ClimTree 2013

International Conference on Climate Change and Tree Responses in Central European Forests

1 to 5 September 2013

ETH Zurich, Switzerland

Program and Abstracts

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WSL

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Organizing Committee:
Thomas Wohlgemuth, Peter Bebi, Harald Bugmann, Kathrin Priewasser,
Cyrille Rathgeber, Susanne Senn-Raschle, Andreas Rigling, Andreas Schuck, Heinrich Spiecker

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Partners

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Organizing Committee

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Chairs

Session 1 and 2	Rupert Seidl, Miroslav Svoboda, Frank Krumm, Marco Conedera
Session 3	Ivano Brunner
Session 4	Damien Bonal, Michael Scherrer-Lorenzen
Session 5	Nicole Estrella, Yann Vitasse
Session 6	Heinrich Spiecker, Harri Mäkinen
Session 7	Andreas Rigling, Günter Hoch
Session 8	Ulf Büntgen, Jesús Julio Camarero Martínez
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Session 12	Veronika Braunisch, Rudi Suchant, Raphaël Arlettaz
Session 13	Andrea Battisti, Alain Roques
Session 14	Jonathan Lenoir, Jean-Claude Gégout

Invited Talks

Keynote Speakers

Craig D. Allen, US Geological Survey, Los Alamos, NM, USA
Harald Bugmann, ETH Zurich, Switzerland
Charles D. Canham, Cary Inst Ecosytem Studies, Millbrook, NY, USA
David Frank, WSL Birmensdorf, Switzerland
Lorena Gómez-Aparicio, CSIC Seville, Spain
Reto Knutti, ETH Zurich, Switzerland
Rolf Manser, Federal Office of the Environment, Bern, Switzerland
Heinz Rennenberg, Freiburg i. Br., Germany

Introductory Talks

Matthew Ayres, Dartmouth College, Hanover NH, USA
Ulf Büntgen, WSL Birmensdorf, Switzerland
Jofre Carnicer, University of Groningen, The Netherlands
David A. Coomes, University of Cambridge, UK
Barry A. Gardiner, INRA Villenave d'Ornon, France
Douglas L. Godbold, Boku Vienna, Austria
Marc Hanewinkel, WSL Birmensdorf, Switzerland
Louis R. Iverson, USDA Forest Service Delaware OH, USA
Jonathan Lenoir, Université de Picardie Jules Verne, Amiens, France
Manfred J. Lexer, Boku Vienna, Austria
Jordi Martínez Vilalta, CREAF Barcelona, Spain
Jörg Müller, TU München, Germany
Greg A. O'Neill, BC Ministry of Forest and Range, Vernon, Canada
Rupert Seidl, Boku Vienna, Austria
Heinrich Spiecker, University of Freiburg i. Br., Germany
Elizabetz M. Wolkovich, University of British Columbia, Vancouver BC, Canada

Instructions

Talks

For each regular talk, there will be a 20 min time slot (15 min for the talk and 5 min for discussion). In order to allow the audience to switch rooms between sessions, the chairs of each session will be asked to keep strict time management. We ask you to arrive on time in your session room, in order to prevent delays.
Each conference room is equipped with a Windows computer, a beamer and a laser pointer. We provide MS Office 2010. Please note that it will not be possible to use your own computer. Please make sure that your presentation can run under Windows.
Please provide your presentation either as PowerPoint or PDF File on a USB memory stick.
The registration desk will open on Sunday (Sep 1) 6 pm. Please hand over your presentation to the staff at the registration desk upon arrival. It will be possible to check the presentation on correct functioning and display of all slides. All presentations need to be handed over to the conference staff no later than the evening proceeding the day the talk is scheduled!

Posters

Sessions
Since poster boards are located in close proximity to the lecture halls, no special sessions will be organized for poster contributions. However, poster authors need to be present during breaks at the day of the affiliated sessions (see program).

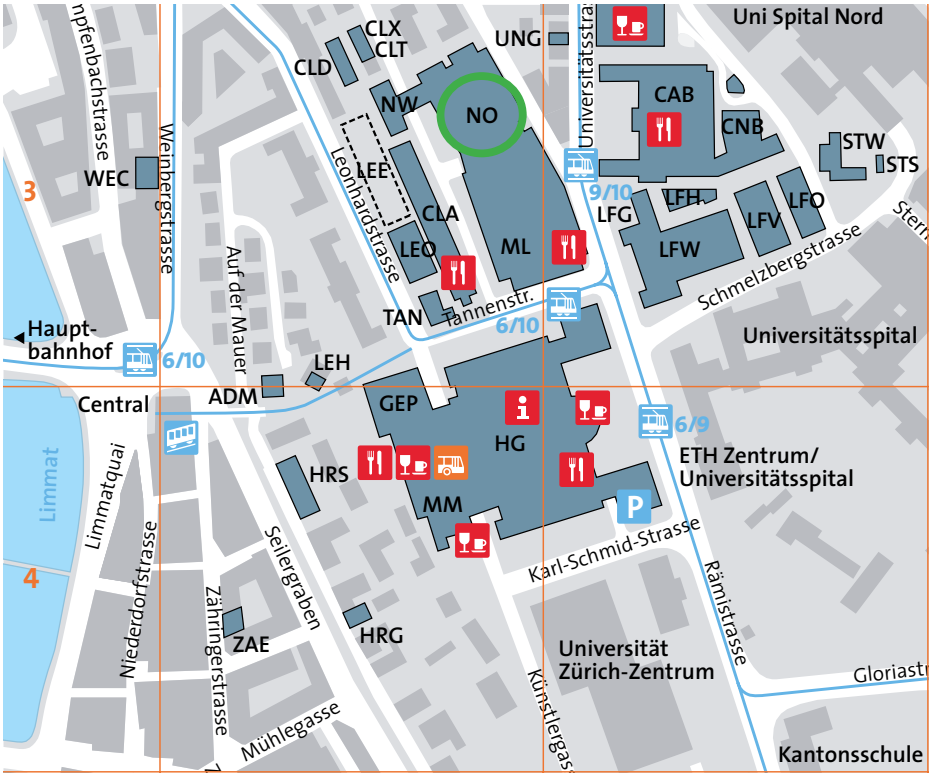
Installation
Please pin up your poster on Monday morning (2nd Sep). Posters will remain on exhibit during the entire conference. Push-pins will be provided.

Instructions
Posters need to fit a maximum size of 120 by 85 cm on the board (A0 portrait format is recommended).

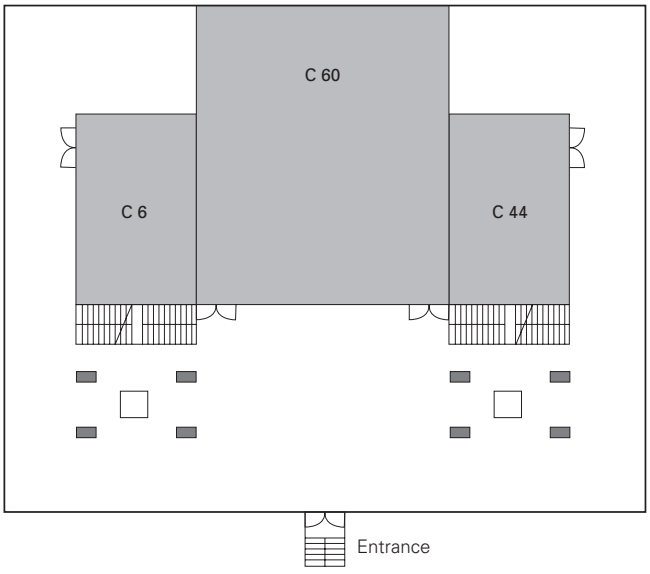
Abstract order and presenting authors
Abstracts are ordered in the categories keynotes, lecture sessions (introductory and regular talks per session) and poster sessions. Within "Lecture-Sessions" abstracts are listed according to the order of presentation, and within "Poster-Sessions" abstracts are ordered alphabetically. Presenting authors are indicated in bold letters.

Maps

Campus



Rooms



- Bus Station (Meeting Point for Excursions)
- Tram
- Cable Car (Polybahn)
- Lunch
- Coffee/Snack
- NO NO Building
- HG Main Building

Conference Program in Brief

Sunday (1 Sep.)
Excursion E1 Davos: 7:15 Bus Station, Tunnel ETH Main Building (HG); return ca. 18:00
Excursion E2 Leuk: 7:00 Bus Station, Tunnel ETH Main Building (HG); return ca. 18:00
Registration/Icebreaker at the NO Building: 18:00–20:00

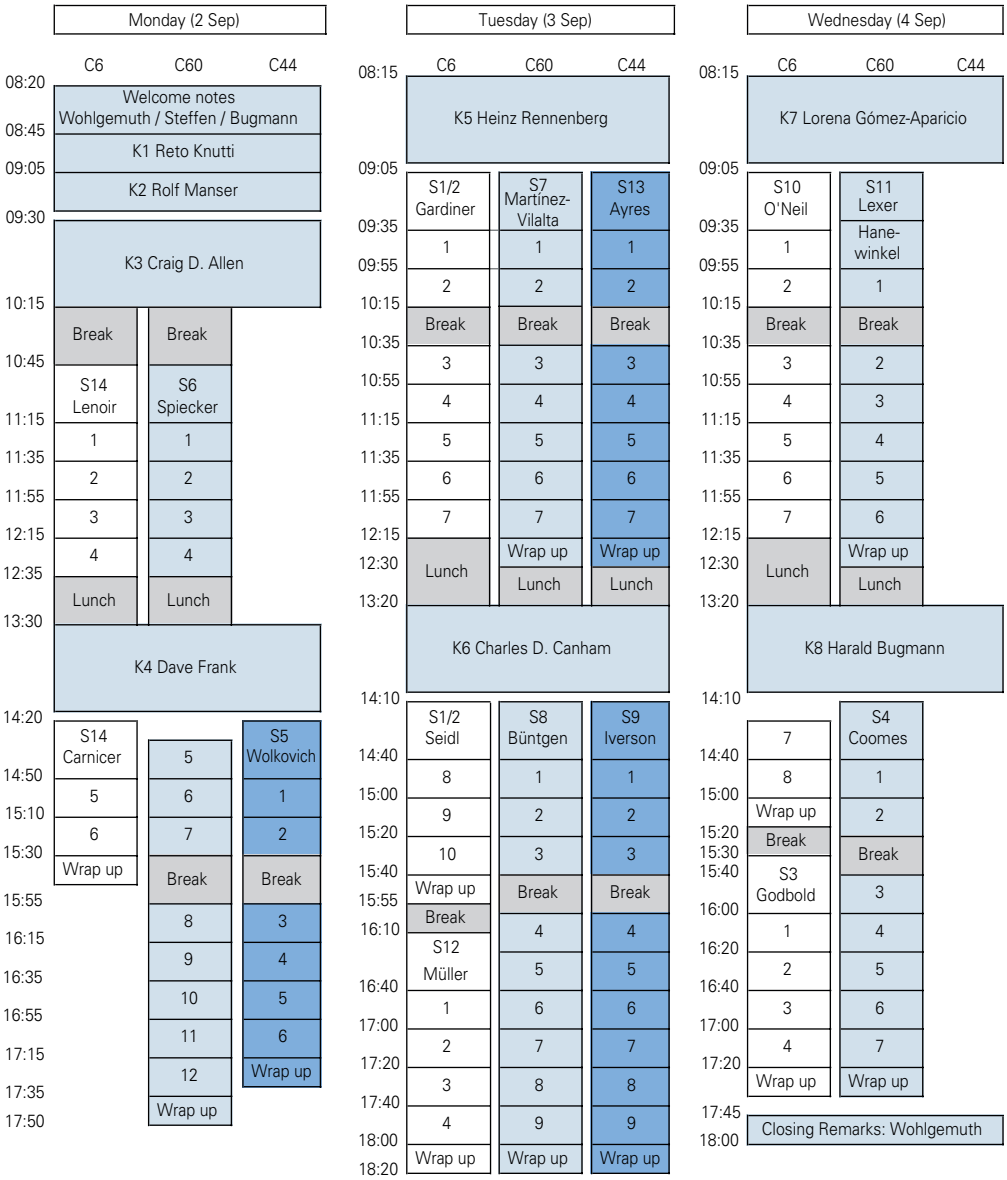
Monday (2 Sep.)
Registration: Starting at 7:30
Conference Talks and Posters: 8:20–17:50, NO Building
Apéro Session Chairs and Organizing Team: 19:30 Restaurant "Grünes Glas"

Tuesday (3 Sep.)
Conference Talks and Posters: 8:15–18:20, NO Building
Social Dinner: 19:30–22:30, Restaurant "Ziegel oh Lac", Rote Fabrik, Zürich

Wednesday (4 Sep.)
Conference Talks and Posters: 8:15–18:00, NO Building
Wind and Climate Change Party: 18:45 Bus Station, Tunnel ETH Main Building (HG); return ca. 23:00

Thursday (5 Sep.)
Excursion E3 Davos: 7:15 Bus Station, Tunnel ETH Main Building (HG); return ca. 18:00
Excursion E4 Leuk: 7:00 Bus Station, Tunnel ETH Main Building (HG); return ca. 18:00

Conference Talks: Time Table



Monday, 2nd September

PLENARY SESSIONS (Room C60)

Introduction

8:20	Opening Remarks	
	Thomas Wohlgemuth	Head Organizing Committee, WSL Birmensdorf
	Konrad Steffen	Director, WSL Birmensdorf
	Harald Bugmann	ETH Zürich

Keynotes

8:45	Reto Knutti	Climate projections for Central Europe
9:05	Rolf Manser	Forest Policy in a Changing Climate – What Are We Expecting from Scientists?
9:30	Craig D. Allen	Drought Stress as a Core Driver of Forest Disturbances and Tree Mortality: A Global Perspective
13:30	David Frank	The Climate Sensitivity of Radial Tree Growth across Europe

PARALLEL SESSIONS

10:45–15:45 (Room C6): Jonathan Lenoir and Jean-Claude Gégout

Biotic Responses of Trees and Understory Vegetation to Contemporary Climate Change (Session 14)

10:45	Jonathan Lenoir (Intro I)	Is Recent Climate Change the Primary Driver Behind Contemporary Biotic Responses of Trees and Understory Vegetation?
11:15	Pieter De Frenne	Forest Densification Moderates Understorey Plant Responses to Macroclimate Warming
11:35	Meinrad Küchler	Response of Swiss Forests to Management and Climate Change
11:55	Sebastian Zielis	Lagged Response of Forest Ecosystem to Previous Year´s Weather as Key to Better NEP Models
12:15	Nina Buchmann	The Swiss Fluxnet: Greenhouse Gas Fluxes and Responses of Two Swiss Forests to Natural and Anthropogenic Impacts
12:35	LUNCH	
13:30	Keynote David Frank (Room C60)	
14:20	Jofre Carnicer (Intro II)	Forest Responses to Climate Change at the Large Scale: Unraveling the Role of Forest Succession, Inter-Specific Interactions and Trait-Based Strategies
14:50	Robert Gruwez	Negative Effects of Temperature and Changing Precipitation on the Seed Viability of *Juniperus communis*
15:10	Anton Fischer	Can a Species Composition Change as Response on Temperature Increase in Forest Ecosystems already Be Seen? – Beech Forests in Bavaria as an Example

10:45–17:50 (Room C60): Session 6, Heinrich Spiecker and Harri Mäkinen

Impacts of Drought on Tree Growth and Vulnerability (Session 6)

10:45	Heinrich Spiecker (Intro)	Impacts of Drought on Tree Growth: Research Methods and Results of Selected Case Studies
11:15	Anton Bürgi	Drought Periods since 1900 and Growth of Forest Stands: A New and Consolidated Analysis of Long-Term Data Series
11:35	Arne Nothdurft	Spatio-temporal Prediction of Tree Mortality based on Long-term Sample Plots, Climate Change Scenarios and Parametric Frailty Modeling
11:55	Linda Feichtinger	Effects of Drought and Century-Long Irrigation on Radial Growth and Needle Traits of Scots pine
12:15	Markus Wagner	Effects of Drought Stress on Tree Growth in Central German Beech Forests
12:35	LUNCH	
13:30	Keynote David Frank (Room C60)	
14:30	Jörg Kunz	Physiological and Growth Responses of Minor Tree Species of Central Europe to Drought
14:50	Hans Göransson	Drought Decreases the Over Yielding Caused by a Tree Mixture in a British Deciduous Forest
15:10	Matthias Haeni	TreeNet
15:30	BREAK	
15:55	Ilona Meszaros	Leaf Water Relations, Sap Flow Density and Stem Radial Changes in Two Co-Existing Oak Species
16:15	John Major	Total Biomass, C and N Partitioning and Growth Efficiency of Mature Pedigreed Black Spruce on a Dry and Wet Site
16:35	Guy Vranckx	Can Climate Change Exacerbate the Genetic Consequences of Forest Fragmentation? Effects of Drought Stress on Heterozygosity-Fitness Correlations in Pedunculate Oak
16:55	Ellen E. Schuch	Physiological Characterisation of Swiss Native Oak Species Using the Dual Isotope Approach
17:15	Patrick W. Sherwood	Examining Mechanisms of Enhanced Susceptibility to Diplodia Tip Blight in Drought-Stressed Austrian Pine

14:20–17:30 (Room C44): Nicole Estrela and Yann Vitasse

Phenology and Climate Change (Session 5)

14:20	Elizabeth M. Wolkovich (Intro)	The Race for Spring: Understanding the Diversity of Tree Phenological Responses to Climate Change
14:50	Chris Kollas	Critical Temperatures Determining the Elevational and Latitudinal Range Limits of European Broad-Leaved Trees
15:10	Martine Rebetez	Impact of Forest Cover on Temperature under the Canopy
15:30	BREAK	

15:55	Nicole Estrella	Individual Phenological Behaviour of Juvenile and Mature Beech Trees
16:15	Yann Vitasse	Are Experimental Studies Valuable to Infer Phenological Responses of Temperate Forests to Climate Change?
16:35	Susanne Jochner	Can We Detect a Nonlinear Response to Temperature in European Phenology?
16:55	Julia Laube	Chilling × Photoperiod – A Full Factorial Experiment on the Spring Phenology of Trees

Tuesday, 3rd September

PLENARY SESSIONS (Room C60)

Keynotes

8:15	Heinz Rennenberg	Nitrogen Cycling in Forest Ecosystems in a Changing Climate
13:20	Charles D. Canham	Disentangling Responses to Climate Change versus Broader Anthropogenic Impacts in Forests of the Eastern U.S.

PARALLEL SESSIONS

09:05–12:30 (Room 60): Andreas Rigling and Günther Hoch
Drought-Induced Tree Mortality – Patterns, Processes and Mechanisms (Session 7)

9:05	Jordi Martínez-Vilalta (Intro)	Drought-Induced Tree Mortality: Lessons from Mediterranean Scots pine Populations
9:35	Jose Gruenzweig	Life and Death of Drought-Adapted Trees under Climate Change
9:55	Tamir Klein	Pine Mortality at the Drought Limit: All Eyes on Cavitation
10:15	BREAK	
10:35	Yann Salmon	Scots Pine Physiological Response to Drought
10:55	Mathieu Lévesque	Long-Term Growth and Gas Exchange Responses of Conifers to Drought in Central Europe
11:15	Roman Zweifel	TreeNet – Quantifying Tree Water Deficits and Missing Water of Forest Ecosystems from Dynamic Stem Radius Changes
11:35	Pierre Vollenweider	Structural Changes Indicative of Drought Stress and Tolerance in Oak Foliage
11:55	Bradley Matthews	Can Simulations of Stand Hydrology Improve Modelling of Spruce Bark Beetle Infestation Risk?

09:05–15:55 (Room C6): Rupert Seidl, Miroslav Svoboda, Frank Krumm and Marco Conedera
Disturbance Ecology and Management in a Changing World (Session 1 and 2)

9:05	Barry A. Gardiner (Intro I)	Disturbance in European Forests and the Impact of a Changing Climate
9:35	Marc Scherstjanoi	Swiss-wide High Resolution Simulations of Forest Dynamics with LPJ-GUESS

9:55	Werner Rammer	A Simulation Tool for Assessing Future Wind Disturbance Impacts on Forest Landscapes
10:15	BREAK	
10:35	Axel Albrecht	Combining an Individual-tree Forest Growth Model with Storm Damage Modeling – Approach and Results of Silvicultural Scenarios
10:55	Dominik Thom	The Sensitivity of Wind and Bark Beetle Disturbance to Slow and Fast Drivers in Central European Forests
11:15	Ferenc Pasztor	Drivers of Wind and Bark Beetle Disturbances in Austria
11:35	Michael Maroschek	Selective Browsing and Bark Beetle Damages under Climate Change: Interacting Disturbances Affect Ecosystem Service Provisioning
11:55	Natalie Zurbriggen	Spatially Explicit Simulations of Snow Avalanches in Swiss Alpine Forests under Climate Change
12:15	LUNCH	
13:20	Keynote Charles D. Canham (Room C60)	
14:10	Rupert Seidl (Intro II)	Intensifying Natural Disturbance Regimes and Implications for Forest Management
14:40	Alexander Peringer	Shifting Tree Species Dominance and Corresponding Landscape Structure in Wood-Pastures in a Changing Climate
15:00	Davide Ascoli	Fire effects and post-fire management on beech forests in the southern Alps
15:20	Miquel De Cáceres	Analyzing the Response of Mediterranean Forests to the Combined Effects of Changes in Drought and Fire Regimes: Insights from a Landscape Simulation Model Based on Vital Attributes

09:05–12:30 (Room C44): Andrea Battisti and Alain Roques

Tree Vulnerability to Pests in Relation to Climate Change (Session 13)

9:05	Matthew Ayres	Consequences of Climate Change for Biotic Disturbances in North American Forests
9:35	Andrea Battisti	Response of Forest Pests to Climate Change in Europe
9:55	Lorenzo Marini	Population Dynamics of the Spruce Bark Beetle: A Long-Term Study
10:15	BREAK	
10:35	Sigrid Netherer	Rosalia Roof Project: A Drought Stress Experiment as Basis for Risk Modelling *(Ips typographus)*
10:55	Oliver Jakoby	Phenology of the Spruce Bark Beetle *Ips typographus* – Modelling the Effect of Climate Change
11:15	Christelle Robinet	How Could Climate Change Affect the Potential Spread of Pine Wilt Disease in Europe?

11:35	Deepa Pureswaran	Will Northward Expansion of Eastern Spruce Budworm with Climate Change Affect Boreal Forest Resilience?
11:55	Pierluigi (Enrico) Bonello	Water Stress Decreases Ash Resistance to *Agrilus planipennis* without Affecting Phloem Phenolics

14:10–18:15 (Room C44): Ulf Büntgen and Jesús Julio Camarero Martínez

Frontiers in Dendroclimatology and -ecology (Session 8)

14:10	Ulf Büntgen (Intro)	Frontiers in dendroclimatology and -ecology
14:40	Ansgar Kahmen	Climate, Tree Physiology, or Both: What is the Information Recorded in Oxygen Isotope Ratios of Tree-Ring Cellulose?
15:00	Katalin Csilléry	Climate Induced Changes in the Growth Rate and Physiological Optimum of two Drought Sensitive Species
15:20	Niels Bleicher	Climatic Relevance of Vessel-Chronologies in Oak from Different Ecological Settings Close to Lake Constance
15:40	BREAK	
16:00	Daniele Castagneri	New Insights of Spruce Response to Climate through Two-Hundred Year Tracheid-Size Chronologies
16:20	Francesco Giammarchi	Long-Term Productivity Changes of Two Norway spruce (*Picea abies* (L.) Karst.) Alpine Forest Chronosequences under Shifting Environmental Conditions
16:40	Jussi Grießinger	Detecting Permafrost changes within a tree stand – an example from the Swiss Alps
17:00	Irene Fernandez	Sign of Biome Sensitivity to Atmospheric CO_2 Changes in Growth Rings from Coniferous Forests
17:20	Miroslav Svoboda	Disturbance Regime in Temperate Mountain Spruce Forests of Central and East Europe – Preliminary Results from Dendroecological Reconstruction
17:40	Kathrin Motz	Validating a Climate Interpolation Model (CIM) Using Tree Ring Data from the Austrian Central Alps

14:10–18:15 (Room C60): Niklaus E. Zimmermann and Marc Hanewinkel

Impact of Climate Change on Demographic Changes and Species Ranges (Session 9)

14:10	Louis R. Iverson (Intro)	Assessing Forest Species Risk and Adaptability to Climate Change via Species Distribution Models, Life History Traits, and Dispersal Models
14:40	Heike Lischke	Swiss Forests under a Changing Climate: Is Migration Limiting?
15:00	Juergen Kreyling	Intraspecific Variation Buffers Projected Climate Change Impacts on *Pinus contorta*
15:20	Christophe Randin	Do the Elevational Limits of Deciduous Tree Species Match their Thermal Latitudinal Limits? Implications for Climate Change Projections
15:40	BREAK	

16:00	Ervin Rasztovits	Extreme Drought Events Improves Modelling of Beech Persistence at its Distribution Limit in Hungary
16:20	Jan Wunder	To Grow or to Defend – on the Competition Dynamics of Fast-Growing Neophytic Trees in Southern Switzerland
16:40	Lisa Erdle	Forty Years of Treeline Change in the Swiss Alps
17:00	Anita Roth-Nebelsick	Gas Exchange and Climate: Analysing Interferences of Temperature, Humidity and CO_2 by the Optimality Approach
17:20	Lluís Coll	Simulating the Dynamics of the Pyrenean Montane-Subalpine Ecotone in a Climate Change Context Using the Model SORTIE-ND
17:40	Giorgio Vacchiano	Decline and Succession of Scots pine in NW Italy in Response to Future Climate Scenarios

16:10–18:15 (Room C6): Veronika Braunisch, Rudi Suchant and Raphaël Arlettaz

Challenges in Forest Biodiversity Conservation under Climate Change (Session 12)

16:10	Jörg Müller (Intro)	On the Uncertainty of the Biodiversity in Forests of the Future
16:40	Géraldine Hildbrand	Functional Responses of Two Dominant Species of Pasture-Woodlands to Simulated Climate Change
17:00	Thomas K. Gottschalk	Can Adaptation in Forest Management Mitigate Climate Change Impacts on Bird Species?
17:20	Veronika Braunisch	Mountain Forest Biodiversity under Climate Change: Compensating Negative Effects by Increasing Structural Richness
17:40	Maxime Cailleret	Climate Change and Wildlife Management Interacting Effects on Forest Dynamics in a Protected Area

Wednesday, 4th September

PLENARY SESSIONS (Room C60)

Keynotes

8:15	Lorena Gómez-Aparicio	Climate Change Impacts on Tree Regeneration: Implications for Forest Dynamics in a Drier World
13:20	Harald Bugmann	Tree Population Dynamics and Climate Change: Challenges for Understanding and Modeling

Concluding remarks

17:45	Thomas Wohlgemuth	Head Organizing Committee, WSL Birmensdorf

PARALLEL SESSIONS

09:05–12:30 (Room C60): Konstantin von Teuffel and Peter Brang

Adapted Forest Management (Session 11)

9:05	Manfred Lexer (Intro I)	Adaptation Measures in European Forestry. What will be the Impact on Ecosystem Services?

9:30	Marc Hanewinkel (Intro II)	Economic Consequences of Climate Change for Forest Owners and Uncertainty Management
9:55	Rémy Gobin	Understorey Plant Contribution in Water Balance Along a Gradient of Oak Stand Density
10:15	BREAK	
10:35	Niklaus E. Zimmermann	Models of Growth Potential and Habitat Suitability Give Partly Divergent Answers To Climate Change Impact Assessments
10:55	Ulrich Kohnle	Regional Differences in Growth Trends at the Stand-Level Derived from Data of Periodically Measured Experiments (Southwest Germany)
11:15	Susana Pérez	Impacts of Management and Climate Change on Ecosystem Services in Generic Major Alpine Forest Types
11:35	Olivier Picard	From Science to Practice: The French Foresters Experience
11:55	Peter Brang	Will the Pieces of the Puzzle Fit? An Itinerary to Synthesize Research to Useful Guidelines for Adapting Forest Management to Climate Change

09:05–15:15 (Room C6): Jürgen Kreyling and Thomas Wohlgemuth

Adaptability of Tree Species to Climate Change (Phenotypic Plasticity, Genotypic Variation; Session 10)

9:05	Greg A. O'Neill (Intro)	Seed Sourcing 2.0: Assisting Assisted Migration
9:35	Stefan Kapeller	Climate Impacts on Tree Height Variability within Norway spruce Populations
9:55	Aline Frank	Adaptive Genetic Variation of Spruce, Fir and Beech in Switzerland: First Results from a Genecological Study
10:15	BREAK	
10:35	Barbara Moser	Soil Characteristics not Provenances Are Important for *Pinus sylvestris* and *Picea abies* Recruitment under Climate Change
10:55	Silvio Schueler	Effects of Weather Conditions During Seed Maturation on the Adaptive Performance of Seedlings and its Contribution to the Adaptation of Trees to Future Climates
11:15	Madeleine S. Günthardt-Goerg	Querco: Swiss Oaks Resistance to Air Warming and Drought
11:35	Steffen Taeger	Effects of Heat and Drought on Seedlings of Scots Pine (*Pinus sylvestris* L.) Provenances
11:55	Christoph Bachofen	Frost Sensitivity Limits Assisted Migration of Pinus halepensis but not *Pinus nigra* into Regions with Spring Frost
12:15	LUNCH	
13:20	Keynote Harald Bugmann (Room C60)	

14:20	Armando Lenz	Adaptation and Plasticity of Winter Freezing Resistance in European Beach Populations Along a Temperature Gradient
14:40	Arvo Tullus	Adaptability of Deciduous Trees to Increasing Air Humidity in Hemiboreal Forest Zone (Estonia)

14:10–17:35 (Room C60): Damian Bonal and Michael Scherer-Lorenzen

Sensitivity and Resilience of Mixed Forests to Climate Change (Session 4)

14:10	David A. Coomes (Intro)	Applications of Airborne Lidar and Inventory Datasets to Modelling the Sensitivity and Resilience of Mixed Forests to Climatic Change
14:40	Liam Cavin	Extreme Drought Alters Competitive Dominance within and between Tree Species in a Mixed Forest Stand
15:00	Rubén D. Manzanedo	Effects of Forest Biodiversity on Local Adaptation to Climate
15:20	BREAK	
15:40	Melissa A. Dawes	Species-specific Tree Growth Responses to CO_2 Enrichment at the Alpine Treeline: Ecosystem Consequences
16:00	Charlotte Grossiord	How do Environmental Conditions Influence the Biodiversity-Ecosystem Functioning Relationship in Boreal Forests?
16:20	David I. Forrester	Complementarity in Mixed-species Stands of *Abies alba* and *Picea abies* Varies with Climate
16:40	Francesco Cortini	Climate, Site Preparation, and Trembling Aspen Competition Effects on White Spruce Growth in Boreal Forests of Western Canada
17:00	Xavier Morin	Impact of Climate Change on the Diversity-Productivity Relationships in European Temperate Forests

15:30–17:35 (Room C6): Ivano Brunner

Responses of Tree Roots (Including Mycorrhizas) to Climate Change (Session 3)

15:30	Douglas L. Godbold (Intro)	Responses of Tree Roots to Climate Change
16:00	Adele Ferrari	Tracing Radiocarbon in Plant and Soils of High Altitudes at Different Soil Temperatures
16:20	René Kerner	Effects of Drought on Proteins of the Ectomycorrhizal Fungus Cenococcum geophilum Fr.
16:40	Brian Tobin	Contribution of Root Debris to Forest C-Sequestration in a Changing Climate
17:00	Robert Jandl	Management Options for a High Elevation Forest

Keynotes

K1: Climate Projections for Central Europe

Knutti, Reto
Swiss Federal Institute of Technology ETH, Zurich, Switzerland

There is clear and widespread evidence that climate on Earth is changing rapidly, and human influence is very likely to be responsible for many of the observed trends. The current large scale trends of warming are almost certain to continue in the near future, but in order to make decisions for mitigation and local adaptation, we need to know how the climate will change locally, and how extreme rainfall and heat waves for example are likely to change. To predict that, we have to rely on complex numerical computer models, which describe the dynamics, thermodynamics, and the physical, chemical, biological and geological processes of the atmosphere, ocean, land surface, biosphere and cryosphere. This keynote briefly discusses the concepts of global and regional climate models, the different complexities, and the history of how have been used to predict future climate change. It then presents an overview of how climate is likely to change in the next decades to centuries from global to local scales. A particular focus is set on climate projections for temperature and precipitation as well as extreme weather events for Central Europe, based on the recent Swiss Climate Change Scenario Report CH2011. Recent developments in methods to quantify uncertainty in predictions, limitations in current models and uncertainties in the emission pathways are discussed.

