). Cambial phenology and intra-annual growth dynamics are sensitive measures to quantify biological response to environmental change, such as gradual warming and increased frequency and severity of climatic extreme events, on forest ecosystems. Since 2005, 13 maple and 15 birch trees have been monitored with high resolution point-dendrometers to study the interaction of forest management (strong thinning, medium thinning, control) and climate on growth phenology (onset, cessation and duration of growth) and productivity (radial increment, growth/day).

The years 2005, 2007 and 2012 experienced anomalous dry conditions during mid-and late summer. Furthermore, during leaf enfolding in May 2010, a three day temperature peak with a maximum of 33°C triggered leaf shedding of the flushing maple trees and forcing them to re-flush with reduced photosynthetic capacity, size, mass and nutrient content (Filewod & Thomas, 2013). Growth period and productivity of maple were reduced significantly, even in comparison to the summer drought years. Over the whole observation period and in comparison to the control and medium thinning, growth of maple trees under the strong thinning tended to initiate earlier, cease later and last longer with a higher intensity. They also showed superior resistance and resilience to events of environmental stress. In contrast, birch was only little affected by the 2010 heat wave and no clear trends and differences in growth phenology and productivity between treatments and years could be identified.

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INTEGRATED ANALYSIS OF STEM RADIAL DISPLACEMENT AND WOOD FORMATION DYNAMICS OF SUBMONTANE NORWAY SPRUCE

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Keywords: dendrometer, microcores, wood anatomy, IADF

Studies of intra-annual growth dynamics with dendrometers, microcores and cell structure analysis are well established in tree-ring research, as these methods are known to provide information on the immediate effects of environmental variations on tree growth. As each of these methods elucidates growth processes from a different perspective, we integrated them in a pilot study to identify complementary and synergetic potentials for a more profound understanding of the process of xylogenesis and its modification by weather conditions.

During the growing seasons 2009 and 2010, stem radial displacement of two Norway spruce (*Picea abies* [L.] Karst.) sample trees from the submontane zone of the Black Forest, Germany, was recorded with high-resolution point dendrometers. Additionally, from the same trees microcores were sampled each week. After the year 2010, the dendrometers were removed and increment cores were extracted at the position of the point dendrometer sensor. Cell parameters (diametre, lumen width, wall thickness) were measured and the spatial scale of the xylem anatomy was attributed to a temporal development with support of the dendrometer and microcoring data.

During the growing season 2009 an intra-annual density fluctuation (IADF) was formed at different intensities in both sample trees. Facilitated by the integrated approach we were able to align and synchronise the cell structure profiles of both trees (Bender et al., 2012). We found clear evidence that the IADF formation was triggered by a late spring and early summer drought period and a distinct tree water deficit, which was monitored by the dendrometers. The results of this study encourage us to further integrate state of the art methods of intra-annual tree-ring research.

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INVESTIGATIONS OF BOLGARKOE GORODISCHE CHARCOAL (BOLGAR ANCIENT VILLAGE, IX-XIII, MIDDLE VOLGA REGION, TATARSTAN, RUSSIA)

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Keywords: Bolgar, dendrochronological analysis, xylotomical analysis, radiocarbon analysis

The aim of the current study is to build a chronology which could be used for dating of archaeological objects in the Middle Volga region, Russia.

Ancient samples of archaeological wood in the Middle Volga region is scarcely investigated because of poor preservation in known excavations. This study reports investigations of wood charcoal from six archaeological excavations in the territory of the Bolgar ancient village (9th-13th Centuries; Askeev et at., 2010; Sitdikov et al., 2013). One hundred and twenty-three charcoal samples were collected. Xylotomical analysis (Gärtner H. and Schweingruber F.H., 2013) of charcoal permitted the definition of species: 65% of samples refer to *Querqus robur*, 30% of samples to *Pinus sylvestris*. Thirty-nine samples were dated using radiocarbon methods at the Ion Beam Physics Laboratory, ETH Zurich, Switzerland (ETH-45676-45789). Several samples of sufficient size were used to calculate tree-rings and to measure tree-ring width.

