



Max-Planck-Institut
für Biogeochemie



Climate Extremes and Biogeochemical Cycles 2013

2 – 5 April 2013, Congress Center Seefeld / Austria

ABSTRACTS

(in alphabetic order of the first author)

ID: 242

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Extreme winter weather events influence summer soil respiration in the high elevation meadows of Yosemite National Park, California

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Extreme weather events can significantly alter ecosystem processes in high elevation meadows. Subalpine meadow ecosystems rely on the seasonal snowpack for insulation from winter temperature extremes, and the subsequent spring snowmelt for recharge. Changes in the depth and duration of the snowpack in addition to the amount of water contained within the snowpack, can drastically alter meadow functioning through alteration of the water table and/or frost damage to overwintering biota. This study examined the effect of interannual variability in the winter snowpack on summer soil respiration along a hydrologic gradient in a subalpine meadow in the Central Sierra Nevada of California. Carbon dioxide (CO₂) efflux from the meadow was measured from snowmelt through September in 2011 and 2012 using soil collars and a LICOR 8100A infrared gas analyzer. Preliminary results show that summer soil respiration is influenced by the duration of winter snow and that the response of soil CO₂ efflux was not consistent along hydrologic gradients in the meadow. We found that high snowpack years can suppress soil respiration in the meadow until late in the summer season as compared to low snowpack years, where soil respiration peaks early in the summer.

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Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Effects of summer extreme events on grassland soil CO₂ efflux in a context of future climate change

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Climate models forecast, for the coming future, an increase in frequency of extremes events, such as heat waves and severe droughts. In grassland ecosystem most of the carbon is stored in the soil and its flux toward the soil is the second larger among all ecosystems. Soil CO₂ efflux derives from two main components, autotrophic respiration being associated with root and rhizosphere respiration and heterotrophic respiration associated with the turnover of soil organic matter by microorganisms. The aim of this work was to evaluate the vulnerability of a grassland ecosystem under summer extreme events in a context of future climate and the possible mitigation effect of increased CO₂. In particular, we studied the extreme event effects on soil efflux and on its autotrophic and heterotrophic components.

Grassland monoliths were exposed, from 2010, to air temperature and precipitation expected for the period 2040-2060. Since March 2011 a CO₂ enrichment was applied and during summer a heat wave and drought stress were applied too.

Total efflux was strongly reduced during the extreme event treatments both at ambient and at elevated CO₂; this reduction was due mainly to the autotrophic component since the treatments seemed to have a mild effect on heterotrophic respiration. The reduction in total flux was well described by the reduction in soil moisture. Soil efflux strongly recovered from extreme events, indeed, total respiration showed a faster recovery compared to heterotrophic respiration. This was associated to a sustained recovery in root respiration, root growth rate and root dry matter content. Instead, root decomposition in extreme treatments, in the same period, was still lower than control. This behavior agrees with preliminary data on daily ecosystem carbon uptake showing a stronger recovery after rewetting. In view of these results, the interactions between extreme events and elevated CO₂ will be discussed.

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Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Large-scale forest productivity responses to climate variation and extremes: tree-ring quantification, patterns, and uncertainties.

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Forested biomes contain the largest terrestrial carbon pools and are thought to currently buffer global warming by tempering the rise in atmospheric CO₂ 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 forest growth to climate variability over large spatial scales and over inter-annual to centennial time-scales. Annual growth rings of trees are a natural archive that can fulfill these needs.

Accordingly, we harmonized existing data and performed a targeted sampling to develop a continental-scale tree-ring network for all major European tree species. We then used this network to i) quantify climate sensitivity of forests across Europe, ii) reconstruct the spatial patterns of growth extremes over the past 500 years, and iii) provide quantification of the variability and timing of biomass production by performing measurements of annual ring-width and density at five long-term eddy-covariance stations. In addition to attributing spatiotemporal growth variability to both broad biogeographic features and the occurrence of temperature and precipitation extremes over Europe, we could employ this network to benchmark climatic sensitivities of forest productivity in the ORCHIDEE and LPJ vegetation models. Comparisons suggest that models 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 effects from the previous years climate. Investigations at the eddy-covariance stations indicate allocation of 45 to 58% of sequestered CO₂ to above-ground biomass increment with a seasonal partitioning of carbon assimilates in trees mainly used for volume increase (previous October to current June) and cell-wall thickening processes (current July to September). These findings enhance mechanistic interpretation of seasonal carbon fluxes, improve quantification of the sensitivity of forested ecosystems to climate variation, and serve as a basis to identify biases and reduce uncertainties in vegetation model representation of the temperate and boreal forests.

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Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Global and regional changes in NPP in 2011: the role of La Niña

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The terrestrial ecosystems are one of the main global carbon sinks and have been responsible for the removal from the atmosphere of approximately one quarter of total fossil fuel emissions. In turn, the activity of the ecosystems is limited by climate constraints such as temperature, water availability and radiation (Nemani et al., 2003). The increasing strength and future behaviour of this sink is still an on-going debate (Zhao and Running, 2010; Ahlstrom et al., 2012) due to high inter-annual variability observed and uncertainties on the global sink response to climate variability (Ballantyne et al. 2012).

Remotely sensed Net Primary Production (NPP) datasets are a valuable tool to assess geographical and temporal variability on the carbon uptake by vegetation. Since 2000, the Moderate Resolution Imaging Spectroradiometer (MODIS) has been used to retrieve a global NPP product which now comprises 12 years of data (2000-2011) with global coverage at 1km resolution (Zhao and Running, 2010).

In 2011 the highest global NPP anomaly was observed on the MODIS record, amounting to more than 1.5Pg. This extraordinary high global NPP anomaly, which was registered especially in the southern hemisphere, followed a decade of apparent decreasing trend (Zhao and Running, 2010). 2011 registered one of the strongest La-Nina events on the instrumental record that brought generally cooler conditions, heavy rainfall on many regions of the southern hemisphere and was associated to high water retention on soils (Blunden and Arndt, 2012). Our goal is, therefore, to evaluate the reasons for such high productivity and its relationship with climate variability.

Results indicate that high global anomaly was mainly driven by very high anomalies observed in the southern hemisphere, mostly in arid to semi-arid regions receiving much higher amounts of rain than average. At the same time cooler than average temperatures were observed, reducing soil water loss by evaporation. Furthermore, a strong correlation between NPP anomalies and El-Nino/Southern Oscillation is found in some of these regions and appears to drive a large fraction of global NPP anomalies.