K2: Forest Policy in a Changing Climate – What Are We Expecting from Scientists?

Manser, Rolf
Swiss Federal Office for the Environment, Bern, Switzerland

Climate change will proceed at a rate which is faster than the natural capacity of forests and trees to adapt to the new conditions. Moreover, there are large uncertainties regarding future temperatures and the amount and distribution of precipitation. Climate change is a serious challenge for forests, forest owners and the objectives of forest policy. How can the goods and services of our forests be maintained under changing climate conditions? Answers to this intricate question have to rely on a sound scientific basis. With a view to gradually minimize uncertainty we need more information in the following fields: How do tree species and forest stands react to climate change? What does this mean for forest goods and services? Which tree species and provenances are best adapted to future climate conditions? What are the costs / the benefits of adaptation strategies, and what are the risks involved? Forest science is a discipline that traditionally needs rather long research phases to produce reliable information. Nevertheless information on promising strategies will soon be needed as today's seedlings will grow in a climate which might be very different when they are grown up. From a practical point of view, existing forests will have to be conduct into ecosystems with an increased adaptive capacity. This has to be reflected in modeling exercises as well as in the tools developed for the practitioners. It makes sense to build on already existing methods and to further develop them.

K3: Drought Stress as a Core Driver of Forest Disturbances and Tree Mortality: A Global Perspective

Allen, Craig D.
U.S. Geological Survey, United States of America

Recent global warming, in concert with episodic droughts, have been causing elevated levels of both chronic and acute forest water stress across large regions. In turn, such increases in water stress amplify the incidence and severity of many significant forest disturbances, including drought-induced tree mortality, wildfire, and outbreaks of damaging insects and diseases. Comparative patterns of drought stress and various forest disturbances are reviewed for several regions (southwestern Australia, Inner Asia, western North America, Mediterranean Basin), including interactions among climate and various disturbance processes. Emerging global-scale patterns and trends of drought-amplified forest die-off and large high-severity wildfires ("mega-fires") also are addressed. From the southwestern USA, new research is presented that derives a tree-ring-based Forest Drought Stress Index (FDSI) for the most regionally-widespread conifer species (*Pinus edulis, Pinus ponderosa*, and *Pseudotsuga menziesii*), demonstrating recent nonlinear escalation of FDSI to levels unprecedented in the past 1000 years, due to both drought and especially recent warming. This new work further highlights strong correlations between drought stress and amplified forest disturbances (fire, bark beetle outbreaks), and projects that by about CE 2050 anticipated regional warming will cause mean FDSI values to reach extreme levels that may exceed thresholds for the survival of current tree species in large portions of their current range. Similar patterns of recent climate-amplified forest disturbance risk are apparent from a variety of relatively dry regions, and given climate projections for substantially warmer temperatures and greater drought stress for many areas globally, the growing water-stress risks to forest health in such regions are becoming clearer. Still, many scientific uncertainties remain, e.g., diverse compensatory and resilience-enhancing mechanisms and processes exist at scales ranging from intracellular tree physiologies and individual tree developmental and morphological processes to forest stand-level structural, compositional, and genetic responses up to landscape-scale feedbacks – how might these ameliorate potential rates of forest disturbances, even in dry regions? How can forest management practices modify on-site water balances to better sustain current forests and associated ecosystem services? How much risk does climate-induced forest drought stress present for: cooler and/or wetter regions, e.g., Central Europe or alpine and northern boreal tree-lines, where tree growth historically has been less water-limited; or places where tree growth and forest health remain robust or are improving; or places where both precipitation and temperature are projected to increase? Recent research efforts that address such key scientific uncertainties associated with climate-induced tree mortality and forest disturbances will be presented.

K4: The Climate Sensitivity of Radial Tree Growth across Europe

Frank, David
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Forested biomes contain the largest terrestrial carbon pools and currently buffer global warming by tempering the rise in atmospheric CO_2 concentrations. However, a limited understanding of forests' climate sensitivity contributes to widely divergent estimates of their past and future carbon sink capacities. To reduce these uncertainties, more extensive empirical data are needed to quantify forest growth dynamics and link tree growth to climate variability across societally relevant spatial domains and time-windows within policymakers' horizons. Annual growth rings of trees are a natural archive that fulfills these needs. In this talk I will present new quantification for the climate sensitivity of radial tree growth from intra-annual to multi-centennial time-scales. Emphasis will be placed on European-wide analysis of major tree species made possible by compiling and harmonizing tree-ring data collected over the past 40 years into an extensive European tree-ring network, as well as newer sampling campaigns along elevational gradients and at eddy-covariance sites where global climate change questions are specifically targeted. I will show new research avenues using long-term empirical data to test and validate (or falsify) Earth system models. We find e.g., that Dynamic Global Vegetation Models tend to underestimate the temperature sensitivity in the boreal zone and overestimate the precipitation sensitivity towards the mid-latitudes. Our results furthermore emphasize the importance of species-specific growth characteristics and lagged climatic effects – considerations necessary for the next generation of vegetation models. I will conclude by describing uncertainties remaining in assessing the climate sensitivity and future changes in forest productivity from tree-ring records, and will provide research strategies for the next decade to tackle these questions.

K5: Nitrogen Cycling in Forest Ecosystems in a Changing Climate

Rennenberg, Heinz
University of Freiburg, Germany

Many tree species have developed in evolution on marginal soils with low nutrient availability. Therefore, trees are thought to be highly adapted to multiple nutrient limitations, in particular of nitrogen and phosphorus, and to possess a low nutrient demand for growth and development. The latter was found not to be correct for temperate forest species such as spruce or beech that require more than 100 kg N ha^{-1} a^{-1} in mature forests and, thus, have a similar nitrogen demand as reported for many agricultural systems. Apparently, high N demand at low N availability in temperate forest trees is rather met by long-term ecosystem N accumulation in a largely closed ecosystem N cycle. Since water relations and nutrient acquisition of trees are known to strongly interact with each other, it may be assumed that changes in precipitation and precipitation distribution, as projected from global climate change at the regional level, have the potential to impair processes within the closed ecosystem N cycle of temperate forest and, hence, tree N nutrition. This is of particular significance for beech, the potential natural vegetation in large areas of Central Europe. This tree species is considered highly sensitive to drought, but is highly abundant all over Europe in ecosystems on calcareous soils with low N availability and low water storage capacity. Recent projections on future distribution of beech estimate that this tree species may be largely extinguished on calcareous soils until 2080 as a consequence of global climate change. We hypothesize that this may not only be due to the fragile water relations of beech, but also to disturbance of processes in ecosystem N cycling. In this lecture experimental approaches with beech trees under greenhouse conditions and in the field will be reported that were aimed to test this hypothesis. These approaches include exposure of young beech to labeled litter, girdling of young and mature trees, as well as exchange of monoliths with young beech trees between cool moist and warm dry forests. The results of these studies clearly show that processes at the beech tree and the microbial community level as well as the competitive interaction of beech trees and microbial communities for N are strongly affected by drought and mediate severe changes in ecosystem N cycling.

K6: Disentangling Responses to Climate Change versus Broader Anthropogenic Impacts in Forests of the Eastern U.S.

Canham, Charles D.
Cary Institute of Ecosystem Studies, United States of America

In the face of rapid environmental change and given the inherently long time scales of tree population dynamics, it seems inescapable that forests are increasingly in disequilibrium, lagging in their responses to anthropogenic changes in the physical and biotic environment. Anthropogenic impacts on forests of the eastern U.S. include (1) climate change, (2) changes in logging regimes, (3) the litany of introduced pests and pathogens that are profoundly changing eastern U.S. forests, and (4) changes in the atmospheric environment, particularly rates of nitrogen (N) deposition and CO_2 concentrations. My research uses a spatially-explicit, individual-based model of tree population dynamics (SORTIE-ND, www.sortie-nd.org) that is linked to continental-scale forest inventory data maintained by the U.S. Forest Service (http://www.fia.fs.fed.us/). Preliminary results indicate that the direct effects of climate change on the distribution and abundance of tree species in the eastern US will be relatively small over the next 50–100 years, in part because climate impacts on sapling and adult tree growth and survival are relatively small. Climate impacts on seedling recruitment and survival appear to be much stronger, but the current occupants of a site have both a numerical and competitive advantage over new colonists. This provides a great deal of inertia to forest structure and composition, and analyses with the model suggest that this inertia would remain even in the absence of dispersal limitation. Tree species in the region show a wide range of responses to current rates of N deposition, and in many of the species the magnitude of expected response to anticipated future reductions in N deposition is of the same magnitude as the expected response to anticipated future temperature increases. Both historical and current harvest regimes are driving successional dynamics that can be expected to result in large changes in both forest structure and composition at a regional scale. Those successional dynamics are promoting the abundance of two late successional species – eastern hemlock and beech – that are currently threatened by introduced pests or pathogens. Processes that supplement the natural mortality rates of adult trees, whether through harvesting or the actions of introduced pests or pathogens, may accelerate the effects of climate change by opening the canopy and allowing new tree recruitment. Models provide the only real tool to integrate these disparate effects, and analyses with SORTIE-ND have all the hallmarks of complex system behavior, including initial condition dependence but predictable general features of system recovery following perturbation.

K7: Climate Change Impacts on Tree Regeneration: Implications for Forest Dynamics in a Drier World

Gómez-Aparicio, Lorena
Spanish National Research Council CSIC, Spain

The sensitivity of early plant regeneration to environmental constraints makes regeneration a critical stage for detecting potential impacts of climate change on tree population and community dynamics. General Circulation models predict an increase in mean temperatures and a higher frequency of extreme climatic events. The ongoing increase in aridity could have serious consequences for tree regeneration in already dry regions, such as the Mediterranean Basin, where summer drought is a main limitation for seedling establishment of virtually all tree species. Experimental studies that have manipulated rainfall and temperature levels in Mediterranean forests have shown that the expected changes in climate, particularly the decrease in rainfall, could cause a reduction in emergence, survival and early growth of many tree species. However, they also suggest that the magnitude of this impact will not only depend on changes in mean climatic values, but even more importantly on changes in the frequency and balance of extremely dry and wet years. Because community dynamics are the result of replacement patterns, an additional concern is that such reductions in regeneration would make difficult to compensate for the increasing rates of adult mortality observed and expected for several tree species in a drier world. This lack of demographic compensation could cause a progressive loss of tree cover in favor of more drought-resistant shrubs, promoting a shrub-encroachment process. Despite these generalities, many uncertainties still remain about the potential interactions of climate change with other factors that could filter climate effects on regeneration, such as soil properties or biotic interactions. Recent studies suggest that these interactions could bring unexpected and counterintuitive results. This talk will present a general overview of our current knowledge about climate change impacts on regeneration dynamics in water-limited Mediterranean forests, offering insights into regeneration in temperate Central European forests where increasing drought stress is becoming a significant problem.

K8: Tree Population Dynamics and Climate Change: Challenges for Understanding and Modeling

Bugmann, Harald
Swiss Federal Institute of Technology ETH, Zurich, Switzerland

Forests play a key role at local to global scales, and their future development thus is of utmost concern not only from a scientific, but also a societal point of view. Our ability to model future tree population dynamics is hindered by a number of factors, including the inadequate temporal and spatial scale of experimental approaches, the insufficient length of most observational time series, and problems with adequate formulations to capture the key ecological processes in models of long-term forest dynamics. In this contribution, I will review these factors and ways to handle them, with the expectation that our predictive understanding can be improved by the skillful combination of approaches and methods. Particularly, I will focus on tree mortality as a process that (1) could lead to dramatic impacts in a global change world, and (2) has attracted a lot of attention over the past years. At the level of empirical mortality models, it appears that approaches combining tree-ring and wood-anatomical data are quite promising because the resulting models feature a fairly high generality (as seen from a case study in the southwestern United States), which does not appear to be the case with the available tree-ring models (as suggested by a range of studies in central Europe). However, implementing such mortality models in succession models does not appear to be feasible at the moment, because wood-anatomical properties are not incorporated in any of the available approaches. Thus, the question arises how to proceed towards the next generation of forest succession models. Greatly increasing their complexity is not a way forward, I believe, and I will explain why this is so. Furthermore, cross-links between mortality and other processes such as tree growth rates need to be taken into account. Again, these are not considered in most dynamic modeling approaches, but they could have strong consequences for the future speed of successional processes and the resulting ecosystem properties such as biomass or species composition. I conclude that although multiple challenges remain, there are promising options to pursue in the future by combining empirical with dynamic modeling approaches.

Session 1 and 2: Disturbance Ecology and Management in a Changing World

Disturbance in Forest Ecosystems: A Process-Based Approach to Understanding and Prediction of Damage in a Changing Climate (Introductory Talk I)

Gardiner, Barry Alan; Mart-Jan Schelhaas

Disturbance is a natural part of forest ecosystem functioning that creates opportunities for forest regeneration and helps support biodiversity. Natural forest ecosystems have developed resilience to these disturbances through a built-in plasticity that allows trees to respond and adjust to disturbance agents and to adapt to changing climatic conditions. However, the rapid pace of contemporary anthropogenic climate change means that this inherent resilience is likely to be insufficient for many species. Consequently there is potential for very serious and critical disturbance events in the future that not only lead to unprecedented levels of damage but significant changes in forest functioning and the services we rely on from our forests. In this paper we will discuss disturbance from the perspective of physical and predictable process and their impact on forest ecosystems. In particular we will focus on the tools and knowledge that are becoming available and which allow calculation of the future risk of damage to forests from key abiotic and biotic agents. We will focus in particular on disturbance in managed European forests, on the impacts of this disturbance, how different disturbance agents interact with the forest and with each other, and how we might forecast damage levels under a changing climate. In addition we will discuss how forest management affects the vulnerability of forests and possible strategies for modifying management approaches in order to better incorporate disturbance as a natural part of forest functioning.

Intensifying Natural Disturbance Regimes and Implications for Forest Management (Introductory Talk II)

Seidl, Rupert

Natural disturbance regimes have intensified considerably in forest ecosystems around the globe in recent decades. In Europe, the damage from wind, bark beetles and wildfire on record for the decade 2001–2010 strongly exceeded all previous decades for all three disturbance agents. Both climatic changes as well as changes in the structure and composition of forest ecosystems are contributing to this trend of intensifying natural disturbance regimes. Considering that a continuation of anthropogenic climate change is highly likely, and that Europe's forests will continue to age (the current age-class distribution is positively skewed), a prolongation of this trend towards more frequent and severe disturbances has to be expected. In this talk I will briefly review what disturbance trends are already evident in (central) Europe, and what might be expected for the future. I will furthermore discuss possible impacts of intensifying disturbance regimes on ecosystem services, and the implications that follow for ecosystem management. I will argue that managing disturbances, and, more generally, risks, will (have to) become a central element in the forest ecosystem management of the future, and advocate for strategies that anticipate risks and foster resilience in management.

Swiss-wide High Resolution Simulations of Forest Dynamics with LPJ-GUESS

Scherstjanoi, Marc; Kaplan, Jed Oliver; Lischke, Heike

To be able to simulate climate change effects on forest dynamics over the whole of Switzerland, we adapted the second generation DGVM LPJ-GUESS to the Alpine environment. We modified parts of the model's leaf phenology and establishment functions, particularly tuned temperature and drought stress related model parameters, and implemented new tree species to represent the potential natural vegetation of Alpine landscapes. To enable area-covering simulations in a fine resolution (1 km) we applied the recently developed upscaling method GAPPARD. GAPPARD approximates results of disturbance-including, gap approach-based model simulations by upscaling results of disturbance-free, deterministic simulations in a postprocessing way. The approximated mean output values are derived from a combination of deterministic simulation runs and a patch age distribution defined by the disturbance frequency. We used the adapted LPJ-GUESS together with GAPPARD to assess the influence of one A1B climate change scenario on dynamics of tree species composition and biomass throughout the 21st century in Switzerland. Thus, for the first time, area-wide, detailed high resolution LPJ-GUESS simulation results for a large part of the Alpine region could be obtained. Our results indicate a high sensitivity of forest biomass to an increasing atmospheric CO_2 and a high sensitivity of single species developments to the species composition and to competition effects.

A Simulation Tool for Assessing Future Wind Disturbance Impacts on Forest Landscapes

Rammer, Werner; Seidl, Rupert; Blennow, Kristina

Wind is the most detrimental disturbance agent in Europe's forest ecosystems. In recent years, disturbance frequency and intensity have increased at continental scale, a trend that is expected to continue under anthropogenic climate change. We here present a process-based model of wind disturbance impact on forest ecosystems, integrated into the dynamic landscape simulation model iLand (the individual-based forest landscape and disturbance model). The wind model operates at the level of individual trees, calculating the turning moment and critical wind speed for stem breakage and uprooting. Through accounting for newly created edges during a wind event the simulated disturbance size, pattern, and severity are an emergent properties of the simulation. We evaluated the new model against satellite-derived wind damage data of the storm Gudrun (January 2005) at a 1391 ha forest landscape in south central Sweden. Both the overall damage percentage (observation: 21.7%, simulation: 22.4%) as well as the comparison of spatial damage patterns documented good correspondence between observations and predictions (prediction accuracy: 62.6%). In addition, an extensive sensitivity analysis showed that potential climate change-related alterations of wind speed and soil frost may influence wind disturbance impacts on forest landscapes significantly.

Combining an Individual-Tree Forest Growth Model with Storm Damage Modeling – Approach and Results of Silvicultural Scenarios

Albrecht, Axel T.; Fortin, Mathieu; Kohnle, Ulrich; Ningre, François

In this study, we combined two models in order to account for extreme windstorm events in forest growth simulations. We used the forest growth simulator BWinPro, an individual-based, distance-independent model. We implemented a storm damage model into this forest growth simulator using the Java programming language. The storm damage model predicts the probability of damage at the individual tree level and represents storm damage from storms that occurred in Southwest Germany between 1960 and 2007. Using this combined modeling system we ran different silvicultural management scenario simulations of 50 years with generated model forest stands. Two different silvicultural regimes were tested: (1) a baseline scenario representing average treatment regimes in nowadays state forests (2) an intensified management scenario in which reduced rotations and target diameters are combined with heavy thinnings. The simulation results show that storms – as one example of extreme climatic events – have significant impact on forest dynamics. Especially in older coniferous stands, average cumulated storm damage can amount to 80% of total volume production. Storm damage was significantly reduced by intensifying forest management in scenario 2. However, variability of results increased under this scenario.

The Sensitivity of Wind and Bark Beetle Disturbance to Slow and Fast Drivers in Central European Forests

Thom, Dominik; Seidl, Rupert; Krehan, Hannes; Steyrer, Gottfried; Formayer, Herbert

Disturbance regimes have intensified in Europe's forests in recent decades, and are increasingly exerting negative impacts on the provisioning of forest ecosystem services. Our understanding of the sensitivity of disturbance regimes to climate and management – a prerequisite for adaptation to such an intensification – is still underdeveloped. We investigated the drivers of the two most detrimental disturbance agents in Central Europe's forests, wind and bark beetles, utilizing district-level disturbance observations for Austria for the period 2002–2010. In a two-stage approach we first analyzed the influence of slow, predisposing variables (i.e., climate, vegetation, stewardship), and subsequently the role of fast, inciting factors (i.e., weather, spatio-temporal disturbance interactions) on observed disturbance levels. Overall, our analysis explained 48.7% (wind) and 67.1% (bark beetles) of the spatio-temporal variation in disturbance damage. Variables related to forest structure and composition were found to influence the predisposition to both disturbance agents more strongly than climatic factors. Weather-related variables and temporal interactions within the disturbance regime were the most prominent inciting factors. Our results underline the potential of forest management to offset the currently ongoing disturbance intensification. However, they also indicate that shifts in both climate means and extremes could strongly affect forest disturbance regimes.

Drivers of Wind and Bark Beetle Disturbances in Austria

Pasztor, Ferenc; Rammer, Werner; Zuvela-Aloise, Maja; Matulla, Christoph; Lexer, Manfred Josef

Storms and spruce bark beetles (*Ips typographus* (L.)) are the two major natural disturbance factors threatening forests in Austria. While timber salvage statistics at national level are frequently used to speculate about the future role of disturbances and about the interrelationships among disturbance factors, sound quantitative knowledge on the main drivers at operational scale of compartments is scarce. We developed binomial generalized linear mixed models (GLMMs) to study the effects of climate, site and stand properties on the annual probability and linear mixed models (LMMs) for the intensity of disturbance events. The data used for model fitting was based on decadal management plans and harvesting records of the Austrian Federal Forests in four management units covering more than 40 000 hectares for a period of six years and climate data provided by the Austrian Central Institution for Meteorology and Geodynamics. Climate data served as means for studying effects of external drivers on disturbance regimes, which may be altered by future climate change. An information theoretic (IT) approach was used to find models that best describe observed data. In the models, timber stock volume and previous disturbances were the most influential explanatory variables. Implications for future management are discussed.

Selective Browsing and Bark Beetle Damages under Climate Change: Interacting Disturbances Affect Ecosystem Service Provisioning

Maroschek, Michael; Rammer, Werner; Lexer, Manfred Josef

Browsing by ungulate game species and disturbances by bark beetles are amongst the most important disturbance processes in Alpine forests. Depending on browsing pressure timely regeneration may be severely impeded or impossible. Selective browsing is able to shift species composition towards less palatable tree species like Norway spruce *(Picea abies)*. Across the Alps damages by the European spruce bark beetle *(Ips typographus)* have been increasing and are projected to further increase under warming climatic conditions, strongly impacting forest ecosystem services. To shed light on the effect of browsing on bark beetle damages, the hybrid forest ecosystem model PICUS is applied to a case study in the Eastern Alps, covering a simulation period of 100 years. The model features browsing and European spruce bark beetle modules. A set of climate and browsing scenarios is applied to a selection of representative Alpine forest types. Under current browsing pressure bark beetle damages increase dramatically under warmer climatic conditions. Reducing browsing pressure will decrease bark beetle damages due to an increased share of other species than Norway spruce, but depending on the magnitude of reduction considerable time-lags exist. This calls for immediate action and additional adaptation measures to sustain mountain forest ecosystem services.

Spatially Explicit Simulations of Snow Avalanches in Swiss Alpine Forests under Climate Change

Zurbriggen, Natalie; Nabel, Julia E.M.S.; Teich, Michaela; Bebi, Peter; Lischke, Heike

Snow avalanches are one of the most important disturbances in the Swiss Alps, affecting humans and ecosystems. Forests can protect against avalanche release, but the protection depends on many factors such as topography, forest density and type, and climate. The interaction between forests and avalanches leads to a positive feedback: forests reduce avalanche release probability and avalanches reduce forest cover. Due to the complex feedback, the influence of climate change on forest ecosystems influenced by avalanches is difficult to project. We combined the dynamic spatially explicit forest landscape model TreeMig with a new empirical avalanche module, to examine the effects of temperature and topography on forests influenced by avalanches. We found that with warmer climate in the Davos study area, simulated avalanches decrease where forest density increases and where snowfall decreases. However, due to new combinations of topography, climate, and forest types in future climate change scenarios, small avalanches were simulated in previously avalanche-free areas. Our simulations suggest that under climate warming, avalanches will remain important and spatial patterns of avalanche-prone areas will show complex changes. Therefore, we suggest that dynamic and spatially explicit simulations of avalanche-forest interactions should be included in projections of future forest dynamics under climate change.

Shifting Tree Species Dominance and Corresponding Landscape Structure in Wood-Pastures in a Changing Climate

Peringer, Alexander; Gillet, Francois; Buttler, Alexandre

Wood-pastures are diversely structured forest-grassland mosaics, which emerge from multiple disturbance regimes at several scales such as grazing and browsing of livestock, logging, wind throw, climatic extremes and long-term climatic fluctuations. Due to the complex spatio-temporal interactions, wood-pasture ecosystems are very vulnerable to climate change. We applied a computer model of wood-pastures (WoodPaM), which simulates the emergence of forest-grassland mosaics in the Swiss Jura mountains based on successional transition rates between grassland vegetation types, growth rates of tree species, cattle habitat preferences, grazing impacts and climate scenarios (temperature and precipitation). A retrospective analysis since the Middle Ages revealed the sensitivity of the forest-grassland mosaic to historic climate fluctuations (Little Ice Age) and grazing pressure, while the system maintained its overall resilience in terms of dominant tree species and landscape structure. Simulated climate warming and droughts, however, triggered shifts in tree species composition from currently dominant Norway spruce to European beech or even Scots pine in an extreme scenario. Unexpectedly, due to the different regeneration strategies and resistance against browsing of spruce, beech and pine, the simulated structure of the grassland-forest mosaic shifted from a dispersed to a clumped pattern in case of beech immigration, or to homogeneous thin pine forests.

Fire Effects and Post-Fire Management on Beech Forests in the Southern Alps

Maringer, Janet; **Ascoli, Davide**; Wohlgemuth, Thomas; Bovio, Giovanni; Conedera, Marco

Fire disturbance in European mountain forests is expected to increase due to global changes. First signs could already be observed during the heat wave in the summer 2003 causing exceptional large fires in beech stands in the southern Alps. Beech is considered a fire sensitive species but post-fire regeneration dynamics are poorly understood and best practices to restore beech forests are missing. To address these issues we implemented a sampling design simulating a chronological sequence from 1970 to 2007 based on 27 burnt sites along the southwestern Alps, which differ in-terms-of fire severity, post-fire-masts and -management. Post-fire canopy cover was related to variables influencing fire intensity and severity, e.g. fire weather indices, topography. Where fire severity was high, canopy opening was immediate and early succession stages were dominated by pioneer species. In moderate severity sites, mortality was progressive and delayed what allowed beech seedling to emerge under intermediate light-conditions and in coincidence with mast years. In managed sites, cutting provided higher beech regeneration right after a mast year, in comparison to unmanaged stands or delayed cuts. Silvicultural measures to restore beech forest after fire should account for the timing of the canopy opening and the time-lag between fire, masting, and cutting.

Analyzing the Response of Mediterranean Forests to the Combined Effects of Changes in Drought and Fire Regimes: Insights from a Landscape Simulation Model Based on Vital Attributes

De Cáceres, Miquel; Brotons, Lluís; Martínez-Vilalta, Jordi; Pausas, Juli

With the decline of agricultural and forest management activities, the current drivers of vegetation dynamics in many regions of the Mediterranean basin are the availability of water and light resources as well as the impact of fire disturbances. This often leads to complex landscape dynamics arising from the interplay between ongoing succession and wildfires, both processes being strongly modulated by climatic conditions. In order to investigate the potential responses of Mediterranean forests to climatic changes predicted for the 21st century, we developed MEDFATE, a spatially explicit landscape model that extends the FATE vegetation succession model. Taking Catalonia (NE of Spain) as study area and Spanish Forest Inventory data for the initialization of the model, we simulated the fate of several Mediterranean oak and pine species under different scenarios defined by decoupling climatic effects between those related to fire regime and those related to drought-driven mortality. The model predicted, under all scenarios, substantial increases in occupancy and basal area for most trees during the first half of the century. However, in the second half of the century several tree species were predicted to accumulate important losses as a result of either water limitations or fire impacts, or both. Aleppo pine was among the most favored species due to its drought resistance and ability to regenerate in burned areas. Moreover, drought-driven mortality events increased the vulnerability of stands to burn as crown fires, indicating complex interactions between both drought and fire impacts.