The current stage of the study resulted in 19 floating (10th-12th Centuries) chronologies of oak. The study is continuing to build an absolute oak tree-rings chronology and towards and binding it with oak chronologies created from other archaeological objects in the Middle Volga region (excavations in Kazan city and Sviyazhsk island).

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USING ENVIRONMENTAL DATA TO UNDERSTAND SPECIES-SPECIFIC DIFFERENCES BETWEEN TREE-RING AND FOLIAR $\delta^{15}N$ AND $\delta^{13}C$

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Keywords: stable isotopes, carbon, nitrogen, tree-ring, foliage

Carbon (C) and nitrogen (N) stable isotopes of tree-rings and foliage are often used as investigative tools in environmental studies. However, the intra-tree and species-specific relationship between foliage and tree-ring stable isotopes is not very well understood, particularly with respect to N. We analysed the stable isotopes of C and N in tree-rings and foliage of *Fagus sylvatica* and *Picea abies* within six long-term monitoring plots in Switzerland (three deciduous forests, three coniferous forests) between 1997-2011. These results were complemented with extensive site-specific environmental data concerning water availability, N deposition, and soil nutrient content.

The mineral nitrogen concentration was significantly higher in the deciduous forests than in the coniferous forests, in part due to the annual input of leaf litter from the *F. sylvatica*. This was seen as a higher $\delta^{15}N$ in the both the tree-rings and foliage of *F. sylvatica* relative to *P. abies*, as increased nitrate availability and subsequent leaching caused an enrichment of remaining soil mineral nitrogen. Foliar $\delta^{15}N$ was higher than tree-ring $\delta^{15}N$ in both species, which is either a result of the direct assimilation of ^{15}N-enriched deposition into the foliage and/or fractionation processes associated with the movement of N between the foliage and tree stem.

The tree-ring and foliage $\delta^{13}C$, however, were both higher in the *P. abies* relative to the *F. sylvatica*. This is due to differences in stomatal conductance, which causes a decrease in tree-ring and foliar $\delta^{13}C$ in *F. sylvatica*. Both *F. sylvatica* and *P. abies* demonstrated a higher tree-ring $\delta^{13}C$ relative to the foliage, caused by a net fractionation event associated with the movement of sugars from the foliage to the tree stem.

THE ROLE OF THE DISTURBANCES ON THE INDIVIDUAL TREE AND STAND BIOMASS ACCUMULATION IN THE NATURAL MONTANE SPRUCE FOREST

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Keywords: tree-rings, dendroecology, maximum radial increment, Carpathians

Disturbances, both natural and human-induced, influence forest growth, biomass accumulation, and impact ecosystem functioning and services. Yet the dynamics and consequences of disturbances remain poorly understood, particularly for unmanaged, natural forest ecosystems comprising 30% of global forest area. Here, we use tree-ring (ca. 2,500 trees) and biometric data (ca. 5,000 trees) from 97 plots across the natural montane spruce forest belt in the Ukrainian Carpathians to analyse biomass accumulation rates and dynamics from the tree, to the stand, and landscape levels. We assess annually-resolved disturbance dynamics and above ground biomass (AGB) accumulation and evaluate the influence of natural disturbances on these processes. The living AGB ranged from 141-399 $Mg \cdot ha^{-1}$ and the current AGB increment between 1.5 and 6.1 $Mg \cdot ha^{-1} \cdot year^{-1}$. Trees in mid-diametre classes (30-50cm), coinciding with the trees age (160-190 years) when AGB accumulation rates began to decline, are responsible for 46% of the living AGB and for 39% of the AGB increment. The highest AGB was observed on the plots that experienced a main disturbance event 160-190 years ago, whereas the highest AGB growth occurs in the most recently (35-40 years ago) disturbed plots. The maximum diametre growth response of individual trees to historical disturbances was tightly coupled with the current stand-level AGB increment ($r_{Pearson}$ = 0.61, P<0.0001). This finding opens up possibilities to estimate stand-level biomass increment even without stand structural data. Although we found strong evidence that individual tree AGB growth increases with tree size, tree age plays a crucial role in this relation. Consequently, both tree size and tree age are still required to adequately model carbon accumulation in forests. Our results furthermore suggest that widely used rotation periods of 70-120 years in managed forests underestimate the time required for AGB in natural spruce forests to recover from disturbance events.