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Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Effects of climate variability and extreme events on components of the carbon balance in Europe during 1961-2100

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Regional climate models project a change in the annual and seasonal mean of meteorological variables in Europe until the end of the century, e. g. mean air temperature is predicted to dramatically increase until 2100. At the same time, the shape of the probability distribution of meteorological variables will change, leading to an altered variability of such variables and frequency of extreme events. Today, the isolated effects of changing variance versus changing mean of meteorological drivers on ecosystem processes, such as gross primary production, autotrophic and heterotrophic respiration, evapotranspiration, mortality and disturbances have not been quantified at a continental or global scale. We contribute to such quantification from a theoretical, mechanistic modelling point of view by artificial modelling experiments using state-of-the-art generic (LPJmL, ORCHIDEE, JSBACH, CLM) and sectorial (BASFOR, DailyDayCent, PASIM) ecosystem models that has been performed in the EU FP7 project CARBO-Extreme.

Using a control climate data set (CNTL) based on the WATCH forcing data and bias-corrected ECMWF ERA-Interim reanalysis data, factorial model experiments with transient/constant climate and atmospheric [CO₂] concentration were performed. Then, these factorial experiments were repeated using a climate dataset in which climate variables hold the same long-term seasonal and annual mean but show much reduced short-term variability ("reduced variability"). This approach was applied for air temperature (REDTEMP), for short-wave and long-wave radiation (REDTEMP) as well as to all meteorological variables (REDVAR).

Analysis of the resulting carbon and water balance estimations for Europe during 1961-2100 enabled disentangling direct effects of temperature or radiation variability from effects of general climate variability and effects of a trend in mean climate conditions on ecosystem functions.

Generally, reduced variability in short-wave radiation (REDRAD) increased the annual gross primary production due to the concave shape of the light response curve of photosynthesis. Therefore, net primary production is also increasing with reduced variability. At the same time, reduced temperature variability (REDTEMP) reduces respiration components because the mean of two respiration rates at extreme high and low temperature is lower than the respiration rate at the mean temperature due to the convex shape of the respiration response to temperature. However, effects are varying over the continent along different climatic zones and ecosystem types. In addition, combined effects of variability of all meteorological variables (REDVAR), and in particular precipitation variability effects lead to more diverse net effects on the European carbon and water balance. These experiments help to understand the impact of climatic variability on ecosystem responses.

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Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Invited Lecture

Perspectives for a new generation of ecosystem manipulation experiments

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Climate change involves changes in all key drivers for ecosystem functioning in terrestrial ecosystems, but the changes in atmospheric CO₂, temperature and water availability exhibit very different patterns of change. Elevated CO₂ will be quite evenly distributed globally and will exhibit relatively constant concentrations temporally. The temperature increase will exhibit stronger spatial differences, a relatively stable increase at a given site with some seasonal differences and with some events of extreme increases. Precipitation will be even more unpredictable spatially as well as temporally with increased variability and strong extremity at some sites. These differences in driver patterns should ideally be reflected in the scenarios applied in climate change experiments. However, this is most often not the case, and the general approach to field scale experimentation may therefore not provide the complete picture of ecosystem responses to climate change.

For example, the consistent finding among climate predictions of an increase in the variability of precipitation patterns with intensified extremity has not been well covered by the treatments applied in the precipitation experiments carried out globally. Many of these studies have addressed the effects of intensified and elongated droughts but although these have applied "extreme" scenarios, the majority have only been "conservatively extreme". This means that they have applied realistic droughts in a statistical/historical sense and have rarely applied droughts being so severe that they had detrimental effects on the ecosystem, even if this would be relevant for the long term ecosystem responses. Such extreme weather events leading to threshold exceedance and severe disturbances are typically unwanted in experiments and/or may be deliberately avoided, as they will compromise the original experimental set-up and the long term perspective of the experiment. Therefore our understanding of the ecological impacts of more extreme events is in many cases limited. Since extreme events will become more frequent in the future and since these may eventually lead to ecosystem disturbances, there is a need for a new generation of ecosystem experiments for both water and temperature specifically targeting exceedance of ecological thresholds.

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Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Intra-specific diversity - a hidden tool to adapt to climatic extremes

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In the EVENT experiments at the University of Bayreuth we focus on the impacts of extreme weather events and responses of organisms and communities to modified climatic variability. Here, we present results from the EVENT 3 experiment, where various European provenances of key species in grasslands and forests were exposed to extreme drought and rain and additionally to warming and late frost events.

We find species-specific variability in the responses to these treatments. For grasses, drought was found to be more important than warming, but the dominant key species respond individually. Astonishingly, late frost events, that were considered to be mainly important for trees were also highly effective for grasses.

The investigated trees show surprising combined effects between extreme moisture conditions and thermal conditions. It can be concluded that the selection of provenances merely based on average annual conditions and especially based on temperature is not likely to yield promising results when transplanting southern provenances to Central Europe in order to design the forests of the future.

However, in some species differences between populations within one species are more prominent than differences between species. This indicates that the adaptation potential within species is considerable and should be identified with clearly focused research approaches.

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Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Delayed leaf-flushing and dieback in apple trees caused by frost drought

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Due to its mild climate, Northern Italy is one of the most important regions for apple production in Europe. However, at irregular intervals winter damage in form of delayed leaf-flushing, dieback of crown parts or even of whole trees occur. It was hypothesised that this phenomenon is caused by frost drought.

In a field experiment the influence of soil frost on different hydraulic and phenological parameters of *Malus domestica* 'Golden Delicious' was analysed. In an apple orchard in Latsch (Italy) the soil under several trees was covered with Styrofoam insulations to extend the duration of soil frost in spring. Soil temperature, soil water potential and air temperature were measured at covered and uncovered (i.e. control) sites. From January to June 2012, level of native embolism, water content of wood, bark and buds and phenology were analysed on treated and control plants.

Under the insulation, the soil stayed about three weeks longer frozen than the control. Within this time, control plants were able to refill their conduits and water content increased. In contrast, in treated plants loss of hydraulic conductivity remained high (about 50%) and water content low until soil thawing occurred and the isolation was removed. In treated plants phenology was clearly delayed: Bud break started after soil thawing, at the same time control plants were already in the mouse-ear stage (green leaf tips 10 mm above the bud scales). Differences in phenology were apparent until end of May when in treated and control plants leaves were fully developed and fruits started to develop.