Contrasting Response of Two Mediterranean Species to Nitrogen Deposition

Fusaro, Lina; Salvatori, Elisabetta; Mereu, Simone; Manes, Fausto

Atmospheric nitrogen (N) deposition is increased in many natural and semi-natural ecosystems. Serious gaps in knowledge exist on the effects of enhanced nitrogen deposition on Mediterranean forests. In a open environment experiment, we have evaluated the response to N addition (30 Kg ha yr^{1}), on two Mediterranean woody species differing for leaf habitus (the evergreen *Quercus ilex* L. vs the deciduous *Fraxinus ornus* L.). For the first experimental period all plants were watered at field capacity (W) and N was added weekly. After this period, the irrigation was suspended (WS) and interaction (WSN) was considered. Nitrogen addition has only slight effects on biomass storage in decidous species, but significantly change in evergreen. For F. ornus assimilation rate reduction is less intense than in WS plants than WSN, although there isn't difference YPD between experimental set. Q.ilex has exchange reduction was more marked in WS than in WSN. On the other hand Q.ilex both gs and PN were significantly lower in WSN than in WS. Finally, N addition might improve stomatal control in water deficit conditions and the effects differs between evergreen and deciduous species. N addition could have great implication to understand ecological dynamics of vegetation in Mediterranean area.

Natural Disturbance Regime of the Largest European Primeval Beech Forest

Hobi, Martina Lena; Commarmot, Brigitte; Ginzler, Christian; Bugmann, Harald

In the context of climate change, forest ecosystems are expected to be affected by more frequent or severe disturbances. The largest primeval beech forest of Europe situated in the Ukrainian Carpathians is an outstanding object for understanding the natural characteristics of disturbance patterns and processes. By combining inventory, dendroecological and remote sensing data covering an area of over 100 km^2 inferences on recent and past disturbance events shaping the forests structure are drawn. The uneven-aged structure, the high abundance of old trees and the homogeneity of forest characteristics at larger spatial scales suggest, that the structure of this forest is defined by fine-scale processes. A gap density map derived from high-resolution satellite images reveals a low disturbance severity to be affecting this forest, leading to a small-scale mosaic of canopy gaps mainly ≤ 200 m^2, formed by the death of one to a few trees only, and stand-replacing events to be rare. Reconstructing the disturbance history based on tree-ring patterns provides strong evidence, that asynchronous small to moderate disturbances have shaped this forest in the past. The results of the three methodological approaches applied indicate, that this forest is in a dynamic equilibrium and may in the absence of catastrophic disturbance events maintain its structure in the long-run.

Tree Mortality in Self-thinning Subalpine *Picea abies* Forests

Panayotov, Momchil; Tsvetanov, Nickolay; Krumm, Frank; Kulakowski, Dominik; Bebi, Peter

Subalpine forests in European Mountains have changed much in the last century mostly due to reduced cattle grazing, decreased tree felling and limited or adapted management. As a result there are numerous 100–150 years old forests, which are in the self-thinning phase. High mortality, increase of dead wood and predictions for warming raise many questions for the future ability of such forests to maintain certain functions. To study the processes in subalpine forests we set six 22 x 22 m plots in unmanaged forest patches which established after stand-replacing disturbances in the Parangalitsa reserve in Bulgaria. We sampled all trees and extracted and analyzed tree-ring cores. We found that mortality rates increased after trees have reached ages of 40–50 years. Most trees died after they have experienced sharp growth reductions following years with climate anomalies. Summer droughts contributed more to mortality than cold spells. While at lower elevations most dead trees experienced one sharp growth reduction, at higher elevations tree mortality followed after 2 to 3 such events. Most trees lived for 10 to 30 yrs after the first growth reduction. Demography in self-thinning forests is traditionally thought to be driven by competition, however, our data show an important role of climate in mediating this mortality.

Session 3: Responses of Tree Roots (Including Mycorrhizas) to Climate Change

Responses of Tree Roots to Climate Change (Introductory Talk)

Godbold, Douglas; Smith, Andrew; Lukac, Martin; Göransson, Hans

The turnover of tree fine roots and mycorrhizal hyphae are critically important in soil C dynamics. However, both tree fine roots and mycorrhizas can be influenced by a range of factors associated with both physical and chemical climate change including soil temperature, drought and elevated atmospheric CO_2. This paper will address the effects of a number of climate change factors on the tree roots and mycorrhizas. Emphasis will be placed on the investigations carried out under elevated CO_2, as well as experimental tree mixtures grown under elevated atmospheric CO_2 or drought. Elevated atmospheric CO_2 has often been shown to increase the production of fine root biomass, but seems to have a lesser effect on the mycorrhizal extramatrical mycelium. To investigate the interaction between tree mixture and elevated CO_2, Alnus glutinosa, Betula pendula and Fagus sylvatica were planted in areas of single species and a three species polyculture in a free-air CO_2 enrichment study (BangorFACE). Fine root biomass and morphology responded differentially to the elevated CO_2 at different soil depths in the three species when grown in monocultures. In polyculture, a greater response to elevated CO_2 was observed in coarse roots, and fine root area index. Total fine root biomass was positively affected by elevated CO_2 at the end of the experiment, but not by species diversity. In plots of six year old stands of Alnus glutinosa, Betula pendula, Fagus sylvatica and the mixture of the three species, subcanopy roofs were constructed. The roofs covered 70% of the total area and were made of transparent plastic. Again, a differential response was shown between the species to drought was shown which was modified by tree mixture. These results will be discussed within the context of similar studies.

Tracing Radiocarbon in Plant and Soils of High Altitudes at Different Soil Temperatures

Ferrari, Adele; Hagedorn, Frank; Niklaus, Pascal A.

Treelines are associated to mean growing season temperatures of about 6 °C, suggesting low temperature to be the principal factor preventing trees from growing at higher elevations. It remains however unclear whether air or soil temperature limits plant growth, and whether belowground carbon allocation and plant growth respond similarly to temperature changes. We aimed to study whether, and how, soil temperature affects net plant carbon assimilation and allocation under treeline conditions. We established a soil temperature manipulation experiment in the Swiss Alps, at 2280 m a.s.l, with each a naturally occurring tree *(Pinus mugo)* and a forb species *(Leucanthemopsis alpina)*. The soil temperature treatment included ambient soil temperatures (control), warming by 6°C, and cooling by 6°C. Plants were pulse-labelling with $14CO_2$ under the respective temperature conditions and 14C quantified in plant tissue, soil microbial biomass, soil organic matter, and soil respiration. The allocation of 14C labelled assimilates correlated positively with soil temperature, both in below- and aboveground plant parts. Total soil respiration increased exponentially with soil temperature, while 14C in soil respiration supported the existence of a temperature threshold for carbon metabolization below ground. A similar pattern was observed for 14C in microbial biomass, probably reflecting suppressed rhizodeposition at lower temperatures.

Effects of Drought on Proteins of the Ectomycorrhizal Fungus Cenococcum geophilum Fr.

Kerner, René; Delgado-Eckert, Edgar; Del Castillo, Estela; Peter, Martina; Kuster, Bernhard; Tisserant, Emilie; Müller-Starck, Gerhard; Pritsch, Karin

Cenococcum geophilum is a widely distributed ectomycorrhizal fungus potentially playing a significant role in resistance and resilience mechanisms of its tree hosts when exposed to drought. Although the overall beneficial effect of the symbiosis between *C. geophilum* and their tree hosts has been well studied, the molecular responses to drought in both, the fungal organism itself and the fungal-plant interaction is poorly understood. Proteomic approaches have great potential for providing new insights on fungal- and ectomycorrhizae- related processes at the molecular level, but there is very little information on the application of such methods. In this study, we performed a large scale protein analysis to understand molecular mechanisms of drought regulation on the proteome of *C. geophilum* pure cultures. The results indicated that 12 proteins were differentially abundant in mycelia subjected to drought compared to controls. The induced responses in *C. geophilum* point towards regulation of osmotic stress, maintenance of cell integrity, and counteracting increased levels of reactive oxygen species formed during water deprivation. These mechanisms of drought resistance and tolerance are potentially relevant for alleviating plant drought stress.

Contribution of Root Debris to Forest C-Sequestration in a Changing Climate

Tobin, Brian

The decomposition of harvest residues in managed forests has an important influence on the carbon (and nitrogen) stocks of these ecosystems. Harvest residue amounts were evaluated (measured aboveground and estimated for belowground roots) after two thinning events in a first rotation Sitka spruce stand in the Irish midlands. Using various methods the decomposition rates of the various elements within the deadwood pool were estimated (logs, stumps, brash and coarse roots). Using these decomposition rates and the associated deadwood inputs, a cumulative stock of the deadwood carbon pool was established. The stand's future development was estimated, using a dynamic stand model (GROWFOR) and information from the forest management plan, and extended until rotation end at 41 years-old. A standard thinning regime was assumed and future harvest residue inputs were calculated, and the cumulative deadwood pool extended to estimate how long the carbon capital of the pool would persist into the second rotation (maintaining site sequestration rates as well as nutrition). The impact of anticipated changes to climate on this deadwood pool (and its component parts) are discussed as well as potential changes to management systems.

Management Options for a High Elevation Forest

Jandl, Robert; Schindlbacher, Andreas; Jandl, Nathalia

We simulated the growth of a subalpine Cembran pine forest under different climate and management scenarios for 1960 to 2100. The growth simulation model was Caldis, which is calibrated on data of the Austrian Forest Inventory, the soil carbon model was Yasso07. We wanted to derive a management plan that maintains the current biomass stock and conserves the forest carbon stock and that is economically feasible. We found that climate change improves the productivity. Even in the long run the positive effects of climate change prevail. A non-management scenario suggests a maturation of the forest without severe episodes of mortality. Due to the protected location the potential disturbance by storm is negligible. For economical harvest operations we defined a minimum amount of harvested stem volume. The target volume depends on the harvesting technique. At the present site the manual felling and the operation of a long-distance cable system is the only harvesting system which costs can be covered with the revenue from timber sales. The alternative combined method of manual fellings and timber transport by helicopter is far more expensive. An extensive form of management with partial harvests every 50 years allows the maintenance of the current biomass density. A more intensive management with harvests every 30 years leads to a decline in the aboveground biomass and a reduction of the soil C pool. Due to the limited distance from the valley bottom to the timberline it is hardly possible to extract the target timber volume with the long-distance cable system. Despite high prices for Cembran pine timber, as currently reported from the timber market, a sustainable forest management is hardly possible.

Diversity of Ectomycorrhizas on *Picea abies* Roots in Mixed Stand under Elevated CO_2

Cudlin, Pavel; Vasutova, Martina; Holub, Filip

Elevated CO_2 level is expected to shift ectomycorrhizal (ECM) community towards species characteristic of later successional stages and increase proportion of morphotypes that produced rhizomorphs, large amounts of extramatrical mycelium and thicker mantles. To study ECM community shift in condition of Central European mountain forests (Beskydy Mts.) we have investigated ectomycorrhizas of 9 year Norway spruce in mixed stands with beech (at 81 m^2) grown under ambient (365–377 µmol CO_2 mol^{-1}) and elevated (700 µmol CO_2 mol–1) CO_2 concentrations within glass domes with adjustable windows and on an open-air control site. Ectomycorrhizas were identified based on morphotyping and ITS rDNA sequencing, assigned to exploration type and classified into vitality classes. Based on our preliminary data, the total of 18 taxa of ECM fungi from 26 distinguished morphotypes was identified. Amphinema byssoides, *Piloderma sp.* and *Tuber sp.* are common for all sites. The total of 10–15 morphotypes was found on each site; no dominant morphotype was detected. ECM composition in site with elevated CO_2 differs in higher proportion of Ascomycetes species and low occurrence of Agaricales species. Percentage of turgid ECM tips is similar (40–45%). Most of ectomycorrhizas were assigned to contact exploration type, in contrast to literature data.

Growth Response of *Pinus cembra* to Experimentally Modified Soil Temperatures at the Treeline

Gruber, Andreas; Peintner, Ursula; Kubisch, Petra; Oberhuber, Walter

Temperature is the paramount factor controlling tree growth at high altitudes and it is suggested that aside of aboveground temperature also soil temperature has a direct effect on tree growth. We have evaluated the impact of elevated and reduced soil temperature on the development of *Pinus cembra* within the treeline ecotone (c. 2100 m a.s.l.). Soil temperature in the root zone of naturally grown ca. 50 year old trees was altered by shading and heat-trapping using non-transparent and glasshouse foils, respectively. We monitored radial growth, gas exchange, fine root turnover and ectomycorrhizal abundance and composition. Even though mean soil temperatures at 10 cm depth differed by 2.9° between treatments during the growing season, radial growth and needle gas exchange were not significantly affected in the first experimental year. Nitrogen availability was also not influenced by soil temperatures, but ectomycorrhizal abundance and composition and also fine root turnover responded to soil temperature changes. Whether prolonged soil temperature manipulation will lead to changes in aboveground tree growth and physiology will be revealed during the ongoing growing season.

Nine Years of Irrigation Cause Vegetation and Fine Root Shifts in a Water-Limited Pine Forest

Herzog, Claude; Steffen, Jan; Graf Pannatier, Elisabeth; Hajdas, Irka; **Brunner, Ivano**

Scots pines in the inner-Alpine dry valleys of Switzerland suffer from increased mortality during the past decades. Reasons are longer and more frequent dry periods. Meanwhile, a proceeding replacement of the Scots pines by pubescent oaks has been observed. In 2003 an irrigation experiment was installed to track the changes by reducing the drought pressure on the natural pine forest. After nine years of irrigation we observed major adaptations of the vegetation and shifts in the Scots pine fine root abundance and structure. Irrigation permitted new plant species to assemble and promoted canopy closure with a subsequent loss of herb and moss coverage. Fine root dry weight increased under irrigation and the fine roots had a tendency to elongate. Fine root morphology of the two dominant tree species reacted contrariwise to irrigation with the fine roots of Scots pine having increased SRL but decreased RTD, and with pubescent oak reacting contrary. Structural composition of fine roots remained unaffected by irrigation. A shift to a more negative d13C signal in the irrigated fine root C indicates an increased photosynthetic activity of the pine trees. Using radiocarbon measurement a reduced mean age of the fine roots in the irrigated plots has been determined.

Session 4: Sensitivity and Resilience of Mixed Forests to Climate Change

Applications of Airborne Lidar and Inventory Datasets to Modelling the Sensitivity and Resilience of Mixed Forests to Climatic Change (Introductory Talk)

Coomes, David Anthony

Predicting the responses of forests to climate change remains a highly uncertain science. The good news is that researchers have the data and statistical tools necessary to reduce that uncertainty: airborne lidar remote sensing is proving invaluable for mapping the state of forests across entire regions, whilst national forest inventories provide tree growth, death and recruitment data needed to assess trends in forest demography. I will illustrate how such data are starting to be used to build stochastic models of carbon fluxes from forests that incorporates the key processes driving change at stand (e.g. growth, mortality of individuals) and landscape scales (e.g. disturbance arising from natural hazards such as storm events). These empirically based models should be capable of predicting, with much greater accuracy than previously possible, the sensitivity and resilience of mixed forests to climatic change.

Extreme Drought Alters Competitive Dominance within and between Tree Species in a Mixed Forest Stand

Cavin, Liam; Peterken, George F.; Mountford, Edward P.; Jump, Alistair S.

Extreme climate events are an important driver of the biotic response to climate change. For forest ecosystems, extreme drought has been linked to increased mortality and reduced primary production. However, the response of plant communities to extreme drought events remains poorly understood. We used mortality data from a long-term monitoring programme in England (range core for the focal species), combined with annual growth data from tree-rings, to study the effect of an extreme drought. We examined how differential responses affect competitive dominance between the co-dominant species *Fagus sylvatica* and *Quercus petraea*, both of which are abundant and coexist across Europe. Mortality for the most drought-susceptible species, *F. sylvatica,* occurred alongside a temporary reduction in competition-induced mortality of *Q. petraea*, resulting in the long-term alteration of species relative abundance. Significant intraspecific variation occurred in post-drought recovery in surviving *F. sylvatica*. Prolonged recovery was coupled with the failure to regain pre-drought growth levels. *Q. petraea* instead experienced competitive release. Our results demonstrate that ecosystem responses to extreme drought can involve rapid, non-linear threshold processes during recovery as well as the initial drought impact. These sudden changes can reorder dominance between species within communities, which may persist if extreme events become more frequent.

Effects of Forest Biodiversity on Local Adaptation to Climate

Manzanedo, Rubén D.; Allan, Eric; Fischer, Markus

Understanding adaptation of tree species to climate is important for predicting responses to climate change. Many provenance experiments have documented local adaptation to climate in trees but there have been very few tests under natural conditions, where factors such as forest biodiversity and species composition might affect seedling survival and modify the expression of local adaptation. We planted tree seedlings on 209 forest plots in six countries, from the Mediterranean to northern Boreal regions, within the FunDivEurope Project. We used 5-6 contrasted provenances per country, selected from natural populations growing under conditions ranging from the current climate in the study site (local provenance), to the climate forecast for it in 2080. After two growing seasons, we measured survival along with morphological and phenological traits. Preliminary results (three countries) showed little evidence for local adaptation, with no effects of climate of origin on the performance and mortality of the seedlings. This suggests that individuals of these trees have broad climates tolerances. Seedling mortality decreased with increasing tree diversity in the driest country (Spain) and forest diversity also increased the performance of the tree seedlings, with positive effects on seedling height. These results suggest that seedling regeneration is promoted in diverse forests.

Species-specific Tree Growth Responses to CO_2 Enrichment at the Alpine Treeline: Ecosystem Consequences

Dawes, Melissa A.; Hagedorn, Frank; Hättenschwiler, Stephan; Rixen, Christian

Free air CO_2 enrichment (FACE) experiments can provide insight into how species-specific responses to altered atmospheric conditions influence ecosystem processes. With a nine-year FACE experiment (Stillberg, Davos, Switzerland, 2180 m a.s.l.), we evaluated the impacts of elevated CO_2 in a treeline ecosystem including c. 35-year-old Larix decidua (deciduous) and Pinus uncinata (evergreen) growing in understorey heath vegetation. Both tree species showed sustained photosynthetic stimulation over the nine years. The allocation of extra C to above-ground growth was significant for Larix (annual mean ring width +33%) whereas Pinus showed no growth response, suggesting that Larix could become increasingly dominant in the treeline ecotone if other global changes do not favour Pinus over Larix. Tree species identity influenced leaf N concentrations, growth and species composition in the dwarf shrub dominated understorey, as well as microbial biomass and community structure of the soil organic layers. Effects of tree species on understorey plants and soil processes were often larger than responses to nine years of CO_2 enrichment. Overall, our results suggest that altered tree species composition resulting from different growth responses to elevated CO_2 could have important consequences for the structure and function of treeline ecosystems.

How do Environmental Conditions Influence the Biodiversity-Ecosystem Functioning Relationship in Boreal Forests?

Grossiord, Charlotte; Jucker, Tommaso; Gessler, Arthur; Granier, André; Bonal, Damien

Ecosystem functioning is influenced by species composition and environmental conditions. Positive biodiversity effects on forest stand-level water use efficiency (WUES) have been observed under limiting soil water conditions, but whether such a relationship would explain WUEs patterns under non-limiting conditions remains to be addressed. We investigated the influence of biodiversity on WUES in mature boreal forests over two periods with contrasted soil water conditions (wet year in 2004 and dry year in 2006) by using the carbon isotope composition (δ13C) of tree rings of *Betula pendula, Pinus sylvestris* and *Picea abies* growing in pure or mixed stands. Furthermore, we tested whether differences in WUES would influence stand annual basal area increment (BAIS). We observed a significant increase in δ13CS, and thus in WUES, between the wet and the dry year and a positive effect of biodiversity on δ13CS for the dry year. Below-ground niche overlapping between the coniferous species and the high competitiveness of *Betula pendula* under soil water limiting conditions could explain the observed patterns. Our study thus confirms expectations from the stress gradient-hypothesis that higher physical stress conditions influence carbon and water balance in boreal forest ecosystems.

Complementarity in Mixed-Species Stands of *Abies alba* and *Picea abies* Varies with Climate

Forrester, David Ian; Kohnle, Ulrich; Albrecht, Axel T.; Bauhus, Jürgen

Interactions between plant species can be dynamic, changing spatially and temporally with variability in climatic, soil and stand conditions. We examined how inter- and intra-specific interactions between *Abies alba* Mill. and *Picea abies* (L.) Karst. changed with climate, site quality and stand density in the Black Forest of south-western Germany, using spatially explicit neighbourhood indices. The mixing response, a measure of complementarity, was quantified as the increase in growth of individual trees in a mixed-species neighbourhood compared to a mono-specific neighbourhood. Both species sometimes benefited from growing in mixed-species neighbourhoods, but this complementarity effect (–60% to >200%) depended on climatic conditions and stand density. Complementarity increased for *A. alba* with increasing mean maximum temperatures, those for *P. abies* increased with mean minimum temperatures and site quality, and in each case the magnitude of the effect was amplified with increasing stand density. Complementarity is often considered to become more important in less productive ecosystems, but this study showed that for the given pair of species, complementarity effects can increase as growing conditions improve. A simple model is proposed that describes how relationships between productivity and complementarity change depending on the resources limiting productivity.

Climate, Site Preparation, and Trembling Aspen Competition Effects on White Spruce Growth in Boreal Forests of Western Canada

Cortini, Francesco

We explored the growth of white spruce in relation to climate and site preparation from studies in British Columbia. Results indicate that monthly climate variables showed a stronger relationship to conifer growth than seasonal and annual variables. Future projections indicated that untreated young white spruce plantations in the boreal zone may suffer height growth decreases of up to 10% due to increased drought stress. Vegetation control and mechanical site preparation treatments appear to mitigate effects of climate change to some extent. We also investigated the combined effect of trembling aspen competition and climate on white spruce growth using data from a long-term study spread across the boreal mixedwood forests of Alberta and Saskatchewan. Results indicate that spruce growth, in the absence of competition, is estimated to increase by up to 17% compared with an increase in mean annual temperature from 2 C° to 3.3 C°, while, at high levels of competition spruce growth increases by only 8%. Moreover, effects of aspen on spruce growth increase more than proportionally as temperature increases. This outcome indicates that abundant aspen competition limits the spruce responses to rising temperature, presumably due to competition for light and potentially increased competition for soil resources.

Impact of Climate Change on the Diversity-Productivity Relationships in European Temperate Forests

Morin, Xavier; Fahse, Lorenz; Bugmann, Harald

Climate change affects forest functioning processes such as productivity. But it also alters forest biodiversity through changes in community composition, which in turn modifies forest productivity. Understanding the interplay between climate change, biodiversity and productivity is thus a decisive task for forest ecologists. Building on a novel approach using forest succession models to explore diversity-productivity relationships, we explored how climate change may affect these relationships, employing the model ForClim. We quantified how climate change affects the relationship between diversity and productivity along an environmental gradient in Central Europe, by comparing simulations run under "current conditions" and simulation under 2090–2100 conditions according to scenarios from three Regional Climate Models. The effect of climate change greatly varied across sites. But notably, a loss in tree diversity had a stronger effect on forest productivity in sites experiencing harsher conditions (especially drier) in the 2090–2100 period. We also showed how this finding can be interpreted through changes in functional diversity. Furthermore, we showed how diversity may buffer the impact of climate change on forest productivity through its role on promoting forest stability over time (i.e. lower variance), mostly because of a larger asynchrony in species fluctuations when more species are present in the forest.

Climate Effects on Natural Regeneration and Growth of *Picea abies* in a Dry Mixed-Coniferous Forest in the Alps

Oberhuber, Walter; Schuster, Roman; Swidrak, Irene

We applied dendroecological techniques to determine impact of climate on establishment and growth of *Picea abies* in a dry inner Alpine environment (750 m asl), where *Pinus sylvestris* and *Larix decidua* co-occur. Temporal dynamics of tree establishment, trends in basal area increment (BAI) and timing of key phenological dates of needle, shoot and radial growth were evaluated to determine whether climate change or release from competition were related to natural regeneration of *P. abies* within mixed stands. Based on phenological and climate records we relate synchronicity found among strikingly increasing trend in BAI and tree establishment in recent decades to recurring drought periods occurring during the growing season in late 1940s to early 1950s. Small canopy openings increased light and water availability, which favoured growth and establishment of *P. abies*, while BAI of distinctly declined with increasing temperature and quite constant BAI was maintained in *Pinus sylvestris*. We conclude that stand dynamics at dry-mesic sites is controlled by competition for light and water, whereby shade-tolerance, a protecting canopy and shallow rooting provide *P. abies* a competitive advantage over more drought-tolerant *Pinus sylvestris*, until increase in inter-tree competition for water in dense stands exceeds physiological thresholds for drought resistance.

Session 5: Phenology and Climate Change

The Race for Spring: Understanding the Diversity of Tree Phenological Responses to Climate Change (Introductory Talk)

Wolkovich, Elizabeth M.; Cook, Benjamin I.; Davies, T. Jonathan

Recent efforts to synthesize phenological data from disparate sources have shown a surprising consistency in the mean response of species to warming temperatures from long-term records. An average advance in leafout of 5–6 days per degree celsius of warming can be estimated from diverse observers, across continents and from natural as well as managed systems. However, this consistency masks an enormous diversity of species' responses that range from advances of over a month to delays of several weeks with a similar level of warming. After reviewing this discrepancy using datasets from North America and Europe I outline predictions from plant resource strategy theory for when and why species should vary their timing of spring phenology. I then synthesize recent efforts to better understand and predict variation in phenological responses by using case studies from invaded systems, functional traits and incorporating evolutionary history into multi-species models. I show where some efforts have provided insight, but also where many findings suggest new approaches and perspectives will be necessary to understand the drivers of tree phenology. In particular I highlight how improved models of phenology, which incorporate divergent temperature responses – as well as effects of soil moisture – will be necessary for progress.

Critical Temperatures Determining the Elevational and Latitudinal Range Limits of European Broad-Leaved Trees

Kollas, Chris; Körner, Christian; Randin, Christophe F.

Predicting range shifts of trees in response to climate change requires knowledge about the facet of temperature that constrains their cold limits. Here, we assessed which temperature-based factor explains best the cold limits of seven European broad-leaved tree species by comparing several facets of temperature. In situ temperature was recorded at tree species' cold elevational (Alps) and latitudinal (Sweden) limits. Daily temperatures of the last 50 years were reconstructed using weather station data and the lowest temperatures recurring during the lifespan of a tree were estimated. Most species were found neither to be constrained by winter minimum temperatures nor by growing season temperatures, findings that will remain under climate warming. Notably, in respect to winter freezing resistance, latitudinal ecotypes seem to have evolved, which needs to be accounted for in climate change projections. Further, we found potentially deleterious temperatures at both limits during the period of bud-break, indicating that late frosts are likely candidates controlling broad-leaved trees species' low temperature limits. Changes in late frost events under climate change are still controversially discussed. However, the results call for the use of temperature extremes during key phenological stages when using SDMs to infer impacts of climate change on tree distribution.

Impact of Forest Cover on Temperature under the Canopy

Rebetez, Martine; Von Arx, Georg

The Swiss LWF (Langfristige Waldoekosystemforschung) sites represent diverse physiographic settings and ecosystems. Meteorological measurements have been carried out under the canopy and in open areas since 1998. We compared air temperature differences between open-site and below-canopy, relating them to air humidity and other meteorological parameters as well as to site-specific conditions such as elevation, slope orientation, forest type and LAI (leaf area index). Our observations revealed differential impacts of forest cover on daily minimum and maximum temperature in the understory, but a general moderating effect. The effect on daily maximum temperature was usually strongest at lower elevation, in summer and below dense canopy. It also depended in a complex way on soil moisture and on the general weather situation: it was often strongest during extraordinary warm and dry periods, particularly below dense canopy, thus creating relatively stable conditions for plants and regenerating trees under the canopy. For minimum temperatures, the determining factor appeared to be slope orientation. High-altitude and pine forests showed no or a much smaller moderating effect, which may render the understory vegetation most sensitive to climate change. Our results furthermore suggest a threshold in LAI (canopy density), below which the moderating effect switches, meaning that climate change might alter forest canopy density in a way that ultimately changes forest ecosystem structure and functioning.

Individual Phenological Behaviour of Juvenile and Mature Beech Trees

Estrella, Nicole; Capdeville-Vargas, Renee; Konnert, Monika; Menzel, Annette

Phenological behaviour of trees is not only triggered by climate but also by individual genetics and age. Some trees show their phenological phases earlier some later compared to the overall mean of the group of trees. We observed the individual differences in phenological development (9 Phases) of juvenile (29) and mature beech (22) trees in a forest in Freising, Bavaria over three years. We grouped the trees in three categories: early, intermediate and late appearance. The next step was to identify trees which appear every year in the same category (=fixed) and which switch the categories (= flexible). This characteristic was combined with genetic structure (in form of isoenzyme and micro satellites). The juvenile trees start their bud burst in spring constantly before the mature trees leaf out probably to use the higher amount of radiation before grown up trees shade the understory. Juvenile trees were mainly fixed intermediate. In contrast the mature trees were more flexible. We conclude that due to high plasticity and potential adaptation beech stands are capable to respond to changes in temperatures in a broad range. We were not able to find any connections with the genetic information and the phenological category with the available genetic information.

Are Experimental Studies Valuable to Infer Phenological Responses of Temperate Forests to Climate Change?

Vitasse, Yann; Basler, David; Körner, Christian

For obvious practical reasons, phenological data obtained in warming and photoperiod experiments are generally conducted on juvenile trees or on cuttings/rooted cuttings from adult trees. Hence, a crucial issue arises: are they a good proxy to assess the phenological responses of canopy trees to environmental changes? Timing of leaf-out was compared between canopy trees and tree seedlings grown at canopy height in five temperate tree species within a mature mixed forest in the foothills of the Swiss Jura Mountains. In addition, bud development of natural seedlings, saplings and mature trees of three deciduous tree species was compared to bud development of cuttings from both saplings and adults. We showed that seedlings substantially differ from adult trees in their phenological response to environmental conditions due to ontogenic changes. However, the preliminary results regarding the cuttings suggest that buds may respond autonomously to environmental changes (no whole tree signal interfering with phenology such as hormonal signals). Hence, cuttings might be a good surrogate rather than juvenile trees to infer potential phenological responses of forests to climate change.

Can We Detect a Nonlinear Response to Temperature in European Phenology?