TREE-RING BASED MORTALITY PATTERNS OF FOUR SPECIES IN SWISS NATURAL FOREST RESERVES

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Keywords: tree mortality, natural forest reserve, partial cambial mortality

Natural forest reserves are suitable for studying mortality processes since forest dynamics are not affected by forest management. Based on tree-ring analysis of dead trees, year-of-death dates can be estimated, which allows us to relate climate variability to mortality patterns. However, tree-ring based estimates of year-of-death are potentially inaccurate due to partial cambial mortality, which has been found to commonly occur in declining trees (Bigler & Rigling, 2013). The aim of this study is to assess the patterns of tree mortality across different sites and determine the impacts of climatic variability on structural changes in radial growth rates.

We conducted field work in Swiss natural forest reserves at altitudes ranging from 450 to 1,700m a.s.l. We collected 1,200 increment cores from dead Norway spruce (*Picea abies* (L.) Karst), silver fir (*Abies alba* Mill.), common beech (*Fagus sylvatica* L.) and pedunculate oak (*Quercus robur* L.), which included suppressed to dominant trees. More than 100 increment cores from dominant living trees on the same sites were sampled as well. On three sites for each species, two cores were taken from 50 dead and 12 living trees respectively. Cross-dating the tree-ring series was challenging due to many wedging and missing rings, mainly in the last few years prior to tree death.

Preliminary results indicate that some of the sampled trees died more than 50 years ago. Year-of-death estimates differed in some trees by more than ten years, which makes it difficult to determine the tree-ring based year-of-death conclusively. Decreasing growth trends without a return to the former state indicated a tree would die within a few years.

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XYLOGENESIS OF *PINUS PINASTER* UNDER A MEDITERRANEAN CLIMATE

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Keywords: wood formation, drought, maritime pine, Mediterranean, dendrometers

The dynamics of cambial activity in water-limited environments such as the Mediterranean are still poorly understood. There is evidence that spring precipitation plays an important role in determining tree-ring width and tracheid features (e.g. cell lumen area and cell wall thickness). However, the complex relation between cambial phenology and climate is still far from being understood. In our study, the influence of drought on maritime pine (*Pinus pinaster* Ait.) cambial activity under Mediterranean climate was assessed.

A plantation of maritime pine was selected in the west coast of Portugal, to monitor cambial activity and wood formation using anatomical observations (8 trees) and band dendrometer measurements (25 trees). The trees were monitored weekly over two years (2010 and 2011).

Warmer late-winter temperatures caused an earlier start of xylem differentiation and water stress triggered the differentiation of tracheids with smaller lumen area and an earlier stop of wood formation. In both years, the weekly stem increment dynamics showed a bimodal pattern with two major peaks, in spring and in autumn. The anatomical observations suggest that the second increment peak corresponded mostly to stem re-hydration, since the differentiation of new xylem cells by the cambium was not observed. We concluded that cambial activity in maritime pine appears to be under a double climatic control: temperature, driving the cambial resumption, and water availability affecting growth cessation.

HYDROCLIMATE VARIABILITY FROM SOUTHEAST TIBET INFERRED FROM STABLE OXYGEN ISOTOPES IN TREE-RING CELLULOSE

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Keywords: stable oxygen isotopes, hydroclimate reconstruction, southeast Tibet