These results show, that frost drought impairs the hydraulic system and, in consequence, has strong effects on the phenological development of trees. At unfavourable sites where in spring prolonged soil frost can coincide with high air temperatures trees may be seriously affected.

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Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Impact of climatic extremes on the variability of net ecosystem exchange of European forests

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Climatic extremes are predicted to increase in frequency and magnitude during the current century (IPCC, 2012) with a potential impact on the carbon cycle of European forests. In order to quantify how weather extremes translate into perturbations of net ecosystem exchange (NEE) and of the underlying biological processes implied in the exchanges of CO₂, we analyzed long term eddy covariance fluxes at 16 European forest sites selected on the basis of the maximum available number of records and their representativeness for different climatic/vegetation types.

The impact of anomalies in air temperature (T_{air}), vapour pressure deficit (VPD) and water deficit on the variability over the net ecosystem exchange (NEE) and its respiratory (Reco) and assimilative (GPP) components was evaluated. Secondly the variability of eco-physiological parameters (α -quantum yield; β -max. photosynthetic capacity; r_b-basal respiration at 15°C) retrieved by a semi-empirical model (Lasslop et al., 2010) was considered to test whether climatic extremes can affect CO₂ exchanges over forest ecosystems also by modifying their functional properties.

Climate anomalies resulted to exert a distinct effect across the climate and plant functional types considered: the carbon sink of boreal forests resulted enhanced by positive heat anomalies in spring (0.1 gC d⁻¹/°C), on the contrary T_{air} above average, particularly in the summer season, reduced the carbon sequestration capacity of cool (0.13 gC d⁻¹/°C) and warm (0.36 gC d⁻¹/°C) temperate evergreen forests. The latter were negatively affected in all the seasons, and showed the largest sensitivity to temperature anomalies. Compensation in the changes of Reco and GPP determined a non responsive NEE to T_{air} anomalies for cool temperate forests (spring, fall) and for boreal forests (summer).

The response of eco-physiological parameters to climatic drivers appeared clearly modulated by forest phenology, with distinct patterns for evergreen and deciduous functional types. Parameters tended to saturate in the higher range of temperature and VPD characterizing the growing season, however a decline was observed above a common threshold for all forest types in the range of 5-8 hPa mean daily VPD with the exception of boreal and cool temperate ENF forests where maximum photosynthetic capacity (β) showed an increasing trend even in the highest range of air temperature.

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Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Oral Presentation / Talk

Short-term carbon flow on temperate grassland: the impact of simulated summer drought

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Mean summer precipitation in Switzerland is projected to decrease by the end of the 21st century and there is a tendency towards more frequent dry spells during summer. However, large uncertainties exist in terms of how extreme events like heat waves or drought periods influence the short-term carbon cycle.

Here, we present results from an experiment performed in June 2011 where we investigated the effect of drought on the short-term carbon transport within the plant-soil system of an intensively managed lowland grassland in Switzerland (ETH research station Chamau) using rainout shelters. A pulse labeling experiment with ¹³CO₂ allowed tracing the flow of freshly assimilated carbon from above-ground biomass to the roots and to soil respiration. Continuous measurements of soil respiration and its isotopic composition were performed with a laser spectrometer (QCLAS-ISO, Aerodyne Research Inc., MA, USA) coupled to a custom-built chambers. The measurements were complemented by sampling community above- and below-ground biomass and subsequent stable isotope analysis.

Soil respiration showed a diurnal cycle with highest fluxes during the late evening/night. The labeling experiment clearly identified the high nocturnal fluxes as autotrophic. While photosynthesis and soil respiration were reduced under the drought treatment, the appearance of ¹³C- label in soil respiration was not delayed. Thus, there was no sign of any influence of drought on allocation speed. Our results suggest that during a dry spell, less carbon is entering the plant-soil system while allocation belowground seems to be maintained. On control plots freshly assimilated carbon is used for respiration but also incorporated into root biomass. On drought plots maintenance respiration seems to be the main consumer of freshly assimilated carbon. Since grasslands are widespread agroecosystems in Switzerland and beyond, such results are important for carbon sequestration considerations or for the modeling of the future carbon cycle.

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Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Clouds influence the metabolism of a coastal pine ecosystem

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Assessing the ecological importance of clouds has substantial implications for our basic understanding of ecosystems and for predicting how they will respond to a changing climate. This study was conducted in a coastal pine forest ecosystem that experiences regular cycles of stratus cloud cover and inundation in summer. Our objective was to understand how these clouds impact ecosystem metabolism by contrasting two sites along a gradient of summer stratus cover. The site that was under cloud cover ~15% more of the summer daytime hours had lower air temperatures and evaporation rates, higher soil moisture content, and received more frequent fog drip inputs than the site with less cloud cover. These cloud-driven differences in environmental conditions translated into large differences in plant and microbial activity. Pine trees at the site with greater cloud cover exhibited less water stress in summer, larger basal area growth, and greater rates of sap velocity. The difference in basal area growth between the two sites was largely due to summer growth. Microbial metabolism was highly responsive to fog drip, illustrated by an observed ~3-fold increase in microbial biomass C with increasing summer fog drip. In addition, the site with more cloud cover had greater total soil respiration and a larger fractional contribution from heterotrophic sources. We conclude that clouds are important to the ecological functioning of these coastal forests, providing summer shading and cooling that relieve pine and microbial drought stress as well as regular moisture inputs that elevate plant and microbial metabolism. These findings are important for understanding how these and other seasonally dry coastal ecosystems will respond to predicted changes in stratus cover, rainfall, and temperature.

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Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Addressing present and future variability in ecosystem carbon fluxes through modeling ensembles and model-data fusion approaches

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Future projections of the land carbon fluxes show significant divergence between models. Such discrepancies may stem from different process representations between models but also from varying parameterizations that are based on different observations. Differences in forcing datasets and modeling setups are additional factors that may contribute strongly to the observed differences in long-term trends and interannual variability in simulated ecosystem fluxes. Despite the evidence for divergent model behavior under future climate scenarios, differences in model responses to increased climate variability, and extreme events, have yet to be assessed.