Jochner, Susanne; Sparks, Tim H.; Menzel, Annette

The phenological response to temperature is often regarded as a linear function but a nonlinear relationship might be more realistic. Is there a limit to the latest phenological onset date, for example at extremely low temperatures? Will phenology continue to advance with further warming or does a lower asymptotic limit also exist? We used phenological records provided by PEP725 and gridded temperature data for 1951–2012. Over half a million observations of ten flowering or leafing phenophases derived from 3657 stations in 22 European countries were analysed for (non)linear responses to temperature. Linear response rates ranged between –7.7 (hazel) and –2.7 days/°C (beech, oak). A flatter curve at the cooler edge of the temperature range was evident for most phases. A similar flattening at the warmer edge was not evident. The quadratic component was statistically significant for 8% of the series. A linear relationship between phenology and temperature might not be sufficient when analysing phenological data of very cold (and possibly very warm) environments. Insufficient winter chilling and photoperiodic constraints might imply that linear relationships cannot adequately predict phenological onset dates under future warming.

Chilling × Photoperiod – A Full Factorial Experiment on the Spring Phenology of Trees

Laube, Julia; Sparks, Tim H.; Estrella, Nicole; Höfler, Josef; Ankerst, Donna P.; Menzel, Annette

Increased spring temperatures cause earlier onset dates for leaf unfolding and flowering. In contrast, a temperature increase in winter is associated with delayed development. Photosensitivity is supposed to interfere with temperature triggers, but neither the relative importance nor possible interactions of these three factors have been elucidated so far. We conducted a multi-species climate chamber experiment to test the effects of chilling and photoperiod on the spring phenology of 36 woody species. Several hypotheses regarding the ecotype, floristic status and climatic distribution of species were tested. Long photoperiods advanced budburst for one-third of the studied species, but the magnitude of effects was generally minor. Photosensitive responses were not restricted to climax or oceanic species, which contradicts former hypotheses. Responses to photoperiod were limited to individuals that had not been fully chilled. Increased chilling length advanced budburst for almost all species; its effect greatly exceeding that of photoperiod. Moreover, unfulfilled chilling caused substantial changes in the chronological order that species burst their buds. Our results suggest that species with low chilling requirements, such as pioneer or invasive species, might profit from warmer winters, while the effects of shorter day lengths might only be of lesser importance.

Recent European Spring Phenology Shifts Based on Multiple-Scale Observations

Fu, Yongshuo H.

Numerous studies have reported consistent advanced spring phenology since the 1980s, while recent remote-sense based studies have found that spring phenology was stalled or even retarded during the last decade. The controversial debate requires a multiple scale observations to fully understand recent spring phenology shifts. Therefore, in this study, we examined the European spring phenology changes during 1982–2011 using both in-situ observations and satellite-based NDVI green-up datasets. Results of both in-situ and NDVI observations indicated that spring phenology significantly advanced during the study period at an average rate of 0.5 days year^{-1}, but this trend was not uniform across the period and significantly weakened over the period 2000–2011. Furthermore, opposite trends were found between in-situ and NDVI observations over 2000–2011. This discrepancy may result from the qualitative differences in the characteristics of the two methods. As such, the NDVI data may reflect only the phenology dynamics of the early flushing/flowering species within the ecosystems, and for these early species we did find similar delayed trends in the in-situ observations. This result shows that the NDVI-based methods need to be validated by in-situ observations. Further study of the phenology differences between in-situ and NDVI observations is strongly recommended.

Influence of Genetic and Climatic Factors on Formation of Lamas Growth of Norway Spruce and Scots Pine

Jansons, Aris; Neimane, Una; Rieksts-Riekstins, Juris; Purina, Liga; Dzerina, Baiba

Lamas shoots, which are result of additional height growth late in the season, have negative effect on timber quality by increasing branchyness and frequency of spike knots. Considering forecasted increase of vegetation period length in Latvia, frequency of lamas shoots will likely increase. The aim of the study was to assess factors affecting formation of lamas shoots in open-pollinated progeny trials of Norway spruce and Scots pine in central part of Latvia (56 °N, 24 °E). The results showed that proportion of trees with lamas shoots ranged from 1.2% to 29% for Norway spruce (age 10–11 years) and from 0.5% to 8.0% for Scots pine (age of 6–7 years). Occurrence of lamas shoots significantly differed between trials and consecutive years for both species. Frequency of lamas shoots was higher for faster growing trees in all trials. Apparently rapid increase of temperature in late July is one of the factors triggering formation of lamas shoots. Considering that genetic correlation between tree height and occurrence of lamas shoots was low and variation of frequency of lamas shoots among families was high (ranging from 0% to 42%), selection of genotypes with lowest occurrence of lamas shoots is a formidable task for adaptive forest management.

Querco: Oak Phenology under Air Warming and Drought

Kuster, Thomas M.; Dobbertin, Matthias; Arend, Matthias; **Günthardt-Goerg, Madeleine S.**; Schaub, Marcus

Climate change is expected to increase temperature and decrease summer precipitation in Central Europe. In the framework of the Swiss model ecosystem experiment Querco, the reactions to drought, air-warming and their combination of >700 young trees from four provenances of *Quercus robur, Q. petraea* and *Q. pubescens* each were tested during three years. Warming of 1–2°C and drought (–43% irrigation) led to an earlier bud burst by 1–3 days. The advanced bud burst by drought can likely be explained by a carry-over effect from last year's water availability. We found no differences in bud burst between the three oak species. Warming also led to an earlier start of inter-annual flush growth. However, as shoot growth of air-warmed oaks stopped earlier than of those grown in non-warmed chambers, final biomass was similar. After terminating drought stress, shoot growth fully recovered within few days, showing the superior drought tolerance of this tree genus. While provenances from dry sites produced more biomass than those from mesic sites in the control treatment, all provenances grew similarly when exposed to drought. In conclusion, our findings suggest that phenological patterns will be modified by warming, but that other factors may counteract the warming effects.

Session 6: Impacts of Drought on Tree Growth and Vulnerability

Impacts of Drought on Tree Growth: Research Methods and Results of Selected Case Studies (Introductory Talk)

Spiecker, Heinrich; Mäkinen, Harri

The presentation describes research methods and results of water shortage and its effects on tree growth, forest productivity and tree vulnerability. Impacts of changing climate on tree growth are analyzed by using anatomical, physical and chemical properties of tree rings, and by analyzing shoot-, stem- as well as root growth of trees. Data stem from analyses of recent and ancient wood samples, measurements from short- and long-term experiments and from forest inventories. The data may serve to quantify and model the environment-tree relation, as well as to better understand the impacts of climate variation, extreme events and long-term climate changes on the growth of trees as well as on the vulnerability and productivity of forests. Selected case studies illustrate the potential and limitations of the methods applied and discuss the interpretations derived from results.

Drought Periods since 1900 and Growth of Forest Stands: A New and Consolidated Analysis of Long-Term Data Series

Buergi, Anton; Zingg, Andreas

Drought during the vegetation period has an effect on tree growth. Using daily precipitation data and growth records from long-term research plots, we investigated what can be defined as "drought" and how strong its effect on tree growth is. Dry or humid periods are defined as the deviation from the long-term daily mean of precipitation. Dry periods must last at least 60 days to be considered as being decisive for tree growth. In addition, daily temperature will be included in the model. The drought values are used together with other site and stand parameters as explaining variables in a model for the basal area increment for Norway spruce (*Picea abies* [L.] H. Karst.), silver fir (*Abies alba* Mill.), European beech (*Fagus sylvatica* L.) and oak (*Quercus* L.), based on data from long-term growth and yield plots which are located in the neighborhood of precipitation measurement stations. Using tree ring information from the research plots we will also improve the resolution of the periodical growth information. With these information we will be able to improve the information about the reaction on drought periods of the main tree species of Switzerland.

Spatio-Temporal Prediction of Tree Mortality Based on Long-Term Sample Plots, Climate Change Scenarios and Parametric Frailty Modeling

Nothdurft, Arne

An approach is presented to predict the effects climate change may have on mortality of forest trees. Mortality is modeled using long-term observations from the Pan-European Programme for Intensive and Continuous Monitoring of Forest Ecosystems plots, retrospective climate data and frailty models having a parametric baseline hazard function. The linear predictor is modeled by B-spline regression techniques to allow for nonlinear cause-and-effect curves. Spatio-temporal predictions of tree mortality in the German state of Baden-Württemberg were derived in terms of unconditional hazard ratios and based on climate projection data. According to the model, marginal risk of tree death for 100 year old Norway spruce trees will be doubled until 2100.

Effects of Drought and Century-Long Irrigation on Radial Growth and Needle Traits of Scots Pine

Feichtinger, Linda; Eilmann, Britta; Buchmann, Nina; Rigling, Andreas

Growth adjustments of trees to drought are mainly investigated in short-term manipulation experiments. These however, might not reflect the response to long-term changes in water availability. In this study we used historical water channels as a century-long irrigation experiment at two sites in Valais, an inner-Alpine dry valley in Switzerland. We quantified the response of mature Scots pine to contrasting water availability by comparing radial growth and needle traits (shoot and needle length, total specific needle area (SLA)) in irrigated and non-irrigated trees (control) for the period 2008 to 2012. For irrigated trees, basal area increment was 260% higher, needles were 36% longer, shoots were 114% longer and total SLA was 46% higher than for control trees. However, during the extreme dry spring in 2011, needle length was equally reduced (in %) for irrigated and control trees, whereas total SLA was not affected. This suggests that Scots pine adjusts its crown during drought to maintain a constant total SLA. Our findings support the need of long-term experiments for understanding the future changes in the response of trees to drought.

Effects of Drought Stress on Tree Growth in Central German Beech Forests

Wagner, Markus; Sutmöller, Johannes; Rudolph, Julia; Hansen, Jan; Eichhorn, Johannes; Fleck, Stefan; Scheler, Birte; Meesenburg, Henning; Dammann, Inge; Evers, Jan; Paar, Uwe; Nagel, Jürgen; Spellmann, Hermann

Climate change may substantially alter growth conditions of beech forests in Central Europe. Representing the most widespread tree species in Central German mountain ranges it becomes relevant for forestry and ecological purposes to more thoroughly analyze the risk potential of European beech for drought stress. Tree ring time series and supplemental high-resolution dendrometer measurements from 7 (respectively 4) Level II plots in Hesse were evaluated in relation to climate and water balance (WaSiM-ETH) datasets derived for the years 1931 to 2006 using multiple regression models. Additionally, hydro-climatic time series reaching back to 1961 were computed for 55 Level I beech plots. The most sensitive variables in the dataset with respect to growth were precipitation, air temperature, climatic water balance, relative evapotranspiration (ETr) and relative plant available soil water (SWr). Various combined hydro-climatic indicators corresponded well to tree growth pattern. Confirming other results (Granier *et al.* 2000, Agr Forest Meteorol), diameter growth is interrupted when SWr drops below 40% or when ETr drops below 60%. Years with extremely low diameter increment (1948, 1959/60, 1976, 2004) could be identified using the indices, if a possible time lag of one year for growth response is considered (e.g. 2003/04).

Physiological and Growth Responses of Minor Tree Species of Central Europe to Drought

Kunz, Jörg; Löffler, Georg; Räder, Annemarie; Bauhus, Jürgen

To adapt European forests to climate change it has been suggested to increase tree species diversity and the proportions of drought tolerant species. Regionally, the forest area covered by economically important tree species might be further reduced by an increasing incidence and severity of droughts. Currently neglected broadleaved species like *Sorbus torminalis, S. domestica, Acer campestre* and *A. platanoides*, which are being regarded as drought-tolerant, may offer suitable silvicultural alternatives; however there is little reliable information about their responses to water shortage. Here, we examined the resistance to and recovery from drought of regeneration as well as mature trees using physiological and dendrochronological approaches. Water was withheld for seedlings of the above minor tree species and their common associates *Fagus sylvatica* and *Quercus petraea* in greenhouse and outdoors experiments. Measurements of photosynthesis, transpiration, water-use efficiency and stomatal conductance compared to well-watered individuals showed varying responses to withstand water shortage. A. campestre seemed to be best adapted to drought. Additionally, the response of mature trees to drought was examined through analysis of tree rings before, during and following pronounced drought events using superposed epoch analyses. While *Q. petraea* appeared to be the most drought-resistant species, *S. domestica* seemed to be most resilient. Our tentative results indicate that minor broadleaves are not more drought-resistant than *Q. petraea* but certainly more resistant than *F. sylvatica*. These minor tree species may be recommended to enrich species diversity in forests on drought-prone sites.

Drought Decreases the Over Yielding Caused by a Tree Mixture in a British Deciduous Forest

Göransson, Hans; Bambrick, Michael; Godbold, Douglas

To investigate the effect of predicted drought on tree monocultures and mixtures, sub canopy roofs were constructed in plots of six year old stands of Alnus glutinosa, Betula pendula, Fagus sylvatica and a mixture of the three species. The roofs covered 70% of the total area. Throughfall was excluded from the plots from June to beginning of November 2010 and from mid April to mid September 2011. Alnus and the mixed stands decreased most in above ground biomass. Fine root production was lower in the drought treatment than in the controls for all species. This was reflected in the standing fine root biomass, which after 2 years was lower in the drought than in the control especially in Alnus and the mixed stands. Soil respiration decreased during drought for all species and the mixtures. The mixture in the control tended to have a higher above ground biomass production, higher root biomass and higher soil respiration than expected, based on the monocultures. This over yielding effect could not be seen in the drought treatment. Our results show that predictions of the response of tree mixtures to climate change, cannot be based on knowledge of the response of individual species.

TreeNet

Haeni, Matthias; Zweifel, Roman

In a subalpine forest in Davos, a remarkably close, linear and highly significant relationship has been found between tree growth as measured with dendrometers and the carbon balance as measured by the eddy covariance technique. In this study we include tree growth and eddy covariance data from twelve forests from all over Europe to test in comparison, whether the linear relationship is a universal and significant relationship. Furthermore, we will apply this relationship to TreeNet Switzerland, a young biological indicator network, where continuous data on stem radius fluctuations are measured with point dendrometers from trees all over Switzerland and drought and growth indicators for Swiss forest ecosystems are estimated. Current stem growth rates are related to the ones from past years and interpreted as indicators for forest growth, thus allowing early predictions for the expected annual carbon sink of forest ecosystems.

Leaf Water Relations, Sap Flow Density and Stem Radial Changes in Two Co-Existing Oak Species

Meszaros, Ilona; Nyitrai, Balázs; Kanalas, Péter; Kis, József; Fenyvesi, András; Oláh, Viktor; Demeter, Zita; Szo˝ llo˝ si, Erzsébet

Mixed forests of sessile oak (*Quercus petraea* (Mattuschka) Liebl.) and turkey oak (*Quercus cerris* L.) are widespread in mountainous region of Hungary and have large economic and nature conservation value. Increased temperature and recurrent droughts reported in Hungary have strongly affected these forests with more serious mortality of sessile oak. We investigated the responses of sap flow density, stem diameter changes, leaf water potential and leaf delta 13C to water shortage for sessile oak and turkey oak in a 105 year old forest (North Hungary) in contrasting growing seasons between 2009 and 2012. The site is located at the xeric limit of this climate-zonal forest type and is vulnerable to climate change. The two species showed clear differences in the measured variables and responded differently to drought. *Q. petraea* generally exhibited lower daytime sap flow density and higher leaf delta 13C. During drought *Q. petraea* showed larger stem water deficit than *Q. cerris*. *Q. cerris* tolerated better the water shortage presumably through the use of larger inner water storage and due to deeper root system. The study provides usable results for management of mixed oak forests in connection with climate change at vulnerable sites and also for future plantation planning.

Total Biomass, C and N Partitioning and Growth Efficiency of Mature Pedigreed Black Spruce on a Dry and Wet Site

Major, John E.; Johnsen, Kurt H.; Barsi, Debby C.; Campbell, Moira; Malcolm, John

Worldwide, efforts to reduce atmospheric CO_2 are being explored both by reducing emissions and by sequestering more carbon (C). Total above and belowground biomass, C, and nitrogen (N) parameters were measured in plots of 32-year-old black spruce (*Picea mariana* (Mill.) B.S.P.) from four full-sib families studied previously for drought tolerance and differential productivity on a dry and wet site. Drought tolerant families had lower wood density than drought intolerant families on the wet site but there were no differences between drought tolerant and intolerant families on the dry site. Allometric analysis showed greater total stem dry mass per unit total belowground dry mass for drought tolerant than intolerant families and for wet than dry sites indicating a differential allocation of photosynthate dependent on both genotype and environment. Allometric analysis also showed greater total stem dry mass per unit total needle dry mass (growth efficiency) for drought tolerant than intolerant families and for wet than dry site. This indicates variation in growth efficiency caused by greater net photosynthesis (shown previously) and greater partitioning of biomass to stem relative to total roots. Thus significant increase in biomass and reallocation of biomass in mature spruce trees can be produced through genetic (breeding) and environmental (moisture) change.

Can Climate Change Exacerbate the Genetic Consequences of Forest Fragmentation? Effects of Drought Stress on Heterozygosity-Fitness Correlations in Pedunculate Oak

Vranckx, Guy; Jacquemyn, Hans; Mergeay, Joachim; Cox, Karen; Janssens, Pieter; Gielen, Bie; Muys, Bart; Honnay, Olivier

In small and spatially isolated forest fragments, increased homozygosity may directly affect individual tree fitness, through the expression of deleterious alleles that influence morphological and physiological traits. Climate change induced drought may exacerbate the detrimental genetic consequences of forest fragmentation because the fitness response to low levels of heterozygosity is generally thought to be more pronounced under environmental stress than under optimal conditions. To test this hypothesis, we performed a greenhouse experiment in which fitness traits of 6-months-old seedlings of Quercus robur, differing in multi-locus heterozygosity (MLH), were recorded during 3 months under both a well-watered and a drought stress treatment (50 seedlings per treatment). Heterozygosity-fitness correlations (HFC) were examined by correlating transpiration parameters and various growth traits of individual trees to their MLH and by studying their response to drought stress. We obtained weak, but significant effects of the MLH (= 3–11 %, $p < 0.05$) on several fitness traits. High atmospheric stress (e.g. high vapor pressure deficit (VPD) influenced the strength of the HFCs of the transpiration parameters, whereas only a limited effect of the irrigation treatment was observed. Considering ongoing climate change, increased VPD levels in the future may strengthen the negative fitness responses of trees to low MLH.

Physiological Characterisation of Swiss Native Oak Species Using the Dual Isotope Approach

Schuch, Ellen Elke; Arend, Matthias; Buchmann, Nina; Dobbertin, Matthias; Günthardt-Goerg, Madeleine; Siegwolf, Rolf

The predicted climate change is considered as a serious threat to forest ecosystems. Higher annual temperature and more frequent/intense summer droughts will have strong impact on photosynthetic carbon assimilation of tree species, either due to changes in photosynthetic capacity (A) and/or stomatal conductance (gs), thereby affecting the tree's vitality and competitiveness. These physiological changes can be followed using the dual isotope approach with carbon and oxygen isotopes (13C, 18O, respectively). In the present study, isotopic patterns of carbon and oxygen were analyzed in stems and leaves of young oak trees (provenances of *Quercus robur, Q. petraea* and *Q. pubescence*) subjected to drought, air warming or the combination of both over three years in large model ecosystems. First results showed a general 13C depletion in trees exposed to drought or the combination treatment; air warming alone caused only a minor but significant depletion in 13C. Provenances differed in their discrimination of 13C at low stress intensities, while with rising stress intensities these differences were not longer abundant. Further analysis of oxygen isotope signatures will allow us to separate stomatal and non-stomatal stress responses of photosynthetic carbon assimilation.

Examining Mechanisms of Enhanced Susceptibility to Diplodia Tip Blight in Drought-Stressed Austrian Pine

Sherwood, Patrick William; Villari, Caterina; Capretti, Paolo; Bonello, Pierluigi

Water limitation is an important abiotic factor which can predispose plants to infection. However, the molecular mechanisms of this induced susceptibility are poorly understood particularly in trees. Here we studied the effects of drought on *Pinus nigra* susceptibility to the shoot blight pathogen *Diplodia pinea*. Drought increased host susceptibility (measured as lesion lengths) and resulted in the accumulation of proline and reactive oxygen species (ROS) in the shoots. When trees were both water stressed and infected, there was a significant reduction in ROS levels, accompanied by an increase in free proline concentrations. Proline has several roles in plant physiology including protein synthesis, osmoregulation, oxidative protection during stress events, and serving as a nitrogen storage source. In particular, the ability of proline to scavenge ROS and act as a nutrient source may be contributing to *D. pinea's* success in Austrian pine. We found that proline can enhance in vtiro growth of *D. pinea* by functioning as a preferred N source while also mitigating H_2O_2 damage. *D. pinea* was also examined for enzymatic ROS scavenging ability by growing the fungus on media amended with H_2O_2. Catalase and peroxidase activity increased with increasing concentrations of H_2O_2, but no superoxide dismutase activity was detected.

Where Two Common Swiss Tree Species Fagus sylvatica and Picea abies Access Water with a Seasonal Variation in Soil Depth

Brinkmann, Nadine; Zielis, Sebastian; Kahmen, Ansgar

Access to soil water determines the vulnerability of trees to global change-induced drought events. In this study we investigate two most common European tree species where they take up water from for a seasonal variation of soil depth. For this study we use stable oxygen isotope profiles of soil water that occur along soil depth profiles. Since no isotopic fractionation occurs during water uptake via roots, the δ18O values of xylem water can thus be related to the soil depth where trees take up their water from. The objectives of our study were (1) to determine the origin of source water for Fagus sylvatica and Picea abies and identify differences in the source water depth. (2) Determine potential seasonal and annual variation in the soil depth where our investigated tree species take up their water from. We conducted the study in a highly diverse mixed mountain forest (Lägeren) and a subalpine mountain forest (Davos) in Switzerland. Additional data collection with same sampling technique is running for this field season 2013. The poster will show first results of our study.

Interactive Warming and Drought Effects on the Regeneration of Acer pseudoplatanus and A. platanoides

Carón, María Mercedes; Verheyen, Kris; De Frenne, Pieter

The sexual reproductive stage is considered an especially sensitive phase in the life cycle of plants in the face of climate change, but this phase also provides plants an opportunity to adapt to environmental changes. We analyzed the impact of different temperature and drought treatments on the sexual reproduction of *Acer pseudoplatanus* and *A. platanoides* from populations along a 2200 km long latitudinal gradient. A full factorial experiment was performed: germination, mortality, survival and growth were assessed under three temperature (+0°C, +2.7°C and +7.2°C) and three drought treatments (–0%, –20% and –40% soil moisture). Germination of *A. platanoides* decreased with drought but the effect was partially compensated by rising temperatures, while its mortality increased due to both warming and drought. In *A. pseudoplatanus*, the germination and the mortality decreased and increased following warming, respectively. In both species, warming and drought reduced all the biomass variables and increased the root:shoot ratio. We conclude that future warming might negatively affect the main variables that determine recruitment success (germination, seedling mortality and survival) while increasing drought events might negatively affect seedling growth. These two global-change drivers acting together may strongly modify the population dynamics of these two important tree species.

Storms Killed, Droughts Weakened Trees in Managed Coniferous Forests from the French Alps during the 20th Century

Csilléry, Katalin; Denardou-Tisserand, Anaïs; Kunstler, Georges; Courbaud, Benoît

Over the past two decades, extensive forest tree mortality triggered by droughts and wind-throw have been documented in many temperate forests. Despite its key importance in forest dynamics, tree mortality is one of the least understood demographic processes due to its rare and erratic nature. Here, we analyse unprecedented, century-long time-series of the annual adult tree mortality from several coniferous forests from the Vosges to the Mediterranean pre-Alps that we estimated from forest management data using a Bayesian state-space model. We found that while small scale mortality events occur regularly, on average, every 1.5 years, every once in a while, on average, every 45 years, a large proportion of the forest volume is lost, here, on average, c. 12% (max. 72%) of the total volume. Using parallel time-series of wind-throw we show that (i) most of the catastrophic mortality events can be associated with storms; (ii) droughts have an indirect effect by weakening trees, so they were more susceptible to death in a storm. Our results emphasise that the rare process of adult tree mortality cannot be extrapolated from short time scale observations.

Is the Diversity of Biogenic Volatile Organic Compounds Correlated to Beech Stand Debilitation?

Gabriel, Martin; **Rachow, Christine**; Schütz, Stefan

The impact of drought stress on beech trees *(Fagus sylvatica)* was examined focusing on the emission of biogenic volatile organic compounds (BVOC) and the occurrence of beetles. Beech stands in Northern Germany with sufficient precipitation were compared to stands with low precipitation. BVOC of beech stems were sampled by a stem enclosure. Insects were caught by unbaited flight interception traps. The diversity of emitted BVOC remains constant in stands with sufficient precipitation, whereas the BVOC-diversity increases during the summer in stands with insufficient precipitation. In stands with insufficient precipitation sandy soil was correlated with an increase of beetle diversity and of species specific for decaying or dying wood. The results suggest that soil properties can affect the diversity of beetle species specific for decaying or dying wood at low precipitation stands. BVOC-diversity increases with lower precipitation. Especially beeches at sandy stands might be debilitated by lack of water or nutrients and might show increased vulnerability giving habitats for beetles living in decaying or dead wood.

Dynamics of Radial Growth of Norway Spruce Clones in Relation to Climatic and Soil Factors

Leštianska, Adriana; Střelcová, Katarína; Merganičová, Katarína

Physiological processes are sensitive indicators of stress in plants, especially under extreme environmental conditions. Decreased photosynthesis and transpiration rates contribute to growth reduction and a general decline of forest health. The dynamics of stem diameter growth is affected by a number of factors including genetic factors, weather, climatic conditions, physiological processes and general health of individuals. The contribution presents the results of 5 year-long (2008–2012) dendroecological research in a Norway spruce (*Picea abies* (L.) Karst.) clone forest stand (Northern Slovakia) aimed at analysing genotype variability of growth processes and their relations to meteorological and soil characteristics and droughts effects on growth. Regression techniques were used to analyse the impact of meteorological factors on the radial growth of spruce. Due to different meteorological and climatic conditions within monitored years different values of increments and seasonal courses of their formation were observed. The results show that the beginning of growth depends on the air temperature and the end of radial growth depends on the photoperiod. Sufficient soil water content at the beginning of summer is the most important factor for the radial growth of spruce during vegetation period.

Hydraulic Properties of Norway spruce Wood Estimated by Near Infrared Spectroscopy (NIR) – Possibilities and Limitations

Luss, Saskia; Rosner, Sabine; Gierlinger, Notburga; Schwanninger, Manfred

Classical methods to determine hydraulic vulnerability to drought stress are very time consuming and labour intensive. Hydraulic conductivity and vulnerability to cavitation of conifer wood are directly related to bordered pit properties and thus indirectly to fibre length, wood density and grain angle (inclination of the fibres relatively to the stem axis). All these properties have been already successfully estimated by NIR which is a reliable, rapid, easy to use and non-destructive method. Hydraulic properties of 147 Norway spruce (*Picea abies* L. Karst.) sapwood samples, from six 24-year-old clones, grown on two sites in southern Sweden, were assessed by classical flow experiments. Traits assessed were: P50 (the applied air pressure causing 50% loss of conductivity) and RWL50 (applied air pressure necessary to cause 50% loss of relative water content). NIR spectra collected from the axial and radial surface of each solid wood sample were used to develop NIR-based Partial Least Squares Regression (PLS-R) models for the prediction of RWL50, P50 and basic density. We will present comparisons of different FT-NIR-PLS-R models and discuss the possibilities and limitations of this technique for the estimation of hydraulic properties.

Extending the Range of a Forest Succession Model to the Mediterranean Mountains: The Importance of Accurately Capturing Drought

Mina, Marco; Bugmann, Harald; Cailleret, Maxime

Recent climate impact assessments suggest that Mediterranean regions will be affected more strongly than Central and Atlantic Europe. In Southern Europe, summer temperatures are expected to rise strongly while summer precipitation is likely to decrease, affecting forest ecosystems by increasing drought risk. Yet, little is known on the impacts of changing climatic conditions on tree population dynamics and community assembly in these systems. Thus, the applicability of a climate-sensitive forest succession model (ForClim) was extended to these regions. In order to capture species-specific responses to summer drought, we focused on the relationship between drought and tree growth. We refined the modeling of tree growth to consider the differential effect of each month's water balance on tree growth via seasonal or annual drought indices. Species composition and biomass at three case study areas in Southern Europe were more accurately simulated, indicating that forest succession models should consider intra-annual climate variability and the specific relationship between the water balance and tree growth. As a next step the model will be used for assessing forest responses to changes in climate and in the management regimes.

Temporal Aggregation of Drought Impacts on Diameter Growth

Rohner, Brigitte; Thürig, Esther; Weber, Pascale

Drought impacts on diameter growth have often been investigated based on response functions that quantify relations between monthly drought and tree-ring indices. However, such annual growth information is unavailable in forest inventories, where tree diameters are usually measured on lower temporal resolutions. Therefore, we analysed how drought impacts on diameter growth aggregate from annual to decennial inventory periods, and how this aggregation differs between tree species and biogeographic regions in Switzerland. After having calculated standard response functions for annual diameter growth, we aggregated annual growth over 5 and 10 years and investigated whether mean or extreme drought values in the aggregated time period best described the aggregated diameter growth. For oaks in the Swiss lowlands and in an inner-alpine valley, annual diameter growth was most sensitive to drought during the summer months, and aggregated growth showed the highest correlation with the driest – not mean – summer drought conditions in the aggregated time period. Analogous results for further tree species and biogeographic regions will be completed during the coming weeks. Consequently, this study points out what kind of drought information should be used to analyse and interpret growth variability, depending on the species, site and temporal resolution under investigation.