The precipitation variability of the Indian Summer Monsoon is directly affecting the recharge of “Asia’s Water Tower”, the Tibetan Plateau. River discharge, but also the mass balance of monsoonal temperate glaciers, is controlled by the amount and time of occurrence of the summer monsoon precipitation. Thus, the water availability in one of the most populated regions depends on these factors. Contrary to its importance, relatively few hydroclimatic time series were established for the Tibetan Plateau so far. Hence, a keen demand of temporally and spatially high resolved hydroclimate studies persists. To reconstruct moisture properties, we applied stable oxygen measurements from tree-ring cellulose. We used *Juniperus tibetica* to achieve an 800- year long relative humidity reconstruction in southeast Tibet. The tree samples were collected from a steep south-facing slope at an elevation of 4300m a.s.l. The reconstruction indicates a higher relative humidity at the end of the Medieval Warm Period (MWP) and then oscillates around the mean during the Little Ice Age (LIA). However, since the beginning of the 19th Century it shows a remarkable decline. The increase of relative humidity is correlated to increasing northern hemispheric temperatures (Ljungqvist 2012). Similar patterns were also found in tree-ring $\delta^{18}O$ chronologies from several sites (Liu 2014, Shi 2012). Moreover, we found stable moisture conditions during the LIA and a higher relative humidity at the termination of the MWP. These findings contrast the reported lowered precipitation during the MWP and higher precipitation rates during the LIA (Grießinger 2011). A comparison with complementary $\delta^{18}O$ chronologies reveals insights to a supraregional and time shifted regime change from wetter to drier conditions at around 1800 AD. Nevertheless, that conclusion is only valid for sampling sites from the southern Tibetan Plateau. Humidity reconstructions from the northern Plateau show an inverse characteristic (Sheppard 2004).

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DEVELOPMENT OF A CORE-DRILL FOR NON-DESTRUCTIVE SAMPLING OF SUPER-HARD TROPICAL TREES

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Keywords: tropical dendroclimatology, sampling methods, core drill

Longer palaeoclimate records are needed from tropical regions to give longer term context to 20th Century climatic changes, and to contribute to future climate predictions. Tree-rings form a powerful archive for climate of the recent past yet their use has traditionally been limited to the temperate parts of the world where annual rings provide a dating control. The development of stable isotope dendroclimatic methods, however, has allowed the investigation of non-annual ring forming trees, such as those growing in the non-seasonal tropics, for palaeoclimate information. Tropical hardwoods typically contain the longest climate records due to their longevity as a result of resistivity to disease and decay. Such trees are increasingly rare and often protected under law and so must be non-destructively sampled and their extreme hardness poses methodological challenges. Previous attempts to core the tropical hardwood *Eusiderocylon zwageri* have been unsuccessful; therefore, this research aims to develop a robust, portable sampling system for coring super-hard tropical trees.

The sampling system we present is based on the use of standard 'core-drill' bits attached to a battery powered hand drill. The key development is the removal of the core in sequential segments of approximately 6cm length. The system meets several requirements: (1) to cut through high density wood; (2) to yield low friction to prevent overheating and charring; (3) to allow sampling of long cores from large, old trees; and, (4) to maintain a balance between high power output and ease of use in the field. Three prototype borers were trialed sampling Borneo Ironwood in northern Malaysian Borneo (Sabah).

Results from coring *Eusiderocylon zwageri* revealed that a tungsten carbide cutting head was the most effective core-drill; however, the drill had to be repeatedly retracted to declog sawdust, and the core snapped regularly at ~1.5cm intervals. Several ~60cm cores were ultimately successfully obtained for stable isotope analysis. We present the design for our core-drill based sampling system and discuss its limitations and potential uses and developments.

IS CALCIUM THE ANSWER TO THE TROPICAL DATING ISSUE?

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Keywords: wood calcium, dendrochemistry, tropical trees

Tropical trees play a critical role in modulating climate and carbon cycling at local, regional and global scales. However, few species are amenable to analysis by conventional dendrochronological methods. We present an experimental dendrochemical method for dating tropical trees using the continuous measurement of calcium by LA-ICP-MS. Preliminary development of this method was based on a temperate species (Scots pine) which produced clear annual cycles in the calcium data providing a basis for applying this to a tropical species.