Here we set up an in situ model data fusion experiment using long-term observations (INFUSION) to evaluate modeled projections of ecosystem water and carbon fluxes until 2100. An ensemble of terrestrial biogeochemical models is optimized using a consolidated set of observations and respective uncertainties for two forested sites in France: Hesse and Le Bray. The modeling ensemble is composed by: BASFOR, FöBAAR, JSBACH, LPJ and ORCHIDEE. The INFUSION design entails a harmonized optimization by forcing and constraining the models with the same observations and through a common cost function. Models are driven with local meteorological observations and constrained by eddy covariance observations of carbon and water fluxes, aboveground biomass (AGB) and AGB increments, and soil carbon pools. The set of multiple constraints enforces optimization of the responses of ecosystem fluxes to environmental conditions consistently with the current ecosystem states.

Significant improvements are observed in the modeling performance throughout the models, and modest changes in estimating the interannual variability in carbon fluxes and pools. The divergence in long-term trends until 2100 between models is expected to be reduced upon optimization. An increase in the variability of net ecosystem fluxes results both from the higher interannual variability in the projected forcing as well as the growing ecosystem carbon pools. These results suggest more frequent and amplified responses of ecosystem carbon cycle as conditions currently extreme become more prevalent. Overall, INFUSION emphasizes the importance of a common model-data integration protocol in assessing between-model differences and their relevance in addressing the future sensitivities of ecosystem carbon fluxes to changes in climate variability.

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Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

The use of satellite observations to determine the impact of soil moisture on vegetation growth

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Soil moisture is crucial in regulating vegetation productivity and controlling terrestrial carbon uptake. However, until recently no global long term soil moisture record was available. We used satellite-derived soil moisture in combination with vegetation indices to investigate the impact of soil moisture on vegetation across the world. The vegetation impact at large spatial and long term temporal scales is quantified based on the available 30+year satellite datasets. The approach relies on multiple statistical methods including windowed cross correlation, piecewise linear regression and quantile regression. We found a strong positive relationship between soil moisture and vegetation in the semi-arid regions where water availability is a limited factor for vegetation growth. The vegetation response typically lagged behind soil moisture by one month but with substantial regional variability. Dry regions with a sparse vegetation cover were more sensitive to soil moisture for the high end of the distribution of the vegetation indices than moist regions, suggesting that soil moisture controls the vegetation boost in dry regions. Over the entire period, soil moisture trends were best fitted with a segmented model where both vegetation and soil moisture trends changed simultaneously over similar turning points. Our findings illustrate how soil moisture impacts vegetation at various temporal scales and implies a method to predict carbon emissions or budgets by monitoring remotely sensed soil moisture and provides benchmarks for coupled vegetation climate models.

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Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Full accounting of Pyrogenic-C dynamics at the watershed scale: the case study of the High Park Fire

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A full understanding of the biogeochemical C cycle and its accurate modeling is critical to predict the effects of disturbance from fire on ecosystem C storage and its feedbacks to climate. During fire a fraction of the burned C, estimated to range from 0.12 to 9.5%, is converted to pyrogenic or Black C (BC) and deposited in the soil, where it may runoff, or remain in the system for up to centuries. In many fire-prone ecosystems, BC comprises more than 20% of the soil organic matter, however, we know very little about the amounts and controls of pools and fluxes of BC, and in particular at the watershed scale. In June of 2012, the High Park fire burned an area of more than 35,000 ha along the Cache la Poudre River in Northern Colorado, USA. This extreme event offered us the opportunity to conduct a full initial accounting of BC dynamics, from production to deposition, sequestration in soils and sediments, and runoff in waters at the watershed scale. Our overarching goal is to provide a quantitative understanding of BC production, stocks and dynamics at the watershed scale, for both pre- and post-fire conditions, and to provide knowledge and data for subsequent modeling of BC dynamics at the ecosystem and watershed scale. The experimental design and challenges will be discussed and preliminary data on BC stocks in soils, from areas differing for fire intensity, vegetation type and slope, and in sediments and water will be presented.

ID: 115

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

SECASOL project: direct and indirect effects of short-term climatic variability on soil microbial communities and soil C fluxes.

Jorge Curiel Yuste¹, Francisco Lloret², Josep Barba², Manuel Fernandez-Lopez³, Antonio José Fernandez-Gonzalez³, Josep Peñuelas⁴, Romá Ogaya⁴, Xavier Parladé⁵, Pablo Riesgo Ferreiro⁶, Pau Nolis⁷

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Important effects of climate change on ecosystem functioning at short temporal scales are driven by soil processes, which in Mediterranean ecosystems are largely sensitive to water availability. We have investigated how climate and climate driven changes in Mediterranean landscapes are affecting the structure and function of soil microbial communities and how these changes are further reflected in changes in soil C dynamics. We hypothesize that both direct effects (drought) and indirect effects (through changes in forest structure and composition) of climate change will strongly affect microbial community functioning, and consequently affecting C cycles in Mediterranean ecosystems. More in detail, we have investigated: (1) how drought variability (seasonal and decadal) affect both structure and function (SOM decomposition) of soil microbial communities; (2) how climate-change driven secondary succession would affect soil bacterial and fungal taxonomic composition, as well as soil organic matter (SOM) quantity and quality; (3) how climate change affects soil respiration in the different biological soil compartments (autotrophic, symbiotic and heterotrophic) by using a multi-scalar (spatial-temporal) approach. We addressed the first question in a long-term (10 years) experimental drought design, while the second and third questions were studied in an ecotonal forest where some species sensitive to drought (Scots pine; *Pinus sylvestris*) are being replaced by species better adapted to the new drier conditions (Holm-oaks; *Quercus ilex*). We applied a very interdisciplinary approach for these purposes, combining state-of-the-art molecular methodologies such as high throughput DNA pyrosequencing technique to characterize soil microbial communities, ¹³C solid-state Nuclear Magnetic Resonance (CP-MAS ¹³C NMR) to investigate changes in SOM composition, and different field techniques to study the spatial and temporal variability of soil respiration (soda lime, IRGA and solid-state open path sensors), including partition flux in its main biological compartments.

ID: 208

Session 3: Feedback mechanisms from the biosphere to the climate system

Type of Contribution: Oral Presentation / Talk

Heat wave mitigation through crop albedo management

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Cropland management practices aiming at reducing or suppressing tillage (no-till) in order to retain crop residues on the soil surface may have a potential to sequester carbon in soils and are therefore considered a possible option to mitigate climate change [1]. On the other hand, no-till systems may also modify physical properties like surface albedo thereby affecting land-atmosphere exchanges, but such biogeophysical effects have yet to be investigated [2].