Drought Effects on Seasonal Dynamic of Sap Flow and Stem Circumference Changes in Mature European Beech Stand

Sitková, Zuzana; Střelcová, Katarína; Nalevankova, Paulína; Ježík, Marek

The rising risk of drought is one of the most anticipated consequences of ongoing climate changes, including the negative effects on productivity of forest ecosystems. The objectives of the study were: i/to quantify the transpiration rates and circumference changes on 12 model trees of adult European beech under different soil moisture conditions (water stress and irrigation); and ii/ to investigate how they depend on weather conditions. The measurement of sap flow (Qs), stem circumferences, meteorology and soil moisture was carried out during the growing season of 2012. Irrigation was applied during the drought periods when the soil water potential dropped to minimum levels. The results indicate that the trees stressed by drought achieved substantially lower values of sap flow in comparison to the control group. The highest difference of transpiration between two groups we found in early September under extreme moisture deficit (136 mm irrigated trees and 49 mm control trees). The 20-minute transpiration rates correlated significantly with global radiation, namely in a time shift of 80 minutes. Strong dependency was also observed on vapour pressure deficit and air temperature. The trees out of irrigation responded considerably to low values of soil water potential by shrinking of stem circumferences.

Climate-Induced Forest Productivity Change in the Altai-Sayan Mountains, Central Siberia, during the Holocene

Tchebakova, Nadezhda M.; Parfenova, Elena I.

The Altai-Sayan Mountains are located in south-central Siberia and are noteworthy for a high forest diversity across the elevation gradients. Historical distributions of montane forests and productivity were modeled in relation to changing climate throughout the Holocene to 2100 AD. We developed climate-based regression models to predict forest composition, heights and site quality class (height at 100-year age) from climatic indices that characterized basic requirements for heat and water and cold tolerance. Forest data were derived from 2000 inventory plots covering a wide range of habitats along the heat-moisture gradient. The climatic indices were calculated for various climate change scenarios in the past (pollen-reconstructed climates) and future (HadCM3 B1 and A2 climates). Forest composition and productivity were predicted coupling our forest models with climates in major periods of the Holocene including the near future. The tallest (up to 35 m) stands currently occur in dark-conifer lowland taiga and may have gained 10–15 m in height as a result of climate warming 8000–5300 BP and 2050–2080 AD. The stand heights were predicted to decrease during dry and cold periods 10 000 and 3200 BP and during the dry and warm future periods 2020–2080 AD in light-conifer lowland taiga.

What Determines Growth under Optimal Site Conditions?

Weemstra, Monique; Eilmann, Britta; Sass-Klaassen, Ute; Sterck, Frank

Climate impacts on tree growth are mainly studied on marginal sites. To date, the climate effects on trees growing in favourable environments remain therefore unclear despite the importance of these sites in terms of forest productivity. We present a first study that reveals to what extent radial growth is limited by climate conditions across 10 temperate tree species growing on a homogeneous, productive soil in the Netherlands. We used tree-ring analyses to investigate how species differ in their growth response to precipitation, temperature, irradiance, potential evapotranspiration (PET), and the groundwater table. Even under these favourable site conditions, tree growth was reduced across all 10 species by water deficits in summer, driven by low rainfall and high PET. These qualitatively comparable climate impacts on radial growth coincided with strikingly similar growth rates across all species but *Populus trichocarpa* which grew faster. Yet, species differed quantitatively in their growth responses, especially to the groundwater table. Our study demonstrates that forest productivity in favourable environments may be more affected by climate change than currently expected. The strong responses to the groundwater table of some species suggest that rooting differences across species will become more prominent as water becomes more limited.

Session 7: Drought-Induced Tree Mortality – Patterns, Processes and Mechanisms

Drought-Induced Tree Mortality: Lessons from Mediterranean Scots Pine Populations (Introductory Talk)

Martínez-Vilalta, Jordi

Scots pine (*Pinus sylvestris* L.) is one of the most widely distributed trees on Earth. Despite its huge ecological plasticity, many studies show that its capacity to resist drought is being overcome in several regions, particularly at the southern (and dry) limit of its distribution. This paper summarizes recent work on Mediterranean Scots pine populations addressing the following questions: (1) what are the ecophysiological characteristics that explain the vulnerability of Scots pine to drought and what mechanisms are involved in the process of drought-induced mortality in this species?; (2) what environmental factors are associated with Scots pine demographic rates and drought-induced decline at different ecological scales (intra-population, across populations, regional)?; and (3) what are the likely impacts of more frequent droughts and forest fires on Scots pine forests? Overall, the results currently available suggest that the mid term viability of a substantial part of the Scots pine populations in the Iberian Peninsula is at risk under projected climate change. I conclude by discussing to what degree previous information can be used to identify the more vulnerable individuals or populations, and how could forest management be used to modulate the expected impacts

Life and Death of Drought-Adapted Trees under Climate Change

Gruenzweig, Jose

Climate change in Mediterranean regions does not inflict unprecedented conditions to trees that are adapted to drought, but expose them to increased frequency and duration of extreme hot and dry periods. Recent massive mortality and reduced growth of pine trees *(Pinus halepensis)* in a semiarid plantation and oak trees *(Quercus calliprinos)* in a natural subhumid maquis coincided with greater occurrence of years with particularly low amounts of precipitation. However, it was unclear, how these symptoms were related to increased drought stress. An extreme dry year in the developing pine plantation resulted in reduced growth of the same trees that finally died 25 years later following a period of increased frequency of low-rainfall years. Dead trees had fewer roots than live trees, and they were distributed in shallower layers, thus indicating less access to deeper water stores. Reduced stem and needle growth in live trees, which was particularly pronounced in dry years, was associated with low water potential at the limit of the hydraulic safety margin of pine. At a marginal site for oak growth and survival, trees coexisted with more drought resistant tree and shrub species only on relative favorable locations where deep rooting was possible. At these locations, water status of vigorous oaks was similar or improved as compared with that of more drought resistant species. However, other trees (50% of all oaks) showed moderate to severe stress symptoms following 5 years of below-average rainfall amounts. Recent deviations from the long-term climate record appear to severely affect trees that are adapted to a dry climate.

Pine Mortality at the Drought Limit: All Eyes on Cavitation

Klein, Tamir

Aleppo pine mortality was studied in a semi-arid site in Israel (MAP=280 mm) following subsequent drought years (P<200 mm in 2008 and 2009). Four physiological processes potentially leading to mortality were examined: (1) impact of insect attack; (2) carbon starvation due to prolonged cessation of photosynthesis; (3) carbon mobilization failure; and (4) excessive xylem cavitation leading to hydraulic failure. Three complementary approaches were applied: (a) quantification of wood carbon reserves and isotopic signals in dead, stressed, and healthy trees; (b) assessment of native xylem embolism levels in five provenances; and (c) in-depth study of mortality mechanisms in saplings subjected to drought greenhouse experiment. Bark beetle activity was observed in dead, but not stressed, trees. Isohydric behavior dictated stomatal closure during most of the day during the dry season, yet carbon uptake continued in morning and late afternoon. As drought progressed, non-structural carbohydrates decreased to 20–30 mg g-1 in branches and roots. Trees that died had ca. 0.6 permil higher d13C values than surviving trees, indicative of higher stomatal conductance. Provenance mortality ratios were correlated with embolism levels. In Aleppo pine at the drought limit, processes (1)–(3) are not dominating mortality, whereas excessive cavitation is involved, despite of efficient embolism reversal.

Scots Pine Physiological Response to Drought

Salmon, Yann; Mencuccini, Maurizio

Tree mortality associated with drought stress is increasing worldwide. However, our understanding of the processes leading to tree death remains limited. Therefore we investigated physiological processes involved in tree response to drought in a mountainous forest dominated by Scots pine in northern Spain. Drought-induced defoliation has been associated in Scots pine with higher risk of mortality, and thus was used as a proxy to estimate drought impact on trees. Over a growing season, we measured five physiological variables associated with carbon turnover: Total non-structural carbohydrates concentration (TNSC), leaf assimilation, soil, stem and leaf respiration and five physiological variables associated with water balance: sap flow, stomatal conductance, osmotic pressure, predawn and midday water potential on eight heavily defoliated trees and eight non-defoliated trees from the same population. We found higher assimilation and respiration per leaf area in defoliated trees. Sap flow per unit leaf area was higher in defoliated trees, but was subject to stronger decline during drought than non-defoliated tress. Interestingly, despite seasonal variability no significant differences in TNSC concentration were observed between defoliated and non-defoliated trees. Our results suggest that hydraulic failure rather than carbon starvation is the leading factor in tree health decline with drought.

Long-Term Growth and Gas Exchange Responses of Conifers to Drought in Central Europe

Lévesque, Mathieu; Siegwolf, Rolf; Saurer, Matthias; Eilmann, Britta; Brang, Peter; Rigling, Andreas

Higher atmospheric CO_2 concentrations (ca) can under certain conditions increase tree growth by enhancing photosynthesis resulting in an increase of intrinsic water-use efficiency (iWUE) in trees. However, in Central Europe, the magnitude of these effects and their interactions with rising temperature and decreasing water availability are still poorly understood. We investigated long-term growth and gas exchange responses of mature European larch, Norway spruce, Scots pine, black pine and Douglas-fir in relation to changes in ca and temperature at a xeric site in the dry inner Alps and a mesic site in the Swiss lowlands. Radial growth, δ13C and δ18O in early- and latewood were measured for the period 1960–2009. iWUE significantly increased over the last 50 years by 8 and 29% in both early- and latewood and varied depending on species, site conditions and seasons. Despite the increase in iWUE, radial growth has significantly declined for most species since the 1980s and was not related to tree ageing, but coincided with a warming trend at both study sites. Overall, our results indicate that the warming-induced drought stress has overridden the potential CO_2 'fertilization' on tree growth, hence challenging today's predictions of improved forest productivity of Central European forests.

TreeNet – Quantifying Tree Water Deficits and Missing Water of Forest Ecosystems from Dynamic Stem Radius Changes

Zweifel, Roman; Haeni, Matthias; Zielis, Sebastian

Continuous stem radius changes (DR) measured with high precision point dendrometers allow quantifying tree water deficits (DW) and tissue growth dynamics (GRO). Both are key measures when dealing with drought stress and tree decline on a physiological level. Within the project TreeNet_Switzerland about 100 trees all over the country provide DR readings to an internet-database every 5 minutes (www.treenet.info). We present a procedure to mathematically distinguish between DW and GRO from the original DR measurements and we come up with a new approach to estimate the amount of missing water of forest ecosystems (DWE in mm) from DW. Preliminary results indicate consistent DW across species at any particular site, however speciespecific rates of GRO, and site-specific dynamics of DW among different locations. Further we found a close species-specific link between DW and GRO in which a threshold of DW defines the onset of growth. We successfully quantified DWE from DW and found reasonable relationships to hydrological and microclimatic measures. DW is proposed to be a biological indicator for drought stress since the shrinkage of tree stems integrate over any tree-water-relations-relevant factors in air and soil. A few dendrometers in a forest deliver the integrated information over many cubic meters of air and soil and are therefore proposed to be the better measure for potential drought stress in a forest ecosystem than any combination of soil and microclimate sensors.

Structural Changes Indicative of Drought Stress and Tolerance in Oak Foliage

Vollenweider, Pierre; Menard, Terry

As a consequence of global warming and more frequent droughts, central European oaks are expected to extend their present range. Objectives in this study were to investigate the microscopic injury leading to drought stress symptoms in oak foliage. As part of a model ecosystem experiment, foliage samples from *Quercus robur, Q. petraea* and *Q. pubescens* were harvested after an extended period of drought and analyzed in light and electron microscopy. Oak foliage withstood drought stress for a considerable length of time and developed visible symptoms, in the form of leaf margin necroses, only once the leaf water potential dropped below -1.3 MPa. In sections from the still green part of symptomatic leaves, many structural injuries, increasing in severity abaxially, were observed. In the leaf blade – and amid degenerated epidermal and spongy cells under severe carbon and water shortage – the palisade and stomata guard cells remained functional thus enabling the resumption of gas exchange upon rewatering. The lateral veinlets were plugged which eventually contributed to necroses of leaf margins. Hence, most tissues showed symptoms of drought stress which effects were reduced by the prioritization of essential cell types or sacrifice of marginal leaf parts, thus enhancing tolerance to drought stress in foliage.

Can Simulations of Stand Hydrology Improve Modelling of Spruce Bark Beetle Infestation Risk?

Matthews, Bradley; Netherer, Sigrid; Blackwell, Emma Elizabeth; Hietz, Peter; Henschke, Patrick; Kikuta, Silvia; Rosner, Sabine; Jansson, Per-Erik; Schume, Helmut; Katzensteiner, Klaus; Schopf, Axel

The spruce bark beetle *(Ips typographus)* is the most significant biotic disturbance agent threatening Norway spruce in Europe. Outbreaks of this pest have increased substantially over recent decades, and considering potential climate change effects on both insect propagation and stand stability, this trend looks set to continue. Recognition of this threat, and thus the need for infestation risk assessment systems has subsequently prompted research into this particular pest-host relationship. Despite progress with respect to the pest's autecology as well as infestation susceptibility due to site and stand characteristics, modelling infestation risks is still limited by a lack of understanding regarding the influence of drought stress on predisposition. As part of the ROSALIA ROOF PROJECT (see abstract of Netherer et al) we are investigating the potential utility of an ecosystem water balance model (CoupModel) within a risk assessment framework. By constraining the model against measurements of transpiration and soil moisture, stand water balances will be simulated for three different experimental drought treatments (full drought, partial drought, and control). The simulations will then be compared against measurements of resin flow and bark beetle attack (induced artificially via "attack boxes") to identify water deficit thresholds at which the tree's defence system becomes compromised.

Accurate Modeling of Tree Mortality Is Key for Simulating Forest Dynamics under Climate Change

Bircher, Nicolas; Bugmann, Harald; Cailleret, Maxime

Forest succession models hold promise for predicting future forest dynamics under climate change as they are applicable over a wide range of sites and species under different climatic conditions. However, to date rather simple parameterizations for fundamental ecological processes like tree mortality are implemented in most models, probably due to scarce or missing data. A better modeling of tree mortality using ecologically sound, mechanistic approaches would be crucial for making reliable projections of future forest development. We evaluate several tree ring- and inventory-based mortality functions by implementing them in the forest succession model ForClim. We applied these model versions at sites in the Swiss Alps, a region that is expected to be particularly sensitive to climatic change. Simulation results show that ForClim is highly sensitive to the exact formulation of the mortality submodel. Regarding simulated tree species composition and basal area, tree-ring based mortality functions appear to be better suited for forest succession models than the currently available inventory-based functions. However, tree-ring based models are available for a few tree species only, thus limiting the application of succession models. Therefore, a key challenge is to derive reliable mortality models based on tree-ring data for a broader suite of species.

Physiological Response of Three Beech (*Fagus sylvatica* L) Provenances to Progressive Drought Stress

Ditmarová, L'ubica; Jamnická, Gabriela; Pšidová, Eva; Majerová, Jana

In the context of prolonged and repeated drought periods in Central Europe, the selection of tree species and provenances that are most capable of tolerating water stress are becoming crucial issues for the future of forestation. The effect of drought and water stress resistance of European beech (*Fagus sylvatica* L.) seedlings of three Slovak provenances (PV1: 530 m asl – moderately dry climate, PV2: 625 m asl – beech optimum, PV3: 1250 m asl – humid climate) were tested in controlled laboratory. The 8 month seedlings were deprived of water for 8 days. The water status of the plants (8 per treatment group) was monitored through the water potential (Ψs) of leaves. We observed a considerable increase of free abscisic acid (ABA) in the leaves (45-times in PV1) and the roots (110-times in PV3) of dehydrated plants in comparison with control seedlings. In non-irrigated plants, the values of total chlorophyll content (chlorophyll index) were significantly decreased only in PV2. Water deficit also affected performance of photosystem II (PSII). The actual quantum efficiency of PSII (ΦPSII) markedly decreased in PV2 (0.46) and PV3 (0.54). In PV1, the reduction of open reaction centres of PSII was not significant. The results indicate that the highest resistance against drought stress was recorded in the provenance PV1 with origin in low situated localities in drier climate district in Slovakia. This finding could be helpful for the future of reforestation at the sites affected by frequent summer droughts.

Drought Effects on Seasonal Dynamic of Sap Flow and Stem Circumferences in Young Spruce Stand

Ježík, Marek; Blaženec, Miroslav; Sitková, Zuzana; Střelcová, Katarína; Sedmáková, Denisa; Kovalčíková, Dana

Increasing frequency and severity of droughts arising from ongoing changes in climate negatively affect the productivity and stability of spruce forest ecosystems. The objectives of the study were: i/ to quantify the sap flow rates and circumference changes of 12 Norway spruce (*Picea abies* L.) trees under different soil moisture conditions (water stress and irrigation); and ii/ to investigate how they differed during two seasons with contrasting weather conditions. The study was carried out in central Slovakia (655 m a.s.l). Measured trees were 25 years old, ranged from 14.7 to 21.7 cm in dbh and from 14.8 to 18.2 m in height. The measurement of sap flow (Qs), stem circumferences, meteorology and soil water potential was carried out during the growing seasons of 2009 and 2010. In 2009, irrigation was applied after the soil water potential (SWP) decreased below -0.3 MPa. Mean SWP of control trees during irrigation treatment was -0.78 MPa, while in the case of irrigated trees it was -0.05 MPa. In the season 2010 precipitation was above normal and no irrigation was applied. The results indicate that the trees stressed by drought in 2009 achieved lower values of Qs and cumullative net stem shrinkage in comparison with the irrigated group. Mutual relations between the daily Qs rates, atmospheric evaporative demands and daily maximum stem shrinkage differed significantly between irrigated and control group in 2009. Studied relationships did not differ between groups in 2010.

Micro- and Macromorphological Responses in Foliage of Scots Pine to Changes in Soil Water Availability

Rovina, Carmen Maria; Schleppi, Patrick; Bugmann, Harald; Vollenweider, Pierre

During the past decades, temperature averages, drought frequency and the number of declining stands of Scots pines in central Europe have shown parallel increases. Since 2003, an irrigation experiment, established in central Wallis at low elevation (615 m), has tested whether re-occurring drought is pre-disposing or triggering Scots pine decline. Objectives in this study were to analyze canopy- to cell-level responses in foliage of trees exposed to ambient precipitation+irrigation and thus doubling the water supply, in comparison to control trees. Leaf area indices (LAI) were determined using 2004–2012 hemispherical pictures. Shoot/needle growth, biomass and the tissue area in needle cross-sections were measured using branches with at least three needle generations from two harvests taken in 2006 and 2012. Over time, the irrigation treatment has significantly increased LAI. Since 2004, shoot/needle growth and biomass have positively responded to increased water availability. Similarly, the surface area of all tissues in needle cross-sections has significantly increased whereas their relative area remained unchanged. Together with the unchanged cuticula thickness and specific needle weight, this indicated that the irrigation treatment did not change the needle xeromorphic traits. Hence, our results suggest that water shortage is limiting the growth of control trees via carbon shortage and that competition, rather than drought stress, triggers Scots pine decline.

Session 8: Frontiers in Dendroclimatology and -ecology

Frontiers in Dendroclimatology and -ecology (Introductory Talk)

Buentgen, Ulf

Annually resolved and absolutely dated tree ring-based climate reconstructions form a scientific backbone of the ongoing global change debate (i.e. dendroclimatology), and effects of climate variability on forest ecosystem productivity and functioning can be best estimated from different tree-ring parameters (e.g. ring width, wood anatomy, chemistry and density, stable isotopes), among various spatiotemporal scales (i.e. dendroecology). In this presentation, I will, however, not only exhibit the potential of modern tree-ring research that often benefits from massive sample replication, but I will also emphasize data-related and methodological-induced limitations. In this regard, I will particularly stress drawbacks in our understanding of past climatic changes at interannual to multi-centennial time-scales. Moreover, I will advocate for cross-disciplinary approaches at the interface of archaeology, climatology and ecology, which apply innovative statistical techniques and consider wood anatomical characteristics, for instance. Finally, I will provide timely examples of dendrochronological contributions beyond their traditional research foci, where tree rings might be able to offer additional insight into biological, epidemiological, mycological and even oceanographic forefront investigations.

Climate, Tree Physiology, or Both: What Is the Information Recorded in Oxygen Isotope Ratios of Tree-Ring Cellulose?

Kahmen, Ansgar; Treydte, Kerstin

The oxygen isotope ratios (δ18O) of tree-ring cellulose may carry critical information on long-term responses of trees to global environmental change. Over the past decades the key environmental and physiological processes that influence the δ18O values of tree-ring cellulose have been resolved and synthesized into mechanistic models. Nevertheless there is still substantial uncertainty about what signals are actually recorded in the δ18O values of tree-ring cellulose: Climate, tree physiology, or both. In our talk, we will employ the latest models to illustrate where globally and under what climate scenarios primarily climatic, plant physiological or both types of variables influence tree-ring cellulose δ18O values. Based on our model simulations we will present a mechanistic framework that can help to disentangle the climatic and physiological information that is recorded in tree-ring cellulose δ18O values. As such we seek with our presentation to i) resolve some of the uncertainties that are still associated with the interpretation tree-ring δ18O values, ii) build a bridge between the plant physiological and dendroclimatological community, and iii) show the potential of this powerful proxy to inform about long-term responses of tree physiology to global environmental change.

Climate Induced Changes in the Growth Rate and Physiological Optimum of Two Drought Sensitive Species

Csilléry, Katalin; Cailleret, Maxime; Amm, Annabelle; Oddou-Muratorio, Sylvie; Davi, Hendrik

Drought stress modifies the physiology of individual trees and, repeated droughts eventually provoke an evolutionary change. We studied the effect of drought in silver fir *(Abies alba)* and common beech *(Fagus sylvatica)* that cohabit along an altitudinal gradient on Mont Ventoux, southern France. First, we performed a dendroclimatic time series analysis for the period of 1960–2006. We show that silver fir's growth rate is principally sensitive to the given year's drought conditions, while common beech responds to the previous year's climate. The maximal growth rate was observed at low-intermediate elevations for common beech and at intermediate elevations for silver fir. Recent warming has already caused slight upward shift of these growth optima. To understand the physiological mechanisms underlying the inter-annual and -individual variation in growth rate, we developed a physio-demographic model that couples CASTANEA, an existing physiological model that simulates individual's daily response to climate with a demographic model that converts carbohydrates into growth and seed production and models dispersion and mortality. Using dynamically downscaled climate predictions for the period 2001–2100, we predict significant shifts in the physiological optimum of these two species, which is expected to modify the population dynamics and species composition of the forests of Mont Ventoux.

Climatic Relevance of Vessel-Chronologies in Oak from Different Ecological Settings Close to Lake Constance

Bleicher, Niels; von Arx, Georg

In southern Central Europe long tree ring chronologies have been constructed on the basis of historical, archaeological and subfossil material. Only rarely these have been used for dendroclimatology (Büntgen *et al.* 2011, Science). In order to explore their dendroclimatological poten-tial the climate growth relations of anatomical parameters were investigated. We collected samples from living trees on dry and wet soils. Over 200-year long chronologies of vessel size, early- and latewood width in addition to ring width were constructed using ROXAS and climate growth relations checked following standard procedures (Arstan, DendroClim). We found different stable and significant correlations. Most surprising was a very stable signal of winter and early spring temperatures in the lumen area of earlywood vessels that was independent on stand moisture. While in wet stands earlywood width was related to the preceding year's May temperatures, latewood width reacted to the current year's May temperatures. The results of this study demonstrate the still unexploited potential [hidden] in long oak chro-nologies, particularly with respect to winter temperatures, for which only few proxies exist.

New Insights of Spruce Response to Climate through Two-Hundred Year Tracheid-Size Chronologies

Castagneri, Daniele; Carrer, Marco

Due to methodological limitations and time-consuming procedures, most studies on tree-ring cell characteristics focus just on the last few decades. Therefore, wood anatomy in tree rings has not yet been used to assess tree response to climate over long time period. We built multi-century tracheid size chronologies of Norway spruce to test whether cell characteristics provide stable and valuable information on response to climate. Increment cores were collected at Croda da Lago, eastern Italian Alps, along a 1000 m altitude gradient. Thin sections were prepared with a rotary microtome, and images of cross sections were processed with Roxas software. Parameters of cell distribution were calculated from hundreds to thousands of cells from each ring. Using daily records of temperature and precipitation, tree response to climate was assessed for different time windows over 80 years. Response to monthly climate variables have been assessed over a longer time span. Current and previous summer temperature influenced tree-ring growth at high and low elevation respectively. At cell level, different parameters (e.g., median and maximum lumen size) were only partially correlated to ring width and provided new and more defined information, such as the effect of early and late summer temperature, on spruce growth.

Long-Term Productivity Changes of Two Norway Spruce (*Picea abies* [L.] Karst.) Alpine Forest Chronosequences under Shifting Environmental Conditions

Giammarchi, Francesco; Moshammer, Ralf; Uhl, Enno; Magnani, Federico; Cherubini, Paolo; Pretzsch, Hans; Tonon, Giustino

Two Norway spruce dominated Alpine forest chronosequences, of three different age classes each (pole stage, sawlog stage, mature stage), were chosen respectively in the Italian Eastern Alps and in Southern Bavaria. Following a preliminary dendroecological analysis to assess tree dominance within the stands, six dominant trees per class were selected and felled in order to perform stem analysis. Obtained data was then modelled and compared at cambial age and past growth history reconstructed in terms of dominant height development and dominant height increments. One wooden core per tree was collected and split into five-year long segments and δC13, δO18 and δN15 chronologies were built. Height growth trends and time-related information on changes in CO_2 atmospheric concentration, intrinsic water use efficiency (iWUE) and nitrogen depositions, gathered from isotopic analyses, were eventually combined to assess the causal relationships between increased productivity and environmental drivers. Results pointed out in both sites to sharper trends in younger age classes, particularly in the higher elevation site which seems to respond strongly to changes in climate. Data from isotopic analysis are meaningful as well, with some of the above-mentioned factors being significantly related to growth trends.

Detecting Permafrost Changes within a Tree Stand – an Example from the Swiss Alps

Griessinger, Jussi; Gärtner, Holger; Bast, Alexander

Trees at the subalpine belt in the vast high mountain areas of the Upper Engadin/Switzerland are facing obvious challenges due to drastic warming and changes within the hydrological cycle. Changes do not only appear within a species-specific respond on tree growth or possible shifts within the habitat behaviour and composition of trees, but also in changing plant-physiological adaptions and strategies and resulting limitations for species, Within a pilot study in the Engadin, we present results from a high elevation tree stand which is partly influenced by existing and re-establishing Permafrost. For the period since the beginning of the 20th century we analyzed stable oxygen isotope ratios (16O/18O) to investigate tree growth and water uptake to investigate possible changing water pools due to warming since 1900. First results show a distinct change within the tree-ring 16O/18O values, which indicates a change within the Groundwater-Permafrost system.

Sign of Biome Sensitivity to Atmospheric CO_2 Changes in Growth Rings from Coniferous Forests

Fernandez, Irene; Cabaneiro, Ana

Discrimination of the heavy stable carbon isotope 13C occurs during photosynthetic processes, associated with CO_2 stomatal diffusion and biochemical fixation involving enzymatic reactions. The atmospheric CO_2-C fixed in photosynthesis remains within the growing tree-rings tissues, providing a proper chronological fingerprint of the momentary atmospheric composition and the 13C/12C ratio in dendrological series is considered as a powerful tool for remote atmospheric reconstruction. The d13C of atmospheric CO_2 has changed over the last 200 years by 1.5‰ and during the second half of the XX century, both direct measures and dendrochronological records showed a sharper 13C decline in the atmosphere (Suess effect) of about 0.02‰ per year, mainly ascribed to increased fossil fuel combustion. However, natural isotopic variability among individual trees even under very similar growing conditions often frustrates the accurate dendrological interpretation of 13C atmospheric changes at short time-scales. Here we show evidences of a clear levelling off in the Suess effect at the end of the past century by monitoring d13C shifts in coniferous growing-rings from diverse contrasting ecosystems of the NW of Spain during the last quarter of century. Multiple tree-by-tree differential studies that expressed d13C shifts as 5-year increments respect to the isotopic composition of its own quinquenial growing-rings formed 25 years ago were carried out to minimize disturbances caused by interindividual tree variability and to allow interspecific data standardisation. This Suess effect halt observed during the mid-nineties is consistent with a decrease in global CO_2 emissions as well as with a partial maximum of the air d13C directly measured in this period. Our results indicates that this particular approach for isotopic data management can considerably improve dendrochronological studies by avoiding influences of local and ecological factors and by providing indirect but highly trustworthy reflects of the atmospheric 13C evolution.

Disturbance Regime in Temperate Mountain Spruce Forests of Central and East Europe – Preliminary Results from Dendroecological Reconstruction

Svoboda, Miroslav; Janda, Pavel; Čada, Vojtěch; Bače, Radek; Trotsiuk, Volodymyr; Rejzek, Jan; Mikoláš, Martin

Climate change could significantly alter disturbance regimes in forest ecosystems. In mountain regions of Central and East Europe, scenarios with increased frequency of severe windstorms and droughts, which could trigger large-scale bark beetle outbreaks, are predicted. The aim of this presentation is therefore to present results of dendroecological studies reconstructing disturbance histories from selected areas in Czech Republic, Romania, Ukraine and Slovakia. This study focused on: what historical natural disturbances have shaped the structure and development of primary Picea abies forest? We reconstructed the site's disturbance history using dendroecological methods. Growth patterns of increment cores were screened for (1) abrupt increases in radial growth indicating mortality of a former canopy tree and (2) rapid early growth rates indicating establishment in a former canopy gap. Our study provides evidence that these forests were historically shaped by infrequent, moderate- to high-severity natural disturbances. Our results, however, should be viewed with sufficient caution when making generalizations about the disturbance regime of *P. abies* forests throughout Central Europe. In reality, it is likely that characteristics of the disturbance regime vary in space and time along a continuum from small-scale gap dynamics to infrequent, stand replacing events.