We hypothesised that quantifying patterns of calcium concentration in tropical wood is a viable means of evaluating growth patterns in tropical trees, which will allow us to assess tropical forest growth both temporally and spatially. Initially, variations in calcium concentrations were measured from multiple tracks along the radii of a *Terminalia macroptera* tree, a tropical species from Cameroon with indistinct growth rings. A threshold detection approach was implemented to define annual growth cycles with respect to extreme peaks in the tracer data-series. Validation of the calcium dated series was made through radiocarbon dating which showed reasonable statistical agreement between the dating methods. Additionally, oxygen isotope data for the same tree sample produced a pattern showing clear peaks and troughs. Results from this one sample from both the radiocarbon dating and the calcium analysis demonstrated that the $\delta^{18}O$ series did not represent an annual signal despite the apparent cyclic nature of the peaks. We then further tested the Ca threshold approach on a second *T. macroptera* sample using the same threshold approach as "tuned" to the first sample and ^{14}C dates. Unfortunately, for this 2nd sample, the Ca and ^{14}C results did not agree. This was mainly related to the much faster growth rates of this second sample which resulted in the burn spot size not being optimal for this second sample, and so resulting in a failed result. Ca still holds promise for dating some tropical species, but significant challenges exist due to the "unknown" growth rates of the trees being analysed and possible changes of tree physiology as the trees age. However, despite these ambiguous results, for this one species at least, the assumption that stable isotopes can be used to date ringless tropical trees appears to be flawed. A method for "true" annual dating of tropical trees still remains elusive, but continued effort is paramount to open up tropical dendrochronology.

ACCURATE SPRUCE (*PICEA ABIES*) ROOTS DATING BY MEANS OF MULTI-STEP ANALYSIS (GORCE MTS., POLAND)

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Keywords: spruce roots dating, multi-step approach, cross-dating

A total of ten roots of *Picea abies* L. Karst were taken from three individual trees located at an elevation of 1000-1150m a.s.l. in the Gorce Mts. (Western Carpathians (southern Poland) . Root specimens were cut at various distances from the stems ranging from 0.9 to 2.8 metres. In addition to root sampling, 30 adjacent spruce trees were cored, including the trunks from which the roots were sectioned. The goal of this study was to present a method for the accurate dating of roots by using a multi-step approach. The results of the analyses indicate a need to take all types of missing and wedging annual rings into account when dating roots. Failure to identify such rings may generate significant errors in the dating of roots. Cross-dating analyses were carried out both within single cross-sections (four radii) and longitudinal profiles combined from three to six sections taken from the same roots. In a first step, growth curves were only obtained based on one radius from each section. The second stage of the analysis involved visual cross-dating between four radii of a single cross-section within the root and a subsequent comparison of the growth curves obtained from the different cross-sections to detect wedging rings in the longitudinal profile. The third stage comprised cross-dating between the root growth curves, the stem growth curves and the reference site chronology. Thanks to the use of serial sectioning, on average six additional annual rings were detected. It is not possible to detect these rings by analysing a single radius within one section. It was found that wedging rings which occur in both cross-sections and the longitudinal profile were the most difficult to identify. Such growth reductions were observed in 17.3% of the rings analysed. Interpretation problems in analysing root structure and in precise exposure dating are attributable to environmental factors in addition to geomorphological factors.

RECONSTRUCTION OF GEOMORPHIC PROCESSES TO VERIFY PERMAFROST AGGRADATION ON A NORTH-FACING SLOPE BELOW TIMBERLINE

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Keywords: dendrogeomorphology, snow avalanche, debris flow, mountain permafrost

In the Swiss Alps the lower boundary of discontinuous permafrost is located at about 2300m a.s.l.. However, depending on multifaceted parameters, isolated patches of permafrost can occur in lower elevations, even below timberline. One of these low altitude permafrost sites is found on a slope in the Bever Valley (Engadine, Switzerland). The occurring ice lenses are classified as relict permafrost, i.e. they would not re-establish under present climatic conditions. The slope is covered by a dense forest stand of European larch (*Larix decidua* Mill.) and Swiss stone pine (*Pinus cembra* L.) without indication of dwarfing as typical plant-related permafrost growth form. Tree-ring analyses done on 88 larch trees growing on the slope revealed single trees showing severe and enduring growth reductions starting around 1875. Their position on the slope corresponds with the location of permafrost lenses detected by geophysical soundings. We therefore concluded that the permafrost lenses at this site developed around 1875, as all trees showed a higher growth level for more than hundred years before this suppression occurred. Although these conclusions appear robust, there is a need to verify that these growth suppressions are caused by low soil temperatures and not by geomorphic processes including avalanches or debris flows frequently occurring on this slope.