Here, we investigate the biogeophysical effect of no-till agriculture over Europe using a regional climate model. A drastic no-till scenario where surface albedo is increased over croplands based on values from in-situ measurements is considered. The cooling effect owing to albedo increase under no-till farming appears to be larger during warm events. This is due to the low cloud cover during these events, thus leading to a more efficient radiative cooling from albedo change. This implies a strong potential of no-till farming to mitigate heat wave impacts. Other biogeophysical processes besides albedo change (e.g., changes in soil water and evapotranspiration) and their climatic effect will be also discussed.

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ID: 106

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Quantification of artifacts related to the most commonly used warming techniques

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Experimentally subjecting plants to a warmer environment while striving for natural conditions is by no means an easy endeavour. Here we discuss the extent to which several distinct warming techniques create unwanted side-effects. The first group of techniques rely on (partial) enclosures to warm the air in sunlit conditions. Using an empirically validated energy balance model, we investigated effects climate-controlled greenhouses and passively warmed open top chambers (OTCs) on leaf temperatures. Results show that the different radiation environment inside greenhouses did not produce large leaf temperature deviations compared to outside, providing that greenhouse design avoids significant radiation blockage and allows for sufficient ventilation. In contrast, the drastic wind speed reduction inside OTCs generally approximately doubled the actual (canopy) warming compared to earlier reported increases in air temperature provided by this technique – an effect that was inflated if the plants' stomates closed.

A second technique for heating in sunlit conditions directly warms the canopy, namely infrared (IR) heating. Concerns have been raised regarding the impact of the IR heater technique on the water balance, but a quantification was lacking. Calculating transpiration rates under IR heaters in comparison with air warming at constant relative humidity, we find a 12 to 15% increase in transpiration under IR heaters for a 1 °C warming. Importantly, the artifact is less of a concern when simulating heat waves, as the higher atmospheric water demand underneath the heaters reflects naturally occurring increases of potential evapotranspiration during heat waves resulting from atmospheric feedback. Finally, we also studied the way in which IR heating is applied. Current control methods exclude the vegetation from interacting with the applied warming, because a fixed temperature difference with the controls is maintained. However, canopy temperatures are influenced by stomatal responses of the vegetation, which depend on moisture conditions and therefore also on warming. Here, we present a new control technique which would avoid these problems.

ID: 109

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Moisture extremes and internal lags as controls on photosynthesis anomalies in temperate forests

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Significant advances have been made over the past decades in capabilities to simulate diurnal and season variation of leaf-level and canopy-scale photosynthesis in temperate and boreal forests. However, long-term prediction of future landscape-scale productivity in a changing climate and especially to climate extremes may be more dependent on how climate and biological factors influence anomalies and state shifts in ecosystem carbon exchanges. These exchanges can differ markedly from leaf level responses, especially owing to the prevalence of long lags in nutrient and water cycling. Until recently, multiple long-term (10+ year) high temporal frequency (daily) observations of canopy carbon exchange were not available to reliably assess this claim. An analysis of one of the longest running North American eddy covariance flux towers (16+ years) reveals that single climate variables do not adequately explain carbon exchange anomalies beyond the seasonal timescale. Lagged time-frequency domain analysis, empirical mode decomposition, and Granger causality statistics of climate and carbon cycle anomalies reveals the important role of long-lead short-term moisture anomalies and more recent carbon uptake anomalies in explaining extremes of ecosystem photosynthesis. These results provide a new framework for assessing magnitudes and driving factors of biogeochemical extremes.

ID: 128

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Grassland Responses to Altered Precipitation in Southern Ukraine: First Results from a New Experimental Site

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In recent decades about 40 precipitation (PPT) experiments have been initiated in grassland ecosystems, mostly in the USA and Western Europe. Complementing the worldwide database of PPT experiments, in 2011 we initiated a project called "Nonlinear response of Ukrainian grassland to altered precipitation". The experimental site is located on the steppe plateau on the Crimean peninsula (N44°54.914'; E050°12.289'). Vegetation is represented by *Eryngio-Stipetum ponticae*, a transitional community between steppe and xerothermophilous Mediterranean grassland. 21 experimental plots (2x2m) with rainout-redistribution shelters modeled six PPT regimes: change from the ambient PPT level by 20, 40, and 60% (treatment started in May of 2011). The aim of our research was to analyze changes in carbon cycling processes and plant community structure.

After a year of experiment, aboveground net primary production (ANPP) showed a positive correlation with PPT ($r^2=0.65$, $p=0.001$), varying from 47.9 ± 7.3 g C m⁻²y⁻¹ ("−60%") to 109.47 ± 0.24 g C m⁻²y⁻¹ ("+60%"); for the belowground net primary production (BNPP) we observed no consistent relationship. Average gross ecosystem productivity (GEP) in May-September 2012 positively correlated with PPT ($r^2=0.48$, $p<0.002$) with the peak in May. GEP varied across the treatments from 1.84 ± 0.3 to 6.89 ± 1.1 $\mu\text{mol CO}_2$ m⁻²s⁻¹. Soil organic carbon (SOC) varied from $4.5\pm 0.036\%$ (0-4cm layer) to $1.5\pm 0.079\%$ (16-20cm) in all November samples. Averaged soil respiration in April-October growing season had a significant positive correlation with soil moisture at 15 cm depth ($r^2=0.51$, $p<0.0001$). Also it was positively correlated with PPT ($r^2=0.34$, $p<0.001$), but this relationship appeared to be non-linear in our study.

ID: 154

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

A multisite analysis of the role of high flow extremes on aquatic DOC export

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The release of soil derived DOC into river systems is a major C transport pathway in many upland catchments, particularly where organic-rich soils dominate. Aquatic C export (of which DOC is the primary component) represents 30-50% of C uptake via NEE in peatland catchments. Both soil-stream transport and downstream export of DOC are highly sensitive to changes in hydrological regime and are therefore greatly influenced by climatic extremes such as storm flow and snow melt. Here we utilise long-term DOC datasets from 8 UK streams provided by the 'Environmental Change Network' (ECN), alongside long-term datasets from 6 Swedish streams, to investigate the relative contribution of storm flow events to total annual DOC export. We consider seasonality in the contribution of high flow events to total DOC export, and compare the storm flow responses across catchments considering catchment characteristics such as vegetation community, soil type and hydrological regime. Finally, by combining the information gained in the aforementioned analysis we will consider how DOC export is likely to respond to predicted changes in regional precipitation patterns.