Validating a Climate Interpolation Model (CIM) Using Tree Ring Data from the Austrian Central Alps

Motz, Kathrin; Pichler, Thomas; Leidinger, David; Spiecker, Heinrich; Formayer, Herbert; Nicolussi, Kurt; Vospernik, Sonja

In recent research on climate change precise and regionally explicit climate data are a prerequisite for impact, vulnerability and adaptation studies. CIMs are used to interpolate climate data to local conditions by using a set of regional weather-stations. These models are validated by using local weather stations not being part of the interpolation dataset. Problems arise for places lacking stations for validation. This applies especially to alpine regions, where weather station density is low. Adding to this in mountainous regions the effect of topography on climate is highly relevant calling for thorough validation. We apply an alternative approach that uses forest growth data for validation. Increment cores were sampled from Norway spruce *(Picea abies)* and Cembran pine *(Pinus cembra)* trees along altitudinal gradients of 500 at 4 sites in Tyrol, Austria. The monthly mean values of temperature, precipitation and radiation produced by a CIM for the study region have been validated via relationships with radial tree growth data by using dendroclimatological methods. The results indicate that the general climatic patterns are predicted well by CIMs on a regional scale, however at smaller temporal and spatial scales the performance was reduced, calling for further research to improve interpolation algorithms.

Interactions between Climate-Growth Relationships and Tree Social Status in a Mature Silver-Fir Plantation

Clairet, Natacha; Rathgeber, Cyrille B.K.

Our knowledge about the climatic influences on tree growth is principally based on the dominant trees studies. However, tree social status may influence tree functioning, leading to differential responses to climatic factors. The goal here is to test if there are significant interactions between tree social status and climate-growth relationships, which then will need to be taken into account for assessing the climatic change impacts on forest productivity. Three crown classes (dominant, intermediate and suppressed trees) in a 40-year-old silver fir (*Abies alba* Mill.) plantation near Nancy (France) were studied during 2006–2008. Wood formation and cambial activity were monitored weekly by collecting microcores. Daily meteorological data were collected close to the stand. The daily water balance (model Biljou ©) was calculated. Dominant trees started cambial activity before intermediate and suppressed trees, finished later and grown faster. Three social classes presented similar responses to climate variations. The intermediate trees were more sensitive. Water balance had the main influence in our site. Studies focusing only on dominant trees may be able to assess qualitatively the forest stand responses to climatic changes. However, our work shows that, to evaluate quantitatively this response amplitude, it is necessary to take into account the stand structure.

Potential of Climate Reconstruction from Tree-Rings of Scots Pine and Norway Spruce in Latvia

Dzenis, Jekabs; Elferts, Didzis; Dauskane, Iluta; **Treimane, Agita**

During couple of last decades considerable proportion of studies in the field of dendroclimatology have focused on reconstruction of the past climate. While majority of these studies have been carried in high altitude regions where growth of trees are generally limited by summer temperatures, little attention have been paid for potential to reconstruct past climate variability in the low altitude regions. Aim of this study was to assess the potential of climate reconstruction by using tree-rings of coniferous tree species (Scots pine and Norway spruce) in North-western Latvia. In the study region growth of pine was limited by low temperatures during February–March, while the growth of spruce was positively influenced by increased amount of precipitation during June–July of the current growing season. Neither early wood nor late wood width chronologies of pine and spruce showed significantly stronger relationships with studied climate parameters in comparison to tree-ring width chronologies. Linear least square regression was performed to create transfer models and random period calibration-verification procedure was applied to assess fit and predictive skill of these models. We concluded that with the highest accuracy it is possible to reconstruct mean temperature of February–March by using tree-ring chronology of pine.

Tree Ring Width, Earlywood and Latewood Analysis of 100-Year-Long Oak Chronologies at Síkfőkút LTER Site, Hungary

Nyitrai, Balázs

A 100-year-long tree ring chronology was built in a mixed forest of sessile oak (*Quercus petraea* [Matt.] Liebl.) and turkey oak (*Quercus cerris* L.). This investigation was performed in a LTER site in the North Hungarian Central Range (47˚55'N, 20˚46'E, 320–340 m a.s.l.) established in 1972. Increment cores were taken in November 2010. The climate-growth relationships were examined by calculating Pearson' correlation coefficients between the ring width chronologies and the monthly temperature and rainfall for a 16 month long period (from previous June to current September). Tree ring width, earlywood and latewood measurements showed similar patterns for sessile and turkey oak, except the period of oak decline lasting from late 70's to early 80's. Higher temperature in the previous and current summers than the average had a negative impact on both species while the rainfall of previous autumn and current spring influenced positively the tree ring development. The annual increment was mainly described by the amount of latewood but the earlywood also showed higher fluctuations through the years and between the species.

Wood Formation of *Picea abies* and *Fagus sylvatica* and its Climatic Drivers Along Altitudinal Gradients in the Bavarian Alps

Schuster, Christina; Zang, Christian; **Menzel, Annette**

Along altitudinal gradients in the Bavarian Alps (800–1400 m a.s.l.) we studied intra-annual tree-ring formation in 2011 in *Picea abies* and *Fagus sylvatica*. Aims were to explore general patterns of wood formation related to species, altitude, exposition and tree phenology, and to detect influences of climatic fluctuations on different phases of wood formation. At two gradients (north and south aspect) we established sample sites in 200 m altitudinal steps. Each site was equipped with data loggers for temperature and relative air humidity. Two trees of each species were selected per site and wood samples were taken in regular time intervals over the vegetation period using a microcore tool. Phenology was observed according to the BBCH code scheme. Wood formation generally showed a clear dependence on the species, and wood formation phases were delayed at higher altitudes. Moreover, species differed in timing of wood formation related to phenological phases: e.g., wood formation started in *P. abies* at the time of bud burst and in *F. sylvatica* later with leaf unfolding. The strong relation between the period of wood formation and altitude in *F. sylvatica* suggests that longer vegetation periods due to climate change could increase stem growth.

Session 9: Impact of Climate Change on Demographic Changes and Species Ranges

Assessing Forest Species Risk and Adaptability to Climate Change via Species Distribution Models, Life History Traits, and Dispersal Models (Introductory Talk)

Iverson, Louis Robert; Prasad, Anantha; Matthews, Stephen N.; Peters, Matthew P.

The climate is changing, and tree species currently residing at a specific location are at variable levels of risk of change (increase, decrease, stay put, or migrate in), depending on where they are relative to their overall distribution, their particular traits, and the severity of the changing conditions. We attempt to assess this species risk (in various regions of the eastern U.S.), and their capacity to adapt to a changing climate, through a series of modeling schemes which use species distribution models, life history traits, and dispersal models. For example, sugar maple *(Acer saccharum)* is modeled to lose habitat in middle latitudes, but it has traits that partially compensate for additional stresses incurred by climate change (relatively high adaptability), while balsam fir *(Abies balsamea)* has traits which tend towards low adaptability to climate change (i.e., it is likely to do worse than modeled). Black oak *(Quercus velutina)* is modeled to gain habitat in northern latitudes, and it has traits favorable to conditions projected under climate change; however, will the species be able to disperse to newly suitable habitats? Using a dispersal model, we assess this question, both without and with human assistance in moving propagules across fragmented and topographically flat habitats of the north-central United States.

Swiss Forests under a Changing Climate: Is Migration Limiting?

Lischke, Heike; Schmatz, Dirk

To test the effect of tree species migration on the ability of tree species to follow climate change induced shifts of their potential ranges, we ran Swiss-wide simulations until 2100 in 200 m resolution with the spatio-temporal forest landscape model TreeMig. The model was adapted to represent roughly current species distributions. Starting from these, we simulated future forest development with different scenarios of a) transient climate change (e.g. A1B) b) land-use change (e.g. abandonment of alpine meadows) and c) migration (seed dispersal vs. ubiquitous seeds). The results indicate a decrease in overall biomass, particularly in low elevations, mainly due to extreme drought events. At high elevations, biomass increases due to rising temperatures and the colonization of abandoned meadows. Species compositions change, drought adapted species become dominant in the lowlands, and most species shift their ranges upwards. Migration delays these upward shifts intermediately. For many already widespread species, migration is not limiting. However, a few species which currently occur only in a few parts of the country, can't reach their new suitable habitats due to slow migration. This suggests that e.g. Mediterranean species that are better adapted to the expected dry conditions might be restricted by slow migration.

Intraspecific Variation Buffers Projected Climate Change Impacts on *Pinus contorta*

Kreyling, Juergen; Oney, Brian; O'Neill, Gregory; Reineking, Björn

Many species exhibit ecologically relevant intraspecific variation, and few studies have analyzed its relevance for species distribution modeling (SDM). We compared three techniques for the highly variable species *Pinus contorta.* First, applying a conventional SDM approach (MaxEnt; species model). Second, modeling each of three subspecies independently and combined their projected distributions (MaxEnt; subspecies model). Finally, using a universal growth transfer function (UTF) to incorporate intraspecific variation utilizing provenance trial growth data. Different model approaches performed similarly for current distributions. MaxEnt model discrimination was greater, but the UTF was better calibrated. For future climatic conditions, projections of habitat suitability diverged. When the species' intraspecific variability was acknowledged, the species was projected to better tolerate climatic change as related to suitable habitat without migration (subspecies model: 26% habitat loss or UTF: 24% habitat loss vs. species model: 60% habitat loss), and given unlimited migration may increase amount of suitable habitat (subspecies model: 8% habitat gain or UTF: 12% habitat gain vs. species model: 51% habitat loss) for 2070–2100. We conclude that intraspecific variation may buffer against climate change. A key future research challenge lies in assessing the extent to which species can utilize intraspecific variation under rapid environmental change.

Do the Elevational Limits of Deciduous Tree Species Match their Thermal Latitudinal Limits? Implications for Climate Change Projections

Randin, Christophe F.; Kollas, Chris; Normand, Signe; Vittasse, Yann; Körner, Christian

We compared the upper limits of eighteen deciduous tree species with respect to elevation in Switzerland and latitude in Europe. We hypothesised that species would exhibit the same relative positions along elevation and latitude, which can be expected if species have reached their thermal cold limit along both gradients. We developed a method to identify a least-biased estimate of the elevational and latitudinal cold temperature limits of species and for comparing these two limits. The vertical distance between the elevation of the potential regional climatic treeline and the uppermost species occurrences was calculated and used for comparisons between elevation and latitude. We found a strong relationship between the thermal latitudinal and elevational distances of species' cold limits to the potential treeline. A first group of nine species showed very similar thermal distances to the potential treelines along elevation and latitude. A second group of seven species occupied a climatic niche closer to the treeline at the edge of their latitudinal range, and only two species did not fill their thermal niche. Our study provides support for the common concept of a species range–environment equilibrium. Thermal equilibrium can be therefore decoupled from geographic non-equilibrium situations

Extreme Drought Events Improves Modelling of Beech Persistence at its Distribution Limit in Hungary

Rasztovits, Ervin; Móricz, Norbert; Berki, Imre; Pötzelsberger, Elisabeth; Mátyás, Csaba

Projections of species distribution models (SDMs) for future climate conditions are based on long term mean climate data. For management and conservation issues SDMs have been extensively used, but it is not tested whether models that are successful in predicting current distributions are equally powerful in predicting distributions under future climates. Observations after 2003 confirms that extreme drought events played an important role in driving beech mortality at low-elevation xeric limits. The objective of this study was (1) to set up a simple extreme drought event based vitality model (EDM) using sanitary logging information as a proxy of vitality response of beech and (2) to compare the spatial pattern of the predicted vitality loss provided by the EDM with the distribution limits of the SDMs for three terms (2025, 2050 and 2100) in Hungary to assess model performance. Prediction for vitality loss for 2025 obtained from the EDM was in agreement with those of the SDM, but for the end of the century the EDM predicted a more serious decline in almost all regions of Hungary. The result of the comparison suggests that the increasing frequency and severity of extremes might play a more important role in limiting the distribution of beech in the future near to the xeric limit than long-term means.

To Grow or to Defend – on the Competition Dynamics of Fast-Growing Neophytic Trees in Southern Switzerland

Wunder, Jan; Rigling, Andreas; Fonti, Patrick; Conedera, Marco

Neophytic tree species are currently gaining ground in the forest ecosystems of Southern Switzerland. They may accelerate their expansion in a warmer world with unknown consequences for forest ecosystem goods and services such as biodiversity, carbon storage, and protection of humans and infrastructure from natural hazards. In this project, we apply a combination of ecophysiological and dendroecological methods to elucidate the competition dynamics and physiological decay of two fast-growing neophytic tree species with different life-history strategies: the deciduous short-lived pioneer *Ailanthus altissima* and the evergreen late-successional *Cinnamomum glanduliferum.* We present results from growth and decay measurements of these neophytes and their native competitors at different temporal scales, from annual to sub-hourly resolution. First observations indicate that many large *A. altissima* trees are rotten inside along with an unexpected high number of *C. glanduliferum* trees. This suggests that the enormous growth rates of both neophytic trees may come at the cost of their defences against pathogens such as wood decaying fungi. We test this hypothesis and quantify the growth and decay patterns of neophytic vs. native tree species resulting in a better understanding of the invasion potential – ultimately contributing to a more informed management of neophytic tree species in Southern Switzerland and beyond.

Forty Years of Treeline Change in the Swiss Alps

Erdle, Lisa M.; Barbeito, Ignacio; Bebi, Peter

In the European Alps, climate change and land use change are modifying environmental conditions that may shift tree lines upwards in altitude. Modifying structure and function of traditional agro-pastoral systems, it is important to analyze the underlying processes of tree line succession to predict future land cover changes. To better understand these dynamics, this study models the environmental factors contributing to establishment and growth of individual trees for three high-elevation conifer species (*Larix decidua, Picea abies* and *Pinus cembra*) in the Dischma Valley, in the Central Alps, Switzerland. From studies mapping individual trees and groups of trees over 40 years (1972–2012), we have evidence that south-facing slopes are experiencing greatest changes within the treeline ecotone. On south facing slopes, *L. decidua* has advanced as much as 150 m in elevation. To assess the evolution of species specific responses, a dendro-ecological approach using tree-ring chronologies is being performed summer 2013 to further examine local patterns of colonization.

Gas Exchange and Climate: Analysing Interferences of Temperature, Humidity and CO_2 by the Optimality Approach

Roth-Nebelsick, Anita; Konrad, Wilfried

There are various studies on water-saving effects under elevated CO_2. Mechanistic approaches to the coupling of CO_2 and water relations were therefore included in Dynamic Global Vegetation models, mostly on the Plant Functional Type level, to address CO_2-based modulation of responses to climate change. Main objectives of this study are to 1) identify species-specific effects of CO_2 on temperature and humidity related changes in plant water economy, and to 2) evaluate the relevance of rising CO_2 for future plant performance. Improved knowledge about topics 1) and 2) are relevant to predicting species distribution shifts. A gas exchange model based on the optimality principle, requiring no a priori knowledge of species-specific stomatal control, was applied to mediterranean evergreen and temperate deciduous species, with systematical variation of temperature, humidity and CO_2. The strongly species-specific results indicate that CO_2 level variations typical for the Quaternary (ca. 180–300 ppm) have the most dramatic impact on plant gas exchange and photosynthesis, and therefore the strongest modulating effect on humidity and temperature responses. These first results suggest that climate-change induced effects on plant performance and species distribution will not be highly modulated by further increasing CO_2.

Simulating the Dynamics of the Pyrenean Montane-Subalpine Ecotone in a Climate Change Context Using the Model SORTIE-ND

Coll, Lluís; Ameztegui, Aitor

Most predictive models forecast significant upward displacement of forest ecotones tracking increases in temperatures. However the predicted upward spread of species into existing forests is driven not only by climate but also by other demographic processes operating at a lower scale. In this study, we parameterized and used the model of forest dynamics (SORTIE-ND) to investigate the role of species-specific differences in juvenile growth and recruitment in the evolution of the Pyrenean conifer montane-subalpine ecotone under a climate change context. Predicted estimates of total biomass and tree size distribution of adult stands were consistent with observed values from mixed conifer stands in the study area (composed by *Pinus sylvestris, Abies alba* and *Pinus uncinata*). Our results show that for ecologically similar species (i.e. both pines), even small differences (10%) in the response of sapling growth to climate change can lead to significant differences in the future species composition of these forests (increase in abundance of *P. sylvestris* from 42% to 50.3%). Conversely, in the transition areas composed by species with contrasted ecological requirements (i.e. *P. uncinata* and *A. alba*) other factors such as shade-tolerance emerge as more decisive than temperature-induced changes in driving the future composition of these forests.

Decline and Succession of Scots Pine in NW Italy in Response to Future Climate Scenarios

Vacchiano, Giorgio; Motta, Renzo

Pinus sylvestris is currently experiencing a decline in vitality in inner-alpine regions. Drought is believed to be the main predisposing agent of the decline. Alternative successional pathways, should pine recede from its range, have been hypothesized but are unconfirmed. Our aim is to model the current and future distribution of Scots pine as a function of (bio)climatic, site, and anthropic variables in two regions of NW Italy, based on presence-only datasets (a forest cover map, and a regional forest inventory). Areas of change will be compared against observations of the decline in greenness (MODIS NDVI) following recent dry spells (e.g., years 2003 and 2006). The successional pathways that could occur will be explored by modeling the response to current and projected climate of the distribution of potential replacement species, taking into account their current dispersal range. Scots pine will likely recede in inner-alpine valleys as a consequence of high spring-summer temperatures and unfavorable evapotranspiration at lower altitudes. These areas overlapped to those experiencing a lower-than-average NDVI change in the dry years 2003–2006. The future distribution of *Quercus pubescens* exhibited the highest degree of overlap to the areas where Scots pine is at risk of receding from the landscape.

Can We Predict Latitudinal Range Shifts in Species' Distribution from Altitudinal Data?

Matias, Luis; Jump, Alistair S.

Recent changes in climate at global scale are altering ecological conditions for many species, being its consequences more evident at distribution edges, where range expansions or contractions may occur. Since studies across the latitudinal distribution of species are often complicated, altitudinal gradients have been traditionally used in order to predict latitudinal changes. The current population dynamics at altitudinal and latitudinal range limits would inform us about the future population trends and their consequences for range shifts. In this study, we analyse the changes in the population dynamics of two woody species through altitudinal gradients at their southernmost distribution limit and whether the same pattern is maintained through a latitudinal gradient covering the complete distribution range. We used *Pinus sylvestris* and *Juniperus communis* as focal species, and studied their demographical structure (density and age), growth, seed production and herbivory damage. For both species, populations at lowermost altitude presented older age structure, decreased growth and lower reproduction when compared to the upper limit, indicating an upward range shift. This altitudinal displacement was overall maintained through the latitudinal gradient, but other factors than climate, as herbivore pressure or human management, must be taken into account to properly infer latitudinal processes from altitudinal data.

Session 10: Adaptability of Tree Species to Climate Change (Phenotypic Plasticity, Genotypic Variation)

Seed Sourcing 2.0: Assisting Assisted Migration (Introductory Talk)

O'Neill, Greg Arthur

A growing body of literature highlights the capacity of long-term provenance tests to characterize population differences in adaptation and plasticity, assess possible climate change impacts to trees and communities, and develop seed sourcing strategies to promote healthy and productive ecosystems. Assisting the migration of seed sources to ensure forests are adapted to future climates is emerging as a key aspect of seed sourcing to mitigate anticipated maladaptation in forest trees. A complementary approach of genetic diversification has been suggested to help seed sourcing strategies buffer the considerable uncertainty present in climate and genecology models. These observations have placed new demands on seed source selection systems, while the availability of geographic information systems, fine scale climate models, a new era of provenance tests, and new analytical techniques have revolutionized opportunities for the development of new seed sourcing systems. This presentation examines the rationale and risks of assisted migration and genetic diversification, and explores opportunities for creating new approaches to seed sourcing. A hybrid fixed/focal point seed transfer system and methods to integrate assisted migration into existing fixed and focal point seed transfer systems will be proposed.

Climate Impacts on Tree Height Variability within Norway Spruce Populations

Kapeller, Stefan; Schüler, Silvio

For climate change mitigation, a profound understanding of adaptedness and adaptability of tree populations to climate conditions, both closely related to adaptive genetic variation, is necessary for an estimation of potential risks for future forest ecosystems. Tree populations of Norway spruce are adapted to a wide climatic range and harbor considerable adaptive genetic variation within and among populations. Until today it is unclear, which selection drivers contribute most to spatial patterns of intraspecific variation in Norway spruce. In our study we analyzed results from a comprehensive Austrian provenance test, comprising 379 populations planted at 29 test sites across Austria. We calculated statistics of phenotypic variation for tree heights at age 7, 8, 9, 10 and 15 and correlations to climate parameter. Our results reveil a decline in variation with increasing temperatures and increasing heat-moisture indices at planting sites. We find that for most parts of Austria tree height variation within populations is rather shaped by other environmental selection forces than drought. Instead, spatial and temporal climate variability, may be stronger selective forces, which foster phenotypic and genetic intraspecific variation.

Adaptive Genetic Variation of Spruce, Fir and Beech in Switzerland: First Results from a Genecological Study

Frank, Aline; Sperisen, Christoph; Brang, Peter; Burkart, Anton; Heiri, Caroline

As a result of long-term selection processes, forest tree populations are well adapted to their local environments. How well these populations are adapted to the expected warmer and drier future climate, however, is uncertain. Thus, we established the extensive genecological study "ADAPT" with the aim to assess the risk of maladaptation of today's populations to future climates for the three most common tree species of Switzerland: Norway spruce, silver fir and European beech. In a common garden experiment at two experimental sites, the progeny of 90 autochthonous populations of each species from a large ecological range in Switzerland, which includes populations from the dry inner-alpine Wallis as well as populations from the tree line, is investigated by measurements of growth (seedling height and stem diameter) and phenological traits (bud swelling, bud burst, unfolding of leaves, growth cessation). In this contribution, we will present a first comprehensive analysis of phenotypic variation of spruce and fir in Switzerland based on data collected in spring 2013. By subsequently relating the observed phenotypic variation to environmental factors at seed source locations, patterns of adaptation to today's climates can be derived, and risks of maladaptation to future climates can be estimated. Ultimately, we aim at formulating seed transfer guidelines applicable for Switzerland, which are based on genetic variation and the relative risk of maladaptation for each investigated tree species.

Soil Characteristics not Provenances Are Important for *Pinus sylvestris* and *Picea abies* Recruitment under Climate Change

Moser, Barbara; Wasem, Ulrich; Wohlgemuth, Thomas

Forest managers are increasingly considering plantation of more drought adapted provenances or species in order to facilitate forest persistence under climate change. We sowed five *Pinus sylvestris* and four *Picea abies* provenances collected along a continentality gradient from Switzerland to Romania in three forest stands of the Rhine valley, Switzerland. The stands differed with respect to volumetric soil water content (VWC), which averaged 32%, 22%, and 10%, respectively, during the growing season. In order to create an additional moisture gradient within stands, 0%, 33%, or 66% of the precipitation was removed in each of 15 sowing sites per stand. Spring precipitation in the two years of the experiment was 145% and 73% of the 100y-average, respectively. Seedling emergence and survival was similar in all provenances but differed between years and sites, depending on weather conditions in spring. Height and biomass of two-year-old seedlings were positively correlated with VWC. We found no differences in phenotypic plasticity among provenances or species, and local provenances were able to build up similar carbohydrate reserves under drought as more continental ones. Our results suggest that Central Alpine *P. sylvestris* and *P. abies* are enough plastic to withstand drought events as projected for the next century.

Effects of Weather Conditions During Seed Maturation on the Adaptive Performance of Seedlings and its Contribution to the Adaptation of Trees to Future Climates

Schüler, Silvio; Kapeller, Stefan

The adaptability of forest trees to changing climate conditions mainly depends on two requisites: firstly, on the genetic variation of tree species, and secondly, on the epigenetic status of the responsible genes, that is whether genes are being expressed or not. We aimed at testing for the effects of weather conditions during pollination, embryogenesis and seed development on the performance of seedlings from open-pollinated seed orchards and seed stands from different provenances of the conifers *Pinus sylvestris, Picea abies*, and *Larix decidua*. Extreme environmental conditions that were found in different seed years represent the environmental trigger. In a nursery trial with a normal and a water deficit treatment, we characterized various quantitative traits (i.e. phenology, drought tolerance). Significant differences were found among the tested species, among provenances, among the two precipitation treatments and most importantly among the years in which the seeds were produced. This suggests that the effect of interannual variation of climate during pollination and seed maturation has a larger effect on the performance of produced seeds, respectively the seedlings emerging from these seeds, than previously thought and that it contributes to the adaptations of forest trees to climate change.

Querco: Swiss Oaks Resistance to Air Warming and Drought

Günthardt-Goerg, Madeleine S.; Arend, Matthias; Vollenweider, Pierre; Kuster, Thomas M.

Climate change is expected to increase temperature and decrease summer precipitation in Central Europe. In the framework of the model ecosystem experiment "Querco", the responses to drought (D, -43 to -60% irrigation), air-warming (AW, +1–2 °C versus ambient) and their combination (AWD) of >700 trees, 6-years old at the end of the experiment, from several provenances of *Quercus robur, Q. petraea* and *Q. pubescens* were tested during three growing seasons. Within all species, both AW and D accelerated bud burst whereas the former treatment enhanced and the latter depressed photosynthetic carbon assimilation. Drought-specific injuries developed in foliage under severe drought conditions with the injury range varying according to species and provenance. Although suffering the strongest relative biomass reduction by D, Q. robur still showed superior growth in comparison to measurements in other species. Whilst producing more biomass in the control treatment, the provenances from dry versus mesic sites grew similarly when exposed to drought. Drought adaptive leaf traits showed a high phenotypic plasticity and were affected in opposing ways by AW and D with a neutralizing effect under AWD. Morphological differences between provenances, however, did not reflect the environmental variability between sites of provenance origin. Finally, as demonstrated by 100% tree survival after three years of treatment, the tested central European oaks appeared to be remarkably tolerant to drought.

Effects of Heat and Drought on Seedlings of Scots Pine (*Pinus sylvestris* L.) Provenances

Taeger, Steffen; Menzel, Annette

Climate extremes will increase in frequency and magnitude under climate change and will impact the performance and survival of forest trees such as Scots pine. We analyzed if provenances of Scots pine differ in their response to heat and drought, and if we can identify provenances that are better adapted to such climate extremes. Seedlings of ten provenances of Scots pine (*Pinus sylvestris* L.) from the southwestern to the central part of the species distribution range were sown in a common-garden experiment equipped with a non permanent rain-out shelter and an aboveground heating system. With a full factorial design we investigated their reaction to heating (warming by 3.2 K) and drought (3 months without rain). Provenances differed in growth traits (shoot and root length, diameter, biomass) as well as in biochemical composition of needles (nutrient content, levels of amino acids). Treatment significantly influenced phenology, nutrient uptake and growth parameters but not levels of the stress indicator proline. Differences in water use efficiency (δ13C in leaves to be analyzed) are expected. Spanish and French provenances showed strongest response to drought in terms of biomass allocation, but this presumable adaptation to drought events comes at the cost of low overall growth.

Frost Sensitivity Limits Assisted Migration of *Pinus halepensis* but not *Pinus nigra* into Regions with Spring Frost

Bachofen, Christoph; Wohlgemuth, Thomas; Ghazoul, Jaboury; Moser, Barbara

In the inner-alpine forest-steppe ecotone, *Pinus sylvestris* is an early colonizer after disturbances, but seedling recruitment may fail increasingly due to seasonal drought as a result of climate change. More drought tolerant Mediterranean pine species may be better adapted to future climatic conditions but are thought to be more sensitive to frost events, which are common in inner-alpine valleys until late spring. We tested needles of one-year-old seedlings of 11 provenances of *P. sylvestris, P. nigra* and *P. halepensis*, grown in a common garden experiment, for cold hardiness at temperatures ranging from -5 °C to -35 °C from February to May. P. halepensis showed a weak adaptation to seasonal temperature changes with an LT50 of -17 °C in the fully hardened and an LT50 of -12 °C in the dehardened state. The nine Mediterranean and Central European provenances of *P. sylvestris* and *P. nigra* tolerated freezing at -35 °C in the fully hardened state, which is far below the absolute minimum temperature measured in the Rhone valley during the last century (-20.6 °C). In early May, the LT50 of the same provenances ranged between -6.8 °C and -9.3 °C, showing optimal adaptation to seasonal changes in the risk of frost damage in the Central Alps. During dehardening, cold hardiness was similar in both species, whereas differences between provenances were ecologically insignificant. We conclude that frost tolerance is not the limiting factor for assisted migration of potentially drought adapted *P. nigra* and Mediterranean *P. sylvestris* provenances into the Central Alps.

Adaptation and Plasticity of Winter Freezing Resistance in European Beach Populations Along a Temperature Gradient

Lenz, Armando; Hoch, Günter; Vitasse, Yann; Körner, Christian

European beech naturally grows within a wide range of climatic conditions. In this study we asked whether (1) beech populations growing in contrasting climates differ in their maximum freezing resistance, and (2) if possible differences result from genetic differentiation or phenotypic plasticity. We collected twigs of adult beech trees at three sites along a 90 km natural temperature gradient in the Swiss Jura Mountains on March 7 2013. Freezing resistance of buds was assessed directly after sampling, after hardening samples for 5 days at 6 °C and after an additional hardening of samples for 3 days at 15 °C. Actual freezing resistance correlated with temperatures of the site of origin. Populations from the coldest place had an actual freezing resistance of 40 °C, 15 K more than populations from the warmest place. After the first hardening treatment, the difference in freezing resistance among the three sites decreased to 10 K and after the second hardening treatment, the differences disappeared completely. We conclude that winter freezing resistance in beech shows a high plasticity to temperature changes, allowing individuals to rapidly adjust freezing resistance to changing climatic conditions, especially during unusually warm winters with cold extremes.

Adaptability of Deciduous Trees to Increasing Air Humidity in Hemiboreal Forest Zone (Estonia)

Tullus, Arvo; Kupper, Priit; Sellin, Arne; Sõber, Jaak; Tullus, Tea; Tullus, Hardi; Lõhmus, Krista; Sõber, Anu

Climate change will cause alterations in atmospheric humidity and precipitation. For northern Europe and northern part of central Europe, a rise in humidity and precipitation is predicted. However, terrestrial ecosystem responses to such changes are not exactly known. We studied growth and functioning of silver birches *(Betula pendula)* and hybrid aspens (*Populus tremula* × *P. tremuloides*) in free air humidity manipulation (FAHM) facility, where humidity is elevated on average 7–10% over the ambient level. Growth, gas exchange, hydraulics, foliar and litter data from three control and three humidified plots were collected during five seasons (2008–2012). During the first seasons, the growth of trees remained slower in humidified plots. Photosynthetic capacity, stem sap flux and foliar nutrient concentrations were lower in humidified trees. Growth of humidified birches improved since the third season and exceeded control trees thereafter, whereas humidified aspens' growth remained slower throughout the study period. Leaf senescence of birches in humidified plots was delayed. Although for many regions an increase of drought events is considered one of the main consequences of climate change, our study showed that it will induce significant changes in functioning of plants and ecosystems also in areas with rising humidity.