To reach this objective, a geomorphic map of the slope was created documenting all landforms and depositions caused by debris flows and avalanches. Trees obviously influenced by these processes were marked in the map and 95 *Larix decidua* trees cored for further analysis. Results show that avalanches and debris flows are frequently occurring on the slope, but there is no sign of a severe disturbance dominating the conditions during the 1870-1885 period.

STABLE ISOTOPES RATIOS FROM BRITISH OAK TREE RINGS PROVIDE A STRONG AND CONSISTENT RECORD OF PAST CHANGES IN SUMMER CLIMATE

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Keywords: tree-rings, isotopes, oak, temperature, precipitation

Placing recent climate changes into the context of natural, late Holocene variability requires records far longer than those available from instrumental sources. Much of the annually resolved palaeoclimatic data currently available comes from proxies contained within the annual rings of trees. However, most of this evidence is confined to locations with extreme climates, where tree growth is strongly limited by growing season temperature or precipitation. We therefore have little, statically verifiable, evidence from temperate mid-latitude locations, such as the UK. This has led to a geographical imbalance in past hemispheric climate reconstructions towards remote regions with extreme climates.

Stable isotopes from tree-rings have the potential to rectify this imbalance. The processes which control stable carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotope fractionation should be the same at all locations. For tree $\delta^{13}C$ this is a balance between photosynthetic rate and stomatal conductance; and for $\delta^{18}O$, the isotopic ratio of source water overlaid by an evaporative enrichment signal. The material required to construct long isotope chronologies in mid-latitudes is already in place. European oak tree-ring chronologies have been developed extending over many thousands of years.

At Swansea University isotope ratios from oak trees at eight UK locations have been analysed to produce UK composites for both $\delta^{13}C$ and $\delta^{18}O$ for the period AD 1850- 2010. Both isotope chronologies have very strong, significant and temporally stable relationships with UK-measured summer climate variables: $\delta^{13}C$ with temperature (r = 0.76, P<0.001); and $\delta^{18}O$ with precipitation (r = 0.69, P<0.001). The strength of these relationships is (at least) equivalent to those associated with northern and Alpine treeline locations. The availability of long, annually resolved oak tree-ring chronologies should allow for these isotope records to be extended and used to reconstruct UK summer climate over many centuries and potentially into the mid-Holocene.

RECORD OF LANDSLIDE PROCESSES IN THE WOOD ANATOMICAL STRUCTURE OF FIR ROOTS (*ABIES ALBA*) – EXAMPLE FROM THE CARPATHIAN FOOTHILLS

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Key words: landslide process, dendrogeomorphology, the Carpathian Foothills, wood anatomy

The aim of the research was to detect the activity of a landslide area by analysing the anatomical structure of exposed fir roots. Earlywood (EW) lumen area, percentage of latewood (LW), compression wood and ring-width changes were taken into account. Those indicators were originally used to analyse various erosional processes (Fayle 1968, Gärtner et al. 2001, Bodoque et al. 2005; Gärtner 2007, Rubiales et al. 2008). The relationship between root exposure, landslide activity and precipitation data was additionally investigated. The research was carried out on the small landslide (0,14 ha) activated after heavy rainfalls which occurred in Carpathian Mountains in 2010. In total 12 samples were collected from exposed vertical roots on the edge of the landslide niche. Wood anatomical changes of the roots were analysed in WinCELL Pro (Regent). Our preliminary investigations show that in the case of vertically exposed roots the changes of different anatomical features is not simultaneous. It was concluded that for studying the spatial activity of a landslide it is helpful to consider various anatomical indicators. In almost all samples changes in the earlywood was recognised in 2011. In three roots changes of the EW were established before the significant change of LW and ring-width. In the remaining roots changes of EW were proceeded by the changes of the mechanical function of roots expressed by the occurrence of compression wood. In the study area the correlation between the activity of the landslide and precipitation was revealed in 1958, 1964, 1976, 2001, and 2010. It seems that wood anatomical analysis of roots within the landslide is promising for investigating the initial phase of landslide development.