ID: 233

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Is the link between warming, phenology and carbon uptake limited by climatic extremes?

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Changes in climatic conditions and their effects on phenology and carbon cycling of terrestrial ecosystems are well documented at local to global scales. While there is general consensus on the existence of such links between warming trends, changes in phenology (e.g. vegetative season length) and the effectiveness of ecosystems as carbon sinks, the interplay of underlying mechanisms and their combined long-term trends are less certain and, for example, affect predictions on the future roles of temperate forests in offsetting anthropogenic carbon emissions. This uncertainty mainly originates from the incomplete understanding of the processes and controls that regulate the carbon cycle in forest, but also by the scarcity of long-term observations that can reveal long-term trends in carbon, water and energy exchange between ecosystems and the atmosphere.

One of the few sites with continuous carbon exchange records of longer than a decade is the AmeriFlux site in the Morgan Monroe State Forest in Indiana (MMSF, USA). At this mixed temperate deciduous forest net ecosystem exchange (NEE) of carbon and its environmental drivers have been observed since 1998 (using both eddy-covariance and inventory approaches). From 1998 to 2008, an overall increase in late-summer temperatures led to an extension of the active vegetative season progressively later into the fall and was shown to drive significantly increased net ecosystem productivity (NEP) at MMSF (increase of NEP by about 100 gC m⁻² over a decade). However, in later years (2009 to 2012), a series of extreme short-term climate events, ranging from early to late season droughts, or colder-than-normal springs, have led to very low annual productivity (on average 25% lower than the 1998-2008 mean). Such extreme climate events impacted phenology, carbon exchange and allocation, and nutrient cycling. In particular, observations indicate that drought led to a shift in C-allocation from aboveground to belowground pools, likely as a result of increasing costs of nutrient acquisition with drought induced declines in rates of nutrient mineralization. Further, the 2012 drought was exceptional in that it occurred much earlier in the growing season than previous droughts and led to strong declines in NEE that canceled out the effects of an early start to the uptake season. Thus, extreme climate events have the potential to outweigh positive trends in NEP that are induced by gradual shifts in climate and phenology. Given that extreme short-term climate events are expected to increase in intensity and frequency in a warming world, our results highlight the need to investigate the role of short-term climatic stressors in the acclimation of ecosystems to gradual shifts in climate.

ID: 241

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Oral Presentation / Talk

Warming alters the response of old-field ecosystem processes to precipitation

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We found contrasting responses of plants and microbes to warming, such that under warmed conditions plant-driven processes became more sensitive to precipitation changes, while microbial processes became less sensitive. Over four years, plant growth in an old field near Massachusetts, USA, remained remarkably stable across large changes in precipitation (+50, -50%). However, when the ecosystem was warmed, plant growth responded sharply to precipitation changes. The combination of warming and precipitation removal led to extreme drought conditions in some years, which caused high rates of tree seedling mortality and sharp reductions in plant growth. However, under ambient temperatures, precipitation removal had relatively little effect on plants. Warming is likely to markedly increase the susceptibility of plants in this ecosystem to future droughts, but also enhance their response to extremely wet years. In the microbial community, long-term warming altered the temperature response of microbial processes, in a manner that depended on the season and process. The temperature sensitivity of net nitrogen mineralization and nitrification varied sharply with precipitation treatment under ambient conditions, but under warmed conditions temperature sensitivities converged to a lower rate. Similarly, heterotrophic respiration responded the least to temperature and moisture during the warmest season of the year (summer), but responded more strongly in spring and fall. While warming may seem to have relatively modest effects on some ecosystems when imposed in isolation, warming can dramatically alter the responses of ecosystem processes to precipitation variability and extremes.

ID: 124

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Effects of temporal variability of annual rainfall erosivity and frequency of extreme rainfall events on the soil organic carbon balance in a small agricultural catchment

Peter Fiener, Verena Dlugoš

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There is an ongoing debate to which extent soil erosion in arable landscapes affects the long-term soil organic carbon (SOC) balance. One of the main problems is that the processes of SOC redistribution are highly variable in time and act on very short time scales (min-h), while the overall effect of SOC redistribution on the landscape scale is mainly measurable by SOC patterns developed within decades to centuries. To partly overcome this problem, lumped erosion models, typically with a time step of one year, are coupled with long-term C turnover models. The main aim of this study is to use such a model to analyse the effect of variability in annual rainfall erosivity and erosivity of extreme individual events on SOC redistribution, dynamic replacement of SOC at erosional sites and long-term burial of SOC at depositional sites. The analysis is based on an evaluation of a long-term (1937-2007) high resolution (≤ 5 -min) rainfall data set from ten stations in Western Germany, which allowed to determine long-term variability in annual erosivity, and to identify the frequency of extreme individual events as well as trends in the magnitude of both. The long-term data showed a pronounced variability in annual erosivity (Coefficient of variation of 0.45-0.61 in 71-yr) with individual events having an erosivity up to 4.7 times larger than the long-term annual mean. Moreover, the data indicate a significant positive trend in annual erosivity (4.4% per decade), which results from an increase in frequency and magnitude of erosive events. The erosivity of individual years and thus also of individual extreme events was used as input for the combined soil erosion and SOC dynamics model SPEROS-C, and model results were compared to a reference run with a long-term mean erosivity in a small agricultural catchment. Results show that the temporal variability of extreme years (or individual events) substantially affects the influence of soil redistribution on the SOC balance of the small catchment. In contrast to the reference model run the depositional sites are characterized by a positive vertical C flux into the soil. This can be explained by the fact that in years with extreme water erosion, the depositional sites exhibit a strong sink term, whereas in average water erosion years only tillage erosion occurs which acts as a C source to the atmosphere. Moreover, C depleted subsoil material with reduced mineralization rates is redeposited at depositional sites. Even if the chosen methods and assumptions lead to a somewhat rough estimate, the results show that many studies, that (globally) estimate the effect of soil redistribution on the C balance and that are based on long-term average erosion rates, might be misleading.