Climate Extremes in Tree-Rings of Native and Alien Tree Species in Central Poland

Bijak, Szymon

This study investigates susceptibility of four tree species to climate extremes whose abundance becomes more frequent because of observed climate change. Increment cores were collected in Rogów (51°49'N, 19°53'E) for native *(Quercus robur, Abies alba)* and introduced *(Quercus rubra, Pseudotsuga menziesii)* tree species (15 per species). Ring widths (TRW) were measured and latewood proportion (%LW) calculated. Pointer years (PY) indicating rings with conspicuously smaller/larger TRW or %LW were determined for 1971–2010 period. Data from local meteostation served to describe weather in detected PY. Years with extreme meteorological conditions were also pointed and trees response was analysed. More PYs were found for native oak (14 vs 11) and introduced *P. menziesii* (15 vs 7). Negative PYs of conifers were related to cold January–March and wet August. Oaks showed lower vulnerability to extreme temperature, but produced wider rings in case of more precipitation. Water availability in April–August turned out to be a very important factor shaping tree growth. The extremely dry year 1992 resulted in very narrow rings for all species except *A. alba*. The predicted increase of drought frequency might result in decreased radial increments of the investigated species except for silver fir. *Q. rubra* seems to have adapted to climate conditions in central Poland better than *P. menziesii*.

Genetic Differentiation and Adaptive Potential in an Insect Pollinated Tree

De Kort, Hanne; Vandepitte, Katrien; Honnay, Olivier

Insect pollinated tree species may suffer decreased levels of genetic variation in a fragmented landscape, possibly undermining their capacity to adapt to climatic conditions. As *Frangula alnus* (Common Buckthorn), an insect pollinated tree, is widely distributed along a European latitudinal gradient, this species is very useful to assess the effects of climate on the adaptive potential of trees pollinated by insects. To investigate local adaptation to climate in *Frangula alnus,* we sampled 25 populations from 8 regions ranging from Italy to Sweden. 183 candidate SNPs were successfully genotyped in 526 individuals. To detect putative loci under selection, we used both a hierarchical island model (ARLEQUIN) and a Bayesian model (BAYESCAN). To test for associations between SNPs and climatic variables as proxies for selection pressures, we also applied two landscape genetic methods that take into account spatial autocorrelation: an LFMM (Latent Fixed Mixed Model), and a SAM (Spatial Analysis Method). A total of 18 SNPs was identified as outliers by both ARLEQUIN and BAYESCAN, from which 7 SNPs are under positive selection and 11 under balancing selection. Moreover, all 7 putative adaptive SNPs could be associated with at least one climatic variable, which is strong evidence for adaptation to climate.

Adaptive Potential of *Abies alba* and *Picea abies* under Global Change: A Research Framework

Heer, Katrin; Liepelt, Sascha; Roschanski, Anna; Opgenoorth, Lars; Ziegenhagen, Birgit

The question whether forest tree species are able to adapt to rapid changes of climatic conditions is a critical ecological, societal and economic issue. The ERA-Net BiodivErSA project TipTree seeks to identify traits and associated candidate loci under selection and aims to identify tipping points in the demographic and micro-evolutionary dynamics of tree populations. For one of our study species, *Picea abies,* several genes have already been associated to phenotypic traits under selection. Among the investigated traits bud set and bud burst have been proven to be highly heritable and crucial for fitness under changing climatic conditions. In our working group, we aim to verify whether the same loci are under selection in Abies alba under climate change. For both species we will investigate whether loci associated to putatively adaptive traits such as bud phenology, fecundity, growth rate and water use efficiency are under selection along environmental gradients. As selection is expected to be particularly strong in early life stages we aim to investigate whether there are significant shifts in allele frequencies between generations. Ultimately, the results will be fed into models simulating micro-evolution of tree populations, which integrate different management scenarios.

Photosystem II Thermostability of Different European Beech Provenances

Kurjak, Daniel; Kmet', Jaroslav; Macková, Miroslava; Gömöry, Dušan

The aim of the study was to test sensitivity of photosystem II (PSII) of beech (*Fagus sylvatica* L.) provenances to short-term thermal stress. We assessed five provenances originated from different countries and elevations (Germany: 55 and 140 m a.s.l., Poland: 450 m a.s.l., Slovenia: 1040 m a.s.l., Austria: 1100 m a.s.l.). Trees were grown in an international provenance experiment with randomized blocks, established in Central Slovakia in 1998. We measured changes of the following variables under the temperatures ranging from 30 to 45 °C: maximal photochemical efficiency of PSII (Fv/Fm), number of active reaction centres (RC/ABS), performance index (PI) and damage of oxygen-evolving system (Wk). Only changes at temperature 45 °C are referred here. This temperature induced decrease in all tested parameters in all provenances. Fv/Fm values were significantly higher ("better") in the Slovenian, Austrian and one German (140 m a.s.l.) provenance. Significantly higher values in RC/ABS were found for the Slovenian and Austrian provenance and the Austrian provenance retain higher values of PI in comparison with all others. Wk values were lower for the Austrian, Slovenian and Polish provenance. We conclude that most resistant to thermal stress appear to be provenances from high elevations, especially the Austrian and Slovenian provenance.

Influence of Seasonal Drought and Increased Temperature on Scots Pine Provenances

Seidel, Hannes; Taeger, Steffen; Menzel, Annette

In the last few decades, Scots pine forests have experienced frequent die-offs in their south-western distribution range mediated by recent climate change. Future climate may be characterized by increased mean temperatures and a regional decrease in precipitation including higher drought incidence and severity. Especially seedlings are more vulnerable to drought events than large trees. We investigate how Scots pine seedlings from different European origins can deal with drought and increased temperatures and whether they can adapt to multiple drought events by phenological timing, by trait change and ecophysiological adjustment and which are possible lethal thresholds. Our drought and passive warming experiment includes 10 different Scots pine provenances. The potted seedlings are grown in a vegetation hall (ambient temperature) and in a greenhouse (elevated temperature) and will experience seasonal droughts in spring and/or summer. Besides ample soil and tissue moisture monitoring, we evaluate phenological timing, growth/morphology and photosynthesis by chlorophyll fluorescence. We assume that seedlings from Mediterranean origins can better sustain summer drought than those from continental origins and that reduced growth during spring drought may lead to an adaption against an additional drought event in summer. Results of the spring and summer season are presented.

Ecophysiological Response of Beech and Spruce to Simulated Climate Change across an Altitudinal Gradient

Signarbieux, Constant; Berthelon, Claire; Mudry, Nadia; Vollenweider, Pierre; Buttler, Alexandre

Climate change is driving upward shifts in plants' altitudinal range. We chose two tree species of major ecological and economical importance in the Swiss Jura mountains (beech and spruce) to answer the following questions: (i) Will spruce and beech phenologically and ecophysiologically adapt to simulated climate change and (ii) will species-specific responses differ? By transplanting juvenile trees together with their soil (donor site) downward an altitudinal gradient (from 1340 m to 1071 m, 571 m and 371 m), we tested the response of approx. 5 years seedlings of both species to warmer and drier conditions. Ecophysiological parameters (photosynthetic capacity, Vc,max and plant water status) were measured in situ during the first growing season after transplantation (2012). As a first observation, beech and spruce did not show differences in physiological performance at the donor site. However beech showed higher photosynthetic capacities (Amax and Vc,max) than spruce in the recipient sites, where it was exposed to temperature increase up to 6°C and precipitation reduction up to 40%. This might point to a higher phenotypic plasticity for beech. These observations indicate that beech may profit more than spruce from climate change, amending the forest composition and creating challenges for forest managers.

Adaptive Genetic Variation of Silver Fir in Switzerland

Späni, Martina; Kolly, Anna; Frank, Aline; Heiri, Caroline

Climate change will likely stress forests on many sites. The ability of forest tree populations to cope with climate change depends largely on their adaptive potential, i.e., on their amount of genetic variation. The few existing studies for silver fir *(Abies alba)* found no large differences among populations, neither in molecular markers nor in phenotypic traits. However, most of these studies only incorporated a small number of populations, rendering it difficult to draw general conclusions on the adaptive potential of silver fir. The present study aims to describe the adaptive genetic variation within Switzerland, using a genecological approach. In a common garden experiment at two experimental sites, the progeny of 90 populations covering the range of silver fir in Switzerland is investigated by measurements of growth and phenological traits (annual average temperature and precipitation on sites of origin ranges between 2.68–8.75 °C and 82–238 cm/year, resp.). We will present a first analysis of data collected in spring 2013, aiming at drawing a comprehensive picture of phenotypic variation of silver fir in Switzerland. These results will be central for further analysing correlations with environmental parameters at seed source locations, and for calculating the risk of maladaptation to future climatic conditions.

Session 11: Adapted Forest Management

Adaptation Measures in European Forestry: What Will Be the Impact on Ecosystem Services? (Introductory Talk I)

Lexer, Manfred Josef

Climate change poses significant challenges to forest management. Observed impacts and findings of model based scenario analyses show strong contrasts between bioclimatic regions and vary substantially within regions depending on current forest conditions, demanded ecosystem services and forest management. Accordingly, the diversity of proposed forest management measures and strategies to cope with climatic changes is huge. Within the COST Action ECHOES ("Expected Climate Change and Options for European Silviculture") 483 adaptive measures in silviculture and forest management have been reported for 19 European countries. Based on ECHOES data an overview on adaptation measures in European forestry is given. Stratified into different bioclimatic regions and forest types adaptation measures are then evaluated based on expert knowledge and results from the MOTIVE project to which extent they may support the future provisioning of ecosystem services. Based on this assessment knowledge gaps and further challenges will be discussed.

Economic Consequences of Climate Change for Forest Owners and Uncertainty Management (Introductory Talk II)

Hanewinkel, Marc

The paper deals with economic consequences of climate change. Based on the results of a combination of a European-wide species distribution model with a large-scale scenario model and a classical land expectation value model, it shows effects of a potential shift of major tree species on the economic productivity of Europe's forests under changing climatic conditions. The impacts of such a change of the area of productive species like Norway spruce to forest owners are discussed together with adaptation strategies to mitigate these effects and to deal with the underlying uncertainties. Preconditions for forest owners to apply such adaptive measures are investigated based on a questionnaire that has been distributed to private forest owners across Europe. The answers to the questionnaire show that believing in and seeing effects of Climate Change is a main precondition to apply adaptive measures.

Understorey Plant Contribution in Water Balance Along a Gradient of Oak Stand Density

Gobin, Rémy; Korboulewsky, Nathalie; Seigner, Vincent; Balandier, Philippe

In the context of climate change, water resources of some temperate forest ecosystems may become limiting with risk of stand decline. Therefore forest managers in some countries consider reducing standing wood volume to limit stand water consumption, but this often leads to the development of monopolistic understorey plants. Our objective was to quantify the relative water uptake of two common understorey plants (*Molinia cerulea* Moench and *Pteridium aquilinum* Kuhn) in mature *Quercus petraea* Liebl. stands close to Orléans, France. Twenty plots (10 plots per species) were established in spring 2012 along a gradient of stand basal area sharing the same soil characteristics. On each plot, two circular areas (40 m-diameter) were set up, one weeded and the other untouched. Soil water content (SWC) and tree growth were monitored every two weeks. Understorey had a significant impact on stand water balance in 2012. The SWC minimal values were higher in weeded plots, and under a stand with bracken SWC decreased faster than with purple moor-grass. Understorey vegetation was related to potential evapotranspiration which is dependent on stand basal area. In 2013 we will pay attention to the phenology of both species and consequences on water balance dynamics. These results will be discussed in relation to forest management in the perspective of increasing droughts in the next decades.

Models of Growth Potential and Habitat Suitability Give Partly Divergent Answers to Climate Change Impact Assessments

Zimmermann, Niklaus E.; Psomas, Achilleas; Normand, Signe

Species distribution models (SDMs) are frequently used to assess the general impact of climate change on the habitat suitability of a tree species under climate change. SDMs are empirical models that relate the know distribution of species to climate and other environmental factors, and thus provide a projection of where in space the future environmental conditions most closely match the current envelope (or niche) of the species. Yet, how can we assess the risk of losing a species under conditions that become unsuitable in the future? Here, we present a method to assess such risks by combining frequently available data from forest inventories. We map both the SDM-based habitat suitability, and we calibrate models of potential growth rates of trees within the bioclimatic envelope of suitable habitat. We demonstrate that high suitability and potential growth often segregate along ecological gradients, with highest potential growth often being situated rather at marginal habitat suitability. This information – though not fully surprising – can be used to project climate change trajectories within the habitat suitability/growth environment. It allowed us to discriminate areas of rather low from rather high risk, by assessing growth trends towards marginal habitat suitability under climate change.

Regional Differences in Growth Trends at the Stand-Level Derived from Data of Periodically Measured Experiments (Southwest Germany)

Yue, Chaofang; **Kohnle, Ulrich**

A new method to extract environmentally driven growth trends from data of repeated stand measurements was applied to spruce, fir, beech, and oak on long-term experiments in southwest Germany. Generally, increasing trends are found in spruce, beech, and oak starting in the 1950s and continuing into the 1990s. Comparison with climate data suggests that these patterns appeared to correspond the trend in annual mean temperature. However, two cases of notable deviation between growth and temperature trends were observed. Firstly, the increasing growth trend in fir was disrupted temporarily in the 1970s and 1980s by a distinct depression. Secondly, despite continuing high temperatures and a more or less constant level of precipitation growth trends reversed in all four species in the 1990s. This provides circumstantial evidence that the observed growth trend patterns may be impacted by factors other than climate as well. We suspect e.g. atmospheric nitrogen influx which started to decrease in southwest Germany in the 1990s. Furthermore, we attempted to differentiate growth trends in all four species for two regions with different climate characteristics. The result showed that the resulting zone-specific growth trends conformed in general to similar patterns. However, there was one slight but apparently consistent difference following the trend reversion in the 1990s: whereas in spruce and beech growth trend in the cooler zone (mountainous) clearly suffered a less prominent decrease than in the respective warmer zone (sub-mountainous), the reverse was true for fir and oak.

Impacts of Management and Climate Change on Ecosystem Services in Generic Major Alpine Forest Types

Pérez, Susana; Rammer, Werner; Lexer, Manfred Josef

Forest managers have begun to change their management to adapt to new climate conditions and to fulfill not only the usual needs in forestry (e.g. timber production) but also other emerging ecosystem services demands, such as carbon sequestration and bioenergy production while maintaining biodiversity. The hybrid ecosystem model PICUS v1.5 is employed to simulate two generic major alpine forest types (beech forest and spruce-larch forest) and to quantify and understand how changes in management and different climates can affect the evolution of the forests and the consequences for a set of ecosystem services (timber production, biomass for bioenergy, in situ carbon sequestration and nature conservation values) at stand and landscape level. Intensification as well as extensification scenarios in forest management are studied by comparing the current practice with alternative strategies. Climate change imposes trade-offs between the different forest ecosystem services and management plays an important role to sustain multiple functions of the forest.

From Science to Practice: The French Foresters Experience

Picard, Olivier

Climate change constitutes a challenge for foresters. Uncertainties and the long-term nature of forester decisions make decision-making complex. In the face of climate change, the French private forest institute (CNPF) decided to define a shared strategy as a base for consulting and implementation of adaptation management. A national network (AFORCE) has been created with researchers, forest managers, teachers and technical advisers, to accelerate the technical transfer, and promote the emergence of adaptive forestry (open forests, mixed stands, short rotations, species substitution).The objective is to reach a common language and to acquire up-to-date knowledge. Three groups are working on 3 forest manager's questions: what kind of species to choose? What silviculture to optimize water supply? And what are innovative techniques to plant new forests? To provide answers in a highly uncertain environment, and to achieve awareness of owners, it is necessary to have a solid base of knowledge and practical tools to translate this knowledge into management. AFORCE provides foresters with practical tools, common data bases on a web site and guidelines, to help them to take the best management choices (no-regret measures, reversibility). It also aims to create a common place favourable to exchanges, in seminars with mixed participants. At a local scale, knowing, understanding and anticipating are the first steps before acting. The forest manager needs to follow them if he wants to be able to address the challenge of adapting forests with current and future climate conditions.

Will the Pieces of the Puzzle Fit? An Itinerary to Synthesize Research to Useful Guidelines for Adapting Forest Management to Climate Change

Brang, Peter; Augustin, Sabine; Born, Julia

Big societal challenges often trigger research programs, with the expectation that the knowledge gained will help to address the challenges effectively. The research program "Forests and climate change" in Switzerland was launched in 2009. It encompasses currently >30 research projects which were defined to increase the knowledge of climate change impacts and to elaborate adaptation strategies. The program is now in the phase of clarifying the strategy for the scientific synthesis and of planning the knowledge transfer to forest managers. In this talk, we will present our approach to extract the project results gained on different spatial and temporal scales and with variable degree of generalizability. Developing products which are useful for forest managers has the two main aspects knowledge and acceptance. Extracting suitable knowledge requires sound science, a clear picture of possible deliverables from science, and understanding of the decision making process of the managers. Acceptance is tied to credibility. It can be achieved by close interaction between scientists, managers, and the administration and decision makers at the political level. This interaction in an iterative process helps to build up a shared vision of the issues and to create common ownership of the products.

Evaluating Different Management Scenarios in Protective Forests under Climate Change

Irauschek, Florian; Rammer, Werner; Maroschek, Michael; Lexer, Manfred Josef

The protective forests in Austrian mountain regions are facing widespread problems of overaging, uniform age structures and lack of regeneration. Reasons for that are high harvesting costs, ungulate browsing, lack of planning tools and stakeholder influence, which results in "overcautious" harvesting activities. PICUS v1.5, a climate sensitive hybrid patch model, is used to evaluate possible management approaches and intensities in 3 forest stands situated in the Montafon valley in Vorarlberg/Austria. The sites vary in elevation (1200–1700 m) and species composition (spruce, fir, beech) and are currently managed to protect against gravitational hazards (avalanche/rock-fall/landslide). Harvesting scenarios, relying on cable crane extraction, can be mimicked spatially explicit in PICUS. Resulting forest structures are analysed by the PICUS risk assessor module, utilizing the threshold values from a well-established indicator based assessment scheme. Currently growth conditions are limited by low temperatures, therefore increasing temperature favours growth and regeneration of all species and results in higher shares of silver fir and beech. This will favour protective functions due to higher stem numbers and faster regeneration time and therefore allow higher harvesting intensities. However, higher temperatures will increase the susceptibility of spruce for European spruce bark beetle *(Ips typographus)* and thus counteract positive impacts.

AFORCE, a Network Devoted to the Adaptation of Forests to Climate Change

Perrier, Céline

AFORCE, a R & D network, has been created in 2008 as a response to french forest managers needs that have strongly expressed a lack of clear and precise recommendations to anticipate climate change. It is supported by the ministry for Agriculture and an interprofessionnal association. The main target of AFORCE is to provide french forests managers with practical tools and guides, to help them to make the best management choices. It also aims to create a common place favourable to exchanges. Such an organization will permit to coordinate initiatives that contribute to gather and test available scientific knowledge. 14 forest institutions belonging to research, development, forest management and educational sectors are involved. 5 topics have been defined to structure the network activity, coordinate the actions and centralize the information: forests sites, stand vulnerability, genetic inheritance, growth and forestry, socio-economy. During the first 3 years, the network organized annual calls for new projects. The implementation of fifteen projects has already been supported. Currently, the network manages 3 workgroups. They have to produce recommendations and tools on the following topics: sites diagnosis and species choice, water management in the existing stands forestry, creation and renewal of the forest stands.

Temperate Trees at their Hot and Dry Margins

Zang, Christian; Dorado Liñàn, Isabel; Ewald, Jörg; Hornstein, Daniel; Mellert, Karl-Heinz; Kölling, Christian; Pataki, Bálint; Konnert, Monika; Thiel, Daniel; Menzel, Annette

Under climate change, environmental limits of tree species are a key question for forestry. Thus, reduced vitality, mortality and extinction are expected at the driest and warmest edges of present distribution, which may serve as templates for changes expected in the species distribution center under warming scenarios. The MARGINS project aims at defining and characterizing this critical zone for five important temperate tree species (Abies alba, Fagus sylvatica, Picea abies, Pinus sylvestris, Quercus petraea). We employ forest monitoring and climate data as the basis for species distribution modeling (SDM). To facilitate site selection, we select focal vegetation units for each tree species by intersecting Bohn et al.'s vegetation map with marginal SDMs and climate data. Starting from this coarse scale search raster, local experts will help us to find forest stands at the distributional margins, where we will collect data on around 30 sites for the dendroecological assessment of tree growth and vitality and for the genetic characterization of the populations via appropriate gene markers (isoenzymes and microsatellites), and obtain detailed site characterization through vegetation surveys and the collection of soil and stand properties. To complement this field sampling, we are building reference databases for forest vegetation and tree-ring data from the marginal regions using various data sources.

Session 12: Challenges in Forest Biodiversity Conservation under Climate Change

On the Uncertainty of the Biodiversity in Forests of the Future (Introductory Talk)

Müller, Jörg

Climate warming is predicted to shift species distributions in all types of habitats. Differences in species shifts will lead to a reorganization of species communities, will affect species interactions and may influence the major ecological processes. Trees are long living organism and can buffer climate extremes by their architecture and by their biomass. An overview of examples on species shifts by global warming in forests is given from tropical to boreal forests. Moreover, temperature related interactions of climate, resource and species interactions are presented. Several studies disentangling macroclimate, microclimate and resources indicate that rich forests have a high possibility to buffer climate change effects. Different response of different lineages over the last hundred years in a low range mountain forests underlines that future forest communities can not be predicted from the past. Furthermore, on the considered scale, the response of ectothermic animals was not consistent with expectations based on shifts in the mean annual temperature. Irrespective of the reasons for the overshooting of the response of insects, these shifts lead to reorganizations in the composition of assemblages with consequences for ecosystem processes. Despite the risk for several species, positive effects of increased temperature can increase the potential for threatened species in forests as well. Therefore biodiversity research in forest should consider consequently climate as one treatment in all experiments. For forest managers, the biodiversity enhancing effects by increasing disturbance events, supported by climate warming, should be actively incorporated in their forest management.

Functional Responses of Two Dominant Species of Pasture-Woodlands to Simulated Climate Change

Hildbrand, Géraldine; Gavazov, Konstantin; Zufferey, Vivian; Signarbieux, Constant; Buttler, Alexandre; Gobat, Jean-Michel; Vollenweider, Pierre

Pasture-woodlands in the Jura mountains form ecosystems with high biodiversity but their ecological balance is threatened by current global warming. Responses to simulated climate change and the impact on vegetation and soil have been investigated by means of a transplantation experiment performed along an altitudinal gradient using soil turfs taken at 1400 m (donor site taken as control) and transplanting them downhill at 1000 and 600 m. Here, we report on the functional responses of two dominant herbaceous species with different growth strategies (*Taraxacum officinale* and *Alchemilla monticola*), with respect to their plant development, leaf gas exchange and leaf structure. With a mean summer temperature increase of 4°C and a precipitation reduction of 40% in the transplanted versus control plots, the two species responded similarly and showed no significant changes in leaf CO_2 assimilation rate and leaf structure. However, the leaf turnover and phenological development were accelerated and both species had smaller leaves with unchanged *(Alchemilla)* or lower leaf mass ratio *(Taraxacum)* at lower elevation. Hence, by changing the growth dynamic, climate change may affect the perennial development of some species and, possibly, the intra- and inter-specific competition which in turn could modify the plant species' composition, biodiversity and forage production in pasture-woodlands, as found otherwise in the same experiment.

Can Adaptation in Forest Management Mitigate Climate Change Impacts on Bird Species?

Gottschalk, Thomas

To mitigate climate change effects on forests, adaptations are needed to turn forests into forest types which are less vulnerable against droughts, heat and storm hazards. Currently, it is largely unknown how such adaptations would affect biodiversity. Therefore, I forecasted the effects of a conversion of coniferous forest to deciduous and mixed forests on bird species populations by using four forest change scenarios. Here, I present challenges and achievements related to forecasting those changes at a high spatial resolution (25 x 25 m) and across a national scale (357 000 km²). Models were based on data of the German Common Breeding Bird Survey, a high resolution land-use map and climate data from regional climate simulations. We forecasted the populations of 24 common forest bird species in Germany under expected climate change for the year 2050 and using four forest scenarios. This nationwide modelling approach revealed that forest bird species were affected on two scales: changes of local characteristics of bird locations and changes of characteristics of the landscape matrix surrounding each bird location (e.g. percent cover of forest types and diversity of forest types). In all, population of common forest birds increased by 2.3 million breeding pairs if coniferous forest would be converted to deciduous forests up to an altitude of 700 m. However, those species showing a close relationship to coniferous forests were predicted to decrease by any increase of broad-leaved forest types. In all, forest conversion mitigated climate driven changes for 12 out of the 24 forest species.

Mountain Forest Biodiversity under Climate Change: Compensating Negative Effects by Increasing Structural Richness

Braunisch, Veronika; Coppes, Joy; Arlettaz, Raphael; Suchant, Rudi; Zellweger, Florian; Bollmann, Kurt

Species in mountain environments are expected to face a high risk of range contractions, if not local extinctions under climate change. Yet, most endothermic species are primarily not affected by physiological constraints, but indirectly by climate-induced changes of habitat quality. In mountain forests, where species largely depend on vegetation composition and structure, climate change effects may thus be mitigated by active management aiming at habitat enhancement. We tested this hypothesis using four mountain bird species of conservation concern, which are considered as indicators for complementary forest structural parameters and umbrella species for the associated species communities. Based on species data and environmental information collected at 300 1km^2-plots distributed across Switzerland and Southwestern Germany, we investigated (1) to what extent species' distributions were explained by climate, landscape, and vegetation, (2) how climate change will affect habitat suitability, and (3) whether these changes could be compensated by habitat management. Species presence was modelled under current climate and extrapolated to the conditions of 2050. Climate contributed significantly to explaining occurrence, and expected changes considerably decreased the occurrence probability of all four species. The effects could be partly compensated by modifying single structural parameters, but full compensation was only achieved when different parameters were changed in concert.

Climate Change and Wildlife Management Interacting Effects on Forest Dynamics in a Protected Area

Cailleret, Maxime; Heurich, Marco; Bugmann, Harald

Experimental studies underscore the importance of considering interactions between effects of climate change (CC) and effects of biotic agents. They especially indicate that vegetation responses to climate may be strongly influenced by browsing pressure as this can eliminate the positive effects of higher temperatures or aggravate drought-induced stand deterioration. In consequence, CC effects on different forest functions should be considered before any changes in ungulates management strategy. In the Bavarian Forest National Park (BFNP), the new strategy is to "let nature be nature" considering that ungulate populations should not be influenced by humans. However, it is unclear how the resulting changes in deer density would affect forest development. We conducted a prospective study with the forest gap model ForClim simulating the interacting impacts of browsing and CC on short- and long-term forest dynamics. In the BFNP, CC would favor temperate and drought-tolerant species, such as common beech, to the detriment of silver fir and norway spruce. In the next centuries, the extinction risk of silver fir should stay low if browsing intensity doesn't exceed current level, but may become substantial if ungulates are not regulated by hunting or by predation. These measures would be required to maintain forest diversity in composition and structure.

Exploring the Relationship between Tree Diversity and Forest Ecosystem Services in Face of Climate Change

Pedro, Mariana da Silva; Rammer, Werner; Seidl, Rupert; Lexer, Manfred Josef

The loss of biodiversity in forest ecosystems has motivated ecological research that links biodiversity, ecosystem functioning and the provisioning of ecosystem services (ES). Interest in this topic has been amplified by expected climatic changes. However, current scientific knowledge of how tree species diversity impacts essential ES is still scant. Furthermore, the potential effects of climate change on this relationship remain unknown. This contribution presents a simulation experiment investigating the relationship between tree diversity and biomass productivity, Carbon sequestration, maintaining water cycles and nature conservation values under current climate and transient climate change scenarios. The process-based forest patch model PICUS v1.6 is employed in the Hainich National Park (Germany). Preliminary results confirm a positive correlation of tree diversity and biomass productivity which saturates at higher diversity levels. Increasing species diversity led to an increase in water consumption as well and consequently lower groundwater recharge. Studying transient ES provisioning under climate change scenarios indicated the importance of species traits for maintaining ES (e.g. regeneration mode, growth pattern). Habitat structure (i.e. related to bird species requirements) could be better maintained at higher diversity levels. The findings imply that the relevance of species diversity may vary depending on required ES portfolio.

Mycodiversity Comparison of Autochthonous and Allochthonous Forest Stands in the Beech Habitat on Mt. Vidlič

Novaković, Milana; Karaman, Maja; Matavuly, Milan; Marković, Miroslav; Čapelja, Eleonora

This research represents the beginning of a long-term study on the mountain Vidlič (southeastern Serbia) aiming to compare fungal community in autochthonous and allochthonous forest stands, including their resilience to climate change. During 2011 and 2012, two different forest stands in a beech habitat were compared on the basis of macrofungal diversity. Permanent plots (P1 – natural beech stand, P2 – planted stand of Douglas fir; 1000 m^2 each) were established for monitoring purposes. Higher mycodiversity was observed on P1 (43 species). From the P2, only 28 species were reported. Evident decrease in number of species as well as number of fruiting bodies was observed on this site in the second year, characterized with longer drought periods. Fungal species determined from both forest stands were predominantly members of terricolous saprotrophs. Mycorrhizal species, although detected only from the second plot, are common to deciduous forests and might not be strictly related to Douglas fir. Lower abundance of macrofungi detected on plot 2 might indicate a possible loss of fungal diversity in the stands of non-native tree species. Further investigations will provide more information about the ability of studied fungal communities to cope with the changes in their habitat and allow recommendations for conservation management.