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LONG-TERM GROWTH VARIATION AMONG TROPICAL TREES: PATTERNS, CAUSES AND CONSEQUENCES

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Keywords: dendroecology, tropical tree species, intraspecific variation

Similar-sized individuals in natural tree populations may differ strongly in diametre growth rates. If such growth variation persists over time, this may lead to large differences in the age at which individual trees reach the size at which they start reproducing or can be harvested for timber. This age variation potentially has large demographic consequences; young reproductive trees may boost population growth and therefore contribute much more to population growth compared to slow growers. These fast growers also contribute disproportionately more to future timber harvests than slow growers.

We used tree-ring analysis to study persistent growth differences in populations of 14 tree species from moist and wet forests in Bolivia, Cameroon and Thailand. We quantified the degree to which growth differences persist over time, related long-term growth rates of individual trees to their canopy position, and quantified the relative importance of persistent fast growers for tree population growth.

Results revealed that all species show persistent growth differences and that these growth differences can be maintained for several decades. As a result, the age at reaching reproductive or harvestable size was highly variable. Demographic models (Integral Projection Models) showed that fast-growing individuals importantly drive population growth of our study species.

Our findings imply that persistent growth variation between individual trees appears to be common in tropical forest trees and that this variation drives population growth. This has potential consequences for the analysis of the viability of threatened populations, modelling of tree growth in relation to climate change, and studies on the assembly of tree communities in tropical forests.

THE EFFECT OF RESIN EXTRACTION ON THE BLUE REFLECTANCE MEASUREMENTS

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Keywords: Blue Reflectance, Norway spruce, Scots pine, resin, extraction

The Blue Reflectance (BR) is still a relatively new tree-ring parameter (McCarroll et al. 2002) that has been developed and refined over the last 12 years (Babst et al. 2009, Cambell 2011). It has already been proven to be a good tool for climate analyses and reconstructions (McCarroll et al. 2011; Wilson et al. 2011, Björklund 2013b); however, further studies to evaluate chemical and image-data treatment are still needed. Natural resins present in wood are one of the main factors affecting the blue light measurement process. Resin is known as a mixture of various chemical compounds, mainly aromatic and aliphatic hydrocarbons. These compounds effectively absorb the broad light spectrum, making the measurement process difficult and inaccurate. Resin may be removed by extraction with various solvents appropriate for dissolving hydrocarbonic constituents. The most common method is a continuous extraction in soxhlet apparatus with acetone, alcohol or a mixture of alcohol with organic solvents such as benzene or toluene. The selection of optimal extraction procedure is the crucial step toward establishing the standard procedure for BR analyses. This experiment was designed to assess the influence of the use of three different solvents (acetone, ethanol, mixture of alcohol and toluene) on resin extraction from two coniferous species (Norway spruce, *Picea abies* and Scots pine, *Pinus sylvestris*). Thirty trees per species were cored and four samples per tree were collected. Three samples were treated with different chemicals for ~42 hours and the fourth one was use as a blind sample. The BR was measured using the CooRecorder 7.7; quality of the measurements was validated with CDendro and Cofecha. The time series were compared between trees and treatments. The group of chronologies was built using Arstan. All together 10 chronologies were established and compared with each other and with climate data obtained from CRU 3.1 grid (Harris et al. 2013).


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Science
annual
ABSTRACT
climate
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STUDY
UNIVERSITY
et
species
DATA
YEARS
sites
changes
TEMPERATURE
RECONSTRUCTION
ANALYSIS
ROOTS
DATING
AVIEMORE
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