ID: 206

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Invited Lecture

Ecosystem organization and climate resilience

Rosie Alice Fisher

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One emergent property of competition for resources between alternative plant strategies is that multiple functional trade-offs emerge between growth and persistence. Given a relatively stable past climate, there is, theoretically, a selective advantage for those plants who invest exactly enough, and no more, in survival properties and hence maximize growth rates. Thus, one theoretically plausible present is that ecosystems are perfectly adapted to their past climates, and thus poorly equipped to deal with future climates, particularly if those future climates involve an increase in potentially fatal extreme events. In this talk, I will discuss how dynamic vegetation models, driven with increasing understanding of trait trade-off surfaces, are afflicted by this intrinsic property of theoretical ecosystems, and how alternative present and future scenarios are differentially adapted to their past climate and therefore vary substantially in their climate resilience. In particular, one problem is that the representation of aggregated properties (plant, soil, topography, climate) is likely to cause a systematic bias in selecting for ecosystems that contain fewer resilient strategies in the present, thus overestimating the potential for positive feedback.

ID: 196

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Response of Plant Biomass and Soil Respiration to Experimental Warming and Precipitation Manipulation in a Northern Great Plains Grassland

Lawrence B. Flanagan, Eric J. Sharp, Matthew G. Letts

University of Lethbridge, Canada

The interacting effects of altered temperature and precipitation are expected to have significant consequences for ecosystem net carbon storage. Here we report on the effects of elevated temperature and altered precipitation, alone and in combination, on plant biomass production and soil respiration rates in a northern Great Plains grassland, near Lethbridge, Alberta Canada. Open-top chambers and rain shelters were used to establish an experiment in 2011 with two temperature treatments (warmed and control), each combined with three precipitation treatments (minus 50%, ambient (no manipulation), and plus 50%). A smaller experiment with only the two temperature treatments was conducted in 2012, a year with less rain than 2011. Our objectives were to determine the sensitivity of plant biomass production and soil respiration to temperature and moisture manipulations. The experimental manipulations resulted primarily in a significant increase in air temperature in the warmed treatment. There were no significant temperature or precipitation treatment effects on soil moisture content. Aboveground biomass was not significantly affected by the experimental manipulations. The warmed treatment increased the cumulative loss of carbon in soil respiration (July-September) compared to the control by 497 g C/m² during 2011, and by 185 g C/m² during 2012. This higher soil respiration rate in both years was not directly caused by significant differences among treatments in soil temperature or soil moisture, but was likely an indirect result of increased carbon substrate availability in the warmed relative to the control treatment.

ID: 224

Session 3: Feedback mechanisms from the biosphere to the climate system

Type of Contribution: Oral Presentation / Talk

Discovery of an unknown respiration pathway in soil: consequence for ecosystem response to extreme temperature

Sébastien Fontaine, Gael Alvarez

INRA, France

The respiratory release of CO₂ from soils is a major determinant of the global carbon cycle. It is traditionally considered that this respiration is an intracellular metabolism consisting of complex biochemical reactions carried out by numerous enzymes and co-factors. Here we show that the endoenzymes released from dead organisms are stabilized in soils and have access to suitable substrates and co-factors to permit function. These enzymes reconstitute an extracellular oxidative metabolism (EXOMET) that may substantially contribute to soil respiration (16 to 48% of CO₂ released from soils in the present study). EXOMET and respiration from living organisms should be considered separately when studying effects of environmental factors on the C cycle because EXOMET shows specific properties such as resistance to high temperature.

ID: 113

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Extreme events and the terrestrial carbon cycle - mechanisms, processes and impacts on different ecosystem types

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Severe droughts, heat waves, extreme precipitation or storms can impact the structure, composition, and functioning of terrestrial ecosystems and thus their carbon cycling and carbon sequestration potential. Besides direct impacts on the carbon fluxes of photosynthesis and respiration, extreme events may also trigger further partially lagged phenomena such as heat wave and drought related fires, pest and pathogen outbreaks following heavy storm caused wind throw or drought stress reduced plant health. Extreme events have the potential to cause rapid carbon losses from accumulated stocks, as well as long-lasting impacts on the carbon cycle due to direct and lagged effects on plant growth and mortality, going often beyond the duration of the extreme event itself. Extreme events have the potential to impact the terrestrial ecosystem carbon balance through a single factor or as a combination of factors, and forests, grassland and croplands are differently affected by the various types of extremes.

ID: 221

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Low land-use intensity mitigates drought-induced changes on microbial community functioning in mountain grassland

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Changes in land management and land use substantially alter soil carbon and nitrogen pools and thus nutrient availability for plants and soil microbes. These changes are related to shifts in plant and soil microbial community composition (e.g. higher fungal abundance in grasslands with low land-use intensity), but also microbial functions. Thus, they can affect processes mediated by soil microbes, such as enzyme activity.

In this study we focussed on effects of summer drought events on soil microbial functioning, in particular soil microbial extracellular enzyme activity, in two adjacent mountain grasslands differing in land-use intensity. We hypothesized that soil extracellular enzyme activities and their response to drought events is driven by altered substrate availability caused by land-use-intensity. Therefore, we simulated an extended drought for a period of two months, using rain-out shelter, on a meadow and an abandoned grassland in the Austrian Central Alps. We measured several different actual (cellulase, protease) and potential (exoglucanase, endochitinase, phosphatase, protease, phenol- and peroxidase) enzyme activities in all drought and control plots before, during and after drought treatment.

All extracellular enzyme activities, except potential protease and phosphatase, were significantly higher in the abandoned grassland as compared to the meadow. While drought had no effect on any measured extracellular enzyme activity in the abandoned grassland, it induced a significant increase of actual cellulase, but a decrease of exoglucanase, phosphatase and protease activity. However, phenoloxidase and peroxidase activity were neither affected in the abandoned grassland, nor in the meadow.

We proved that soil extracellular enzymes activities were higher in the abandoned grassland than in the managed meadow and moreover less affected by drought. This, however, may in turn affect nutrient availability especially in managed grasslands and alter the resistance of grassland soil ecosystems to future climate change scenarios.

ID: 142

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Phenology and carbon dioxide source/sink strength of a subalpine grassland in response to an exceptionally short snow season

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In seasonally snow-covered ecosystems, such as mountain ecosystems in the Alps, increasing temperatures may be expected to cause earlier snowmelt and later establishment of snow cover, reduce off-season carbon losses and potentially lead to longer periods of CO₂ uptake and growth.