Session 13: Tree Vulnerability to Pests in Relation to Climate Change

Consequences of Climate Change for Biotic Disturbances in North American Forests (Introductory Talk)

Ayres, Matthew

The properties of forests are a product of disturbance regimes. In North America, a third of which is forested, insects and diseases exceed even wildfires as the dominant source of disturbance. The first U.S. Climate Assessment (2000) predicted consequential changes in forest disturbance because: (1) herbivores and pathogens have high physiological sensitivity to temperature, high mobility, short generation times, and high reproductive potential; (2) tree defenses vary with climate; and (3) effects on pests from their enemies, competitors, and mutualists can change with climate. In fact, the appearance of epidemics in new regions has been rapid and dramatic: e.g., spruce beetles in Alaska, mountain pine beetle in high-elevation forests of the Rocky Mountains, and southern pine beetle in the Northeast. Important drivers have been milder winters, longer summers, and changing precipitation. Climatic effects on forest pest outbreaks can produce feedbacks to climate by influencing ecosystem fluxes in carbon, water, and energy, and by influencing human interactions with landscapes. Human adaptation to climate-induced changes in forests will be aided by general practical theories of pest management that can address new vulnerabilities and also by responding to new opportunities (e.g., increases in forest productivity in many areas, and probably decreases in forest disturbance in some areas).

Response of Forest Pests to Climate Change in Europe

Battisti, Andrea; Larsson, Stig; Roques, Alain

Forest pests are affected in a number of ways by climate change. Effects can be seen at both individual and population level. Generally foresters are considering population responses, such as outbreaks or variations of abundance, that are often associated with weather patterns, although the underlying mechanisms remain often unknown. Climate change may affect the drivers of pest abundance (e.g. drought, storm damage, fire frequency) resulting in a different occurrence and frequency of the attacks. Individual responses are clearly a component of the population responses, although they can be more easily analyzed by a mechanistic approach, by measuring the response of the individuals to the climatic driver. This is a common way by which it is possible to assess the upper edge of the geographic range, and consequently define the potential range expansion caused by climate change. The individual responses are generally of two types, i. direct (e.g. faster development at higher temperature), and ii. indirect (e.g. change of the quality of the host plant or in the higher trophic levels). The combination of the individual and population responses to climate change may help in understanding the general effects of climate change and in making predictions.

Population Dynamics of the Spruce Bark Beetle: A Long-Term Study

Marini, Lorenzo; Lindelöw, Åke; Jönsson, Anna Maria; Wulff, Sören; Schroeder, Leif Martin

Temperature warming and the increased frequency of climatic anomalies are expected to trigger bark beetle outbreaks with potential severe consequences on forest ecosystems. The aim of the study was to quantify the relative importance of predation, negative density feedback, and climatic factors in driving Ips typographus population dynamics by analyzing a unique time series of population density of *I. typographus* across Sweden. We found that availability of storm-felled trees was the main outbreak trigger, while strong intra-specific competition for host trees was the main endogenous regulating factor. Although temperature-related metrics are known to have strong individual effect on *I. typographus* development and number of generations, they did not emerge as important drivers of population dynamics. A positive effect of low summer rainfall was evident only in the regions located in the southernmost and warmest part of the spruce distribution. As the reported damage from storms seems to have increased across whole Europe, spruce forests are expected to be increasingly susceptible to large outbreaks of *I. typographus* with important economic and ecological consequences for boreal ecosystems. However, the observed negative density feedback seems to be a natural regulating mechanism that impedes a strong long-term propagation of the outbreaks.

Rosalia Roof Project: A Drought Stress Experiment as Basis for Risk Modelling *(Ips typographus)*

Netherer, Sigrid; Blackwell, Emma Elizabeth; Hietz, Peter; Henschke, Patrick; Kikuta, Silvia; Rosner, Sabine; Matthews, Bradley; Schume, Helmut; Katzensteiner, Klaus; Schopf, Axel

Apart from temperature regimes favouring insect propagation, outbreaks of the Eurasian spruce bark beetle *(Ips typographus)* have frequently been associated with impaired water supply of Norway spruce stands due to unfavourable site conditions and drought events. So far, empirical data linking soil hydrology, tree physiological indicators of drought stress, and tree susceptibility to bark beetle attack are scarce. Aiming at the development of a model suited for dynamic evaluation of tree and stand disposition to bark beetle infestation by the consideration of site water supply and seasonal precipitation, the interdisciplinary, three-year case study ROSALIA ROOF PROJECT was launched in October 2011. We present a comprehensive set of monitoring data (i.a. volumetric water content of soil, soil matrix potential, sap flow, twig water potential, and resin flow) gathered within two years at 2 fully and 2 partially covered, 18 × 20 m sized experimental plots, and 2 control plots, which had been established in a mature Norway spruce stand in Eastern Austria. Infestation of differentially drought stressed trees is experimentally induced by the use of "Attack boxes" this spring and summer (2013) in order to find correlations between tree water status and attractiveness for bark beetles and to define thresholds for attack.

Phenology of the Spruce Bark Beetle *Ips typographus* – Modelling the Effect of Climate Change

Jakoby, Oliver; Lischke, Heike; Albert, Carlo; Wermelinger, Beat

The European spruce bark beetle *Ips typographus* is the most significant insect pest in European spruce forests. Both the beetles demographic parameters and spruce resistance strongly depend on climatic parameters such as temperature and precipitation. Therefore, an increase in temperature and drought frequency due to climate change is likely to alter outbreak patterns. We use dynamic simulation models to study the effect of climate change on phenology and population dynamics of *I. typographus* in Switzerland. Particularly, we investigate how temperature increase affects annual number of generations, swarming dates, and overwintering stages. We observe a higher average number of generations of *I. typographus* with warmer temperatures. Especially, at lower altitudes (Swiss Central Plateau) three generations per year become more frequent. Also, at higher altitudes where currently usually one generation develops, a second generation will be common. Spring and summer swarming periods will occur earlier in the year. Our results show a direct effect of climate change on the beetle's phenology. However, also indirect effects like extended drought periods that lower spruce resistance might alter infestation risk and course of an outbreak. Therefore, we will discuss how to incorporate spruce susceptibility in the model and how model results can be transferred to forest practice.

How Could Climate Change Affect the Potential Spread of Pine Wilt Disease in Europe?

Gruffudd, Hannah; Evans, Hugh; Haran, Julien; Roux-Morabito, Géraldine; Roques, Alain; **Robinet, Christelle**

The pine wilt disease which can kill pines within a few months has been spreading in southwestern Europe despite severe control measures since its discovery in Portugal in 1999. It has thus become a serious threat to European forests. The pine wood nematode, *Bursaphelenchus xylophilus,* which is the causal agent of this disease, is transported by long-horned beetles of the genus Monochamus. The potential spread of the disease is therefore driven by several factors such as the presence of infested carrier beetles and the occurrence of conditions favorable to the expression of pine wilt. Climate conditions, and consequently climate change, are key parameters to consider when assessing the risk of potential spread of the disease. We investigate how climate conditions could explain: (1) the distribution of *Monochamus galloprovinciallis* (the current carrier beetle in Europe) and (2) the disease expression. The development of the disease is known to be closely related to high summer temperatures and drought conditions. We used the EvapoTransPiration (ETP) model to describe the effects of climate on the nematode growth and survival, photosynthesis and available energy. This model, validated on a disease gradient in Japan, helps us to explore the effects of climate change across Europe.

Will Northward Expansion of Eastern Spruce Budworm with Climate Change Affect Boreal Forest Resilience?

Pureswaran, Deepa; De Grandpré, Louis; Neau, Mathieu; Paré, David; Morin, Hubert; Kneeshaw, Dan

Climate change is altering forest insect disturbance regimes via temperature-mediated phenological changes in trophic interactions among host trees, herbivorous insects and natural enemies. Eastern spruce budworm outbreak centres have now appeared in the boreal black spruce zone that previously only suffered mild defoliation. In a multidisciplinary research team, we are evaluating a rising spruce budworm outbreak in ten permanent research plots on Quebec's North Shore over the course of the infestation. Estimates of defoliation since 2006 reveal that pure black spruce stands currently suffer up to 50% defoliation. Black spruce escapes severe herbivory due to a 2-week delay in budburst phenology relative to emergence from diapause of spruce budworm larvae. Observations suggest that budburst phenology of black spruce along a climatic gradient is sufficiently plastic to permit phenological changes as climate warms, that would be more conducive to herbivory. Mortality of black spruce could result in replacement on rich sites, by balsam fir forests. Poor sites may remain as low productive black spruce stands, or be replaced by even less productive ericaceous shrublands, decreasing the diversity of the plant community. The degree to which forest ecosystems are resilient to new disturbance regimes will have consequences on future forest management strategies.

Water Stress Decreases Ash Resistance to *Agrilus planipennis* without Affecting Phloem Phenolics

Chakraborty, Sourav; Whitehill, Justin G.A.; Hill, Amy L.; Opiyo, Stephen O.; Cipollini, Don; Herms, Daniel A.; **Bonello, Pierluigi**

Global warming is leading to more drought events, which impact trees detrimentally both directly and indirectly, via reduced resistance to pests, including wood boring beetles such as the invasive Agrilus planipennis (emerald ash borer - EAB). To better understand why droughted trees become more susceptible to wood boring insects, we characterized the response of soluble phloem phenolics, which are presumed to participate in the host defense response, to EAB attack in resistant Manchurian and susceptible black ash, under conditions of either normal or low water availability, in an experiment conducted at a mean daily temperature of ~27 (range 20–34) °C. Low water availability increased success of larval establishment and mean larval weight overall, but more so in Manchurian ash. However, low water availability did not affect concentrations of phenolics in either host species. Most of the phenolics identified as being affected by EAB decreased in concentration following attack, except for pinoresinol A, which was induced by attack in both species, but more so in Manchurian ash. This difference may help explain the higher resistance of this ash species to EAB, but none of the responses measured here could explain effects of low water availability on EAB performance.

Rosalia Roof Project – Physiological and Pathological Screening of Spruce Trees under the Effect of Drought Stress

Blackwell, Emma Elizabeth; Netherer, Sigrid; Schopf, Axel

In order to analyse the effect of drought stress on the spruce tree *(Picea abies),* 24 trees have been fully covered and 28 semi covered since June 2012 (ROSALIA ROOF PROJECT). The aim of this study is to investigate the spruce trees susceptibility towards bark beetles and their associated fungi under drought stress events as these might increase under climate change. A periodic screening of tree physiological parameters partially begun during the first study year and will be extended during the vegetative period of 2013 and 2014. Physiological parameters include sap flow, water potential, osmotic potential, tree-stem growth, bark volatile compounds and bark volatile emissions on three trees per plot as well as resin flow, bark anatomy and relative water content of all covered trees and an equivalent amount of control trees. All trees have been continuously monitored for infestations by bark beetles or pathogens since the covering took place. Induced infestation with the spruce bark beetle *Ips typographus* with especially constructed "Attack boxes" as well as inoculations with the blue stain fungi Ceratocystis polonica will take place during the summers of 2013 and 2014. Tree physiological parameters will be discussed according to the degree of drought stress and infestation. Results from this project will enable in-depth insight to the spruce trees physiological reaction to the complex interactions of the trees largest threats, bark beetles and drought.

A retrospective Evaluation of the Occurrence of Cockchafer Population in the Main Outbreak Centres in Poland in the Context of a Changing Environment.

Niemczyk, Marzena

The paper presents a retrospective data analysis of the occurrence of cockchafers' grubs (Melolontha spp.) in four forest districts belonging to the most serious outbreaks centres in Poland. The assessment of grubs colonization in forest soils (1 x 0.5 x 0.5 m pits) was carried out from 2008 to 2012. The results were compared to the corresponding works carried out in the 60s of the last century. The aim of the study was to demonstrate the diversity of cockchafers in the distribution of the main outbreak centres depending on the type of forest habitat, canopy density and forest land use category and to demonstrate changes in habitat structure and distribution of pests over 50 years.
The results of the analysis indicate that during the period, there was a significant acceleration of changes in species composition and structure of forest ecosystems. Melolontha spp., much more often inhabit the fertile, broad-leaved forest habitats now than a few decades ago. Just like in the 60s forest cultures are still areas where the cockchafers' grubs are the most numerous, but more often than in the past, cockchafers enter into the dense forest stands. Today's characteristic of the ecological niche occupied by cockchafers in principle is in conformity with descriptions dating back to more than fifty years ago, referring to the southern neighbours of Poland. Therefore, it should be expected that in a changing climate cockchafers will become more common in dense stands (in Polish climate), and their wide range of occurrence, while providing a prey base, will move more to the north.

Parametrisation of Spruce Bark Beetle Outbreak Model in TANABBO II System in Mountainous Condition

Jakus, Rastislav; Havasova, Maria; Barka, Ivan; Koren, Milan; Blaženec, Miroslav

We have developed experimental system TANABBO tested in years 2002 and 2003 in the High Tatras Mts. The model itself has been created by modelling the initiation of new and spreading of existing bark beetle spots. Currently we are developing higher version of the system TANABBO II. In the GIS environment, we have created time series of the data on spruce stand mortality. LANDSAT images were used. The models are parameterised with using multiple linear regressions. The results are represented in form of predicted spruce mortality maps (dead stands). The models involve all the basic parameters controlling the abundance in the spruce bark beetle: food accessibility, stand resistance against attacks – depending on the stress level to the stand, effectiveness of the protection measures implemented, and the weather course. The prognosis is backed up with the current bark beetle population density, its gradation phase and distribution of infection spots. The spreading is controlled by the just mentioned factors. In the first phase of system development, system is parametrised in Tatra (SK) and Šumava (CZ) mountains.

Growth Compensation in an Oak-Pine Mixed Forest Following an Outbreak of Pine Sawfly (Diprion pini)

Vallet, Patrick; Perot, Thomas; Archaux, Frederic

Growth compensations following a disturbance have been found in different species communities through experimentation, but there are few results obtained in natural conditions, in particular for forest ecosystems. The objective of this study was to determine whether there was growth compensation in a mixed oak-pine forest following an outbreak of pine sawfly *(Diprion pini)* that caused massive defoliation of pines in Europe in the early 1980s. The data were collected in mixed oak-pine stands located in the plains of north-central France. We established a model which incorporated climatic effects in order to predict the ring width under undisturbed conditions and to quantify the response of each species to the disturbance. We found that the growth of both species varied synchronously with a positive covariation outside of the disturbance. During the disturbance, the growth of both species covaried negatively especially in the plots where pine had been the most severely affected. Our results demonstrate that compensation between the two tree species following the insect outbreak did occur. We suggest that growth compensations would especially occur in the case of severe biotic disturbances but probably not in the case of climatic fluctuations.

Session 14: Biotic Responses of Trees and Understory Vegetation to Contemporary Climate Change (CCC)

Is Recent Climate Change the Primary Driver Behind Contemporary Biotic Responses of Trees and Understory Vegetation? (Introductory Talk I)

Lenoir, Jonathan; Bertrand, Romain

Quantifying the relative importance and interactions of recent (i.e., from 1970s onwards) climate change with other global-change drivers on contemporary biotic responses is a challenging and timely issue. By focusing on understory vegetation, we assessed the respective effects of: (i) climate change; (ii) soils acidification and eutrophication ; (iii) forest-canopy closure (a global proxy for human-induced and natural disturbances); (iv) forest fragmentation and (v) plant thermal tolerance to explain community-composition changes in the French forests between 1965–1986 and 1987–2008 (Bertrand 2012, PhD thesis, AgroParisTech Nancy). Highland and lowland forests were analyzed separately. We found that temperature increase is the primary driver explaining 53.4% and 32.9% of the observed community-composition changes in highland and lowland forests, respectively. However, in lowland forests, the observed community-composition changes were mitigated by an increase in the thermal tolerance of plant communities (6.2%) and an increase in forest-canopy closure (2.5%) but amplified by a decrease in the ratio of carbon to nitrogen in the soils (i.e., eutrophication) (1%). These results support the general idea that recent climate warming is the primary driver behind contemporary biotic responses of understory vegetation albeit other global-change drivers such as forest-canopy closure and soils eutrophication may act as secondary drivers mitigating or amplifying climate-warming impacts on understory vegetation. It is noteworthy that community-composition changes in lowland forests seem to be offset by an increase in plant thermal tolerance, suggesting a tradeoff between these two biotic responses to climate warming.

Forest Responses to Climate Change at the Large Scale: Unraveling the Role of Forest Succession, Inter-Specific Interactions and Trait-Based Strategies (Introductory Talk II)

Carnicer, Jofre; Barbeta, Adrià; Sperlich, Dominik; Coll, Marta; Peñuelas, Josep

We review the evidence of global change impacts provided by large-scale forest monitoring systems in Europe. Contrasting defoliation trends have been reported between Southern, Central and Northern European Forests, associated with increased drought impacts in southern regions. In line with these trends, National Forest Inventories in Southern Europe reveal important interactions of water deficit measures with land abandonment and forest succession advance. In Mediterranean forests, large scale surveys show that forest succession is mainly associated with the spread of Quercus species, and increased recruitment suppression of pine saplings by competitively dominant sclerophyllous trees is consistently observed at the large scale. A continuum of contrasting eco-physiological strategies and demographic responses to global change impacts is reported in conifers and angiosperms. The implications of these trends for tree genetic diversity conservation, biodiversity conservation at higher trophic levels are briefly evaluated.

Forest Densification Moderates Understorey Plant Responses to Macroclimate Warming

De Frenne, Pieter; Rodríguez-Sánchez, Francisco; Coomes, David A.; Verheyen, Kris

Biological signals of recent global warming are increasingly evident across a wide array of ecosystems often resulting in the thermophilization of communities. In several ecosystems, however, communities seem to lag behind climate warming generating a 'climatic debt'. We show that temporal changes in microclimate can modulate biotic responses to macroclimate warming. Using data from 1,409 (semi-)permanent vegetation plots in European and eastern North American temperate deciduous forests that were resurveyed with a period spanning (on average) 34 years, we demonstrate that significant thermophilization of ground-layer plants has occurred. This can be attributed to the concurrent decline of relatively cold-adapted species and increase of more warm-adapted plant species. Yet, compositional change was strongly affected by the forest density. The mean thermophilization, and especially the increase of more-warm adapted species, was significantly lower in forests that became denser over time. This link between thermophilization and forest density suggests that changes in microclimate (reduced ground temperatures via increased shading) can temper community reshuffling in response to macroclimate warming. Since forest densities have increased in many temperate regions during the last decades, we propose that microclimatic changes may be buffering the impacts of warming on forest understories to date.

Response of Swiss Forests to Management and Climate Change

Küchler, Meinrad; Küchler, Helen; Bedolla, Angéline; Wohlgemuth, Thomas

The relative contributions of forest management and climate warming to vegetation change in Swiss forests was investigated with two sets of paired vegetation records. In the years from 2008 to 2011, we repeated 126 records dating from 1940 and 325 records from 1995. The herbaceous vegetation and the tree species composition were analyzed separately. The changed composition of the herbaceous vegetation indicates an upward shift of 40 m since 1940 and of 20 m since 1995. 57% of 184 frequent species shifted upward since 1995. The tree species however changed their proportions and altitudinal distributions in a rather heterogeneous way. These changes could be explained by changed management and land use practices. In contrast, the observed altitudinal shift of the herbaceous plants could only partly be explained by direct human impact. Climate induced changes predominantly occurred at higher altitudes. Although weaker than predicted by most projection models (estimating shifts up to 150 m since 1940), the response of Swiss forest vegetation to climate change seems to be strong enough to be relevant for future forest management.

Lagged Response of Forest Ecosystem to Previous Year´s Weather as Key to Better NEP Models

Zielis, Sebastian; Etzold, Sophia; Zweifel, Roman; Eugster, Werner; Haeni, Matthias; Buchmann, Nina

Forest ecosystems are an important sink for atmospheric CO_2 due to their ability to take up large amounts of carbon. Yet, modeling and explaining annual forest net ecosystem productivity (NEP) and their inter-annual variability is challenging. It is likely that lagged ecosystem responses in terms of carbon dioxide loss and/or uptake to weather conditions of the previous year obscure more direct relationships. We used 15 years of flux data from the Swiss Fluxnet site Davos Seehornwald to investigate current and previous year climatic drivers of interannual NEP variability. Furthermore, we expanded the analysis to five additional European forests to validate the results found in Davos. When we considered a time lag in forest ecosystem response to weather conditions at Davos, explained variance of inter-annual variability in NEP increased by 29%. However, current year weather conditions in spring still dominated carbon sequestration. Results from the additional forests in Europe seem to confirm the generality of lagged ecosystem response. Four of the five forests showed increases of explained variance of NEP ranging from 12% to 29% when time lags were incorporated into the analysis. Therefore, considering time lags in climate-vegetation models is promising for more precise calculations of annual carbon budgets.

The Swiss Fluxnet: Greenhouse Gas Fluxes and Responses of Two Swiss Forests to Natural and Anthropogenic Impacts

Buchmann, Nina

Although mountains cover a large area of the globe, and mountain forests are expected to be strongly affected by climate change, their representation in global flux networks is rather sparse. The Swiss FluxNet, a network of agricultural and forest sites with long-term measurements of net ecosystem CO_2 (NEE) and H2Ov (ET) exchange, includes two mountain forests: a mixed beech forest (Laegeren; running since 2005) and a Norway spruce forest (Davos; running since 1997). While intra-annual variability of NEE differs between the two sites, inter-annual patterns are rather similar, the latter supported by biomass and soil inventories. Auxiliary measurements of soil respiration, phenology as well as tree-ring growth and management information enable us to understand the responses of both forests to natural as well as anthropogenic impacts. For example, both forests substantially increased their water use efficiency (gross primary productivity/ET) during the spring drought 2011, much in contrast to Swiss grassland sites. On the other hand, the spruce forest at Davos has been a C sink ever since flux measurements started in 1997, including the year 2003 with its hot and dry summer. Thus, long-term flux measurements provide not only critical information about carbon sequestration but also about drought susceptibility and its underlying mechanisms.

Negative Effects of Temperature and Changing Precipitation on the Seed Viability of *Juniperus communis*

Gruwez, Robert

Climate change is a challenge of increasing concern. However, studies on the combined influence of different climate change drivers on sexual reproduction in plants, one of their mechanisms to cope with change, are still scarce. We studied the combined influence of increasing temperature and changing precipitation on two developmental phases during the sexual reproduction of common juniper *(Juniperus communis)* (gametogenesis and fertilization [SP2] and embryo development [SP3]). In 42 populations throughout the distribution range of common juniper in Europe, 11943 seeds of two developmental phases were sampled. Seed viability was determined through observations of dissected seeds. For each population the growing degree days above 0 °C base temperature (GDD>0 °C) during three key processes (pollination, fertilization and embryo development) were calculated as well as the total precipitation during the year prior to sampling. Temperature had the strongest negative influence and this was most pronounced during SP2. Precipitation only affected SP2 seeds and this effect was dependent on temperature: in warmer regions, seeds were more viable in humid conditions while in colder regions, more precipitation caused a lower viability. Our results suggest that processes during gametogenesis and fertilization are more vulnerable for climate change than processes during embryo development.

Can a Species Composition Change as Response on Temperature Increase in Forest Ecosystems already Be Seen? – Beech Forests in Bavaria as an Example

Fischer, Anton; Fischer, Hagen S.; Jantsch, Matthias

Increasing temperature should cause a shift in species composition towards more thermophilous species. This hypothesis was tested in Bavarian beech forests by using sets of old phytosociological relevés from 1949 to 1985, comparing them with re-assessed (2010) records from the same locations. Referential upper and lower limits of beech forest species distribution were derived from recent relevés on either acidic or calcareous substrate in the whole range of Bavarian beech forests. By means of a partial canonical correspondence analysis with climatic parameters as explanatory variables and edaphic indicator values (e.g. soil acidity) as covariables a trend in species composition change, correlated with increasing temperatures, can only be seen on the 2nd axis for the parameter "temperature sum > 5°C during winter time". It is, however, still hard to break this trend down to certain carriers of this change. The most pronounced increase is shown by Juglans regia, but other reasons like management may explain this change, too. Longevity of many forest species, not only trees, may be the reason of a delayed reaction until strong event(s) like long drought periods will happen. The distribution modeling indicated where species may emerge or disappear in beech forests as soon as forest species start to react on increased temperatures.

Rising Atmospheric Carbon Dioxide, a Potential Catalyst in Global Tree Decline

Czerniakowski, Barbara

Around the 1970s a tree decline phenomenon began occurring on a global scale. Large stands of trees growing on certain soil types began to express yellowing symptoms, dieback and subsequent decline, with mortality extremely patchy. Mundulla Yellows (MY) is a lethal dieback of native species that affects hundreds of thousands of trees in Australia and other countries. MY was first reported in Australia in the 1970s and for many years was postulated to be caused by an infectious biotic agent. However, our work confirmed that MY is associated with adverse soil conditions such as high levels of dissolved inorganic carbon and mineral toxicities, which culminates in mineral imbalance, physiological iron deficiency and ultimately death. It is now evident that in the last 40 years the soil environment supporting the affected trees has became increasingly hostile to trees that were previously well adjusted to Australian conditions. What has triggered the onset of tree declines during the 1970's? The exponential rise of CO_2 in the atmosphere that occurred in the 1960's–70's may be linked to the onset of MY and other tree declines. Atmospheric CO_2 levels have risen at less than 0.2 ppm each year for nearly two centuries, but since 1960, they have increased over six-fold. This increase in CO_2 concentration has been shown to alter biogeochemical processes at earth's surface enhancing weathering rates of certain minerals. The proposed influence of rising CO_2 on the Australian native tree decline and its potential link with other tree declines will be presented.

Environmental Conditions and Community Composition on European Forest Productivity: A Field-Based Approach

Defossez, Emmanuel; Morin, Xavier

Global change affects directly forest productivity, a major ecosystem process, by modifying the abiotic environmental conditions. But global change also affects ecosystem functioning indirectly, through its impact on biodiversity, because ecosystem functioning is tightly linked to species richness and composition. Yet, direct and indirect effects of global change on ecosystem functioning have almost always been studied separately, because they refer to different spatial scales. Here we will present an ongoing project, aimed to disentangle the effect of environmental conditions and tree community composition on forest productivity. To do so, a latitudinal gradient of altitudinal gradients of small forest plots (ca. 1000 m^2) with varying tree species richness was explored. We monitored vegetation structures and tree individual traits to explore the effects of community composition effect on traits distribution and productivity at both inter- and intra-specific levels. This field-based design covers a large range of abiotic conditions from Mediterranean to Alpine environments (between the Provence to the North of French Alps); mountain and Mediterranean forests have indeed been identified as particularly sensitive to climate change. First results will be presented, focussing on Beech forests (with pure and mixed stands).

Thirty Years After the Air-Pollution Related Diebacks: Perception and Communication of Climate-Change Related Forest Declines

Kaennel Dobbertin, Michèle

In the 1980s, the concerns of scientists, policy makers, and the general public in Western Europe and North America were aroused by cases of an unexplained and unprecedented new forest disease. Especially in Germany, "Waldsterben" was expected to devastate whole forests within the coming years, which received considerable alarmist media coverage. The researchers who questioned the reality of Waldsterben and the implication of air pollution as a main cause were at best ignored, at worst suspected by the media of being partial or corrupted. Nowadays, drought and frost are considered to have been among the most likely causes of these declines. Recently, publications documenting tree mortality due to drought and warm temperatures raised the possibility that forest ecosystems may already be shifting globally in response to climate-induced physiological stress. Based on a questionnaire sent to 20 scientists involved in forest decline research, I compare their perception of recent declines with those of the 1980s. I examine whether Waldsterben has influenced forest research and management. In particular, in light of the credibility crisis it created in Central Europe, I draw conclusions about the communication of climate-change related declines to the general public.

Changed Altitudinal Distribution of Tree Species in Switzerland: A Response to Climate Change?

Küchler, Helen; Küchler, Meinrad; Bedolla, Angéline

The altitudinal and regional distribution of tree species in Switzerland has markedly changed in the past decades. To investigate the relative impacts of climate change and forest management, we analyzed the change in altitudinal optima and ranges of frequent tree species, separately for the occurrences in the herbaceous, shrub an tree layers. We used data from two sets of repeated vegetation records and from the National Forest Inventory (NFI). The first replicates of the repeated records were taken in 1940 (n=126) and 1995 (n=325) respectively; the second visit was carried out in the years from 2008 to 2011. The three NFI surveys (n=4800) date from 1985, 1995 and 2005. The altitudinal distributions of frequent tree species showed very diverse patterns of change, which even differ for the occurrences of these species in the herbaceous, shrub and tree layers. Most of the changes can be explained by management or land use change. Up to the present, the response of tree species to climate change at a regional scale has been of secondary importance in comparison to other impact factors.

The Influence of the Reforestation by *Pseudotsuga menziesii* (Mirb.) Franco. on Forest Herbaceous Cover

Rućando, Marko; Ilić, Miloš; Krstivojević, Mirjana; Igić, Ružica; Vukov, Dragana

The Vidlič Mountain is protected natural area in southeastern Serbia. After frequent fires, reforestation is usually done by planting allochthonous species, usually *Pseudotsuga menziesii*. The main aim of this study was to estimate the influence of reforestation on the herbaceous species composition, species richness and diversity. Two study sites were compared: a natural beech and spruce forest *(Fagus moesiacae montanum)* and a *P. menziesii plantation* (PP) grown on a beech and spruce habitat. The survey was done on three plots per each site (plot size 300 m^2), during spring, summer and autumn of 2011 and 2012. Shannon diversity index values and species richness for PP decreased through seasons, due to increased abundance of highly competitive and opportunistic species (*Pteridium aquilinum* and *Rubus caesius*), as is shown by high Berger-Parker index values. Due to inhibitory effect that lower temperature can have on growth of competitive species like *P. aquilinum*, and with higher temperature then 2011. Increased dominance index values in 2012 are explained by a positive effect of warmer temperatures on competitiveness of opportunistic species like *Pteridium aquilinum* or *Rubus caesius* and may translate effects of contemporary climate change. Reforestation by allochthonous species results, among other consequences, in opening the ecological niche for competitive species that – by expanding – negatively influence the herbaceous plant species richness and diversity.

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