This study investigates the effect of an extremely short snow season on the phenology and ecosystem carbon sequestration of a subalpine grassland in the Aosta Valley (Italy). We made use of a “natural experiment” comparing phenology and ecosystem CO₂ fluxes of a subalpine grassland during a year (2011) marked by one of the shortest snow season on record (1928-2010) with those of two average years (2009, 2010).

A variation of more than one month (43 days) in the date of snowmelt in 2011 caused a similar shift (35-40 days) in the beginning of the carbon uptake period (CUP), and together with a later establishment of snow-season in autumn contributed to a two months longer CUP. The combined effect of the exceptionally short snow season, with smaller net CO₂ losses, and the extended CUP, lead to an increase of about 100% in annual net carbon uptake. However, the earlier snowmelt was followed by changes in ecosystem structure and functioning with a reduction in the summer carbon sequestration rate. Assuming an increasing occurrence of events such as the observed, the trade-off between smaller CO₂ losses during shorter winters and smaller gains during longer summers will be crucial in determining the annual carbon balance of subalpine grasslands.

ID: 200

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Multi-year (12 years) assessment of in situ measurement and land surface model estimate of evapotranspiration over a Mediterranean agricultural site : response to climate variability and uncertainties analysis

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Vegetation productivity and water balance of Mediterranean regions will be particularly affected by climate changes. In order to analyze and predict these changes through land surface models and to improve the model's response to climate extremes, a critical step is to quantify the uncertainties associated with these models (processes, parameters) and their implementation over a long period of time. This paper aims at assessing the uncertainties in evapotranspiration and energy fluxes estimated from a Soil Vegetation Atmosphere Transfer (SVAT) model over a Mediterranean agricultural site. While similar past studies focused on particular crop types and limited period of time, the originality of this paper consists in implementing the SVAT model and assessing its uncertainties over a long period of time (12 years), encompassing several cycles of distinct crops (maize, wheat, sorghum, sunflower, peas) and bare soil periods in between crop cycles. Besides, this long period of time allows to analysing the model performances with regards to climate variability and extremes, in particular for the 6 wheat crop cycles of the period.

The SVAT model being analyzed in this paper is the ISBA model in its a-gs version which simulates the photosynthesis and its coupling with the stomata conductance, as well as the time course of the plant biomass and the Leaf Area Index (LAI). The model is evaluated over the INRA-Avignon (France) crop site, for which 12 years of energy and water fluxes, soil moisture profiles, vegetation measurements, agricultural practises, detailed soil hydrodynamic properties are available. The model is continuously implemented over this site from May 2001 up to November 2012, accounting for the succession of crop and bare soil periods.

The first part of this work aims at characterizing the response of the crop site in terms of evapotranspiration to climate variability, from the analysis of the available in situ measurements. Both crop and bare soil periods are analyzed with particular focus on climate extremes (ex: 2003 heat wave, 2012 dry and cold winter). In the second part, the uncertainties in evapotranspiration and energy flux estimates are quantified from both 12-year trend analysis and selected daily cycles spanning a range of atmospheric conditions and phenological stages. While little differences are observed in the simulations based on the local atmospheric measurements and those using the SAFRAN re-analysis atmospheric dataset, errors in the ECOCLIMAP global map of land surface parameters (soil properties and LAI time course) lead to the largest discrepancies in evapotranspiration estimate. While the net radiation flux is correctly simulated, the cumulated latent heat flux is under-estimated for both crop and bare soil periods. This latter finding is consistent with the over-estimation of the root-zone soil moisture. The main source of uncertainties is due to the underestimation of the maximum water content available for the crop which substantially varies with crop cycles and time. Then, the analysis focuses on the relationships between these uncertainties and climate variability and particular attention is paid to the model response to climate extreme. This study will provide key insights on the use of land surface models for climate change studies.

ID: 136

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

How snowpack controls soil microbial communities and associated CO₂ respiration during extreme winter events

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The central research question of this project is how soil respiration and soil microbial community composition and activity of subalpine grasslands are affected by snow cover thickness. Current winter season data on source and fate of CO₂ produced in soil under ambient and reduced snowpack will be presented, testing hypotheses on the underlying mechanisms.

In the scope of this talk, focus will be laid on the assumptions that (1) under ambient snow regime with a consistent snow cover, temporal variations in soil respiration rates are independent from fluctuations in soil temperature and moisture, but are determined by DOC concentration in the soil solution. In contrast, (2) reduced snow cover leads to intensive freeze-thaw cycles in the soil with larger amplitudes of microbial biomass, DOC and soil CO₂ production and efflux over the course of winter. Expected (3) shift in microbial community composition towards decreased fungal / bacterial ratios due to snow removal will further result in (4) a stronger incorporation of labile C in microbial biomass and more pronounced priming effects of soil organic matter turnover.

As a perspective, adequate carbon budgets for temperate mountain ecosystems could be constructed, relating snow insulation capacities to soil carbon availability, to microbial diversity and activity, and ultimately to the production and efflux of CO₂ from soils under various snow conditions. We hope to contribute some further understanding on the process of temperature decoupling of soil respiration in winter, which should feed into the development of more accurate global carbon circulation models.

ID: 171

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

13C and 15N labelling for studying the effects of long-term warming on C and N allocation in a Mediterranean shrub community

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The effects of 10 years of passive night time warming on C and N allocation were studied in a Mediterranean shrub community of Porto Conte (Italy, European INCREASE network) by means of 13C and 15N pulse labelling. Reflective curtains spanned over the vegetation at night decreased the loss of IR radiation from soil, resulting in the increase of minimum air and soil temperature by approximately 1 °C. Such temperature increase mimics the scenarios of most General Circulation Models for the global surface temperature changes over this century.

Cistus monspeliensis, a dominant shrub species within the experimental site, was labelled in 13CO₂ enriched atmosphere for 1.5 h in October 2012. Control and night warmed plots were labelled with three field replicates.

15N labelling was performed one day before the 13C label by uniformly adding to the soil tracing amounts of KNO₃ (5 kg N ha⁻¹). 15N labelling was not restricted to one species: all growing plants had an access to applied 15N.

The objective of combined 13C and 15N labelling was to evaluate the effects of warming on C and N allocation to pools and fluxes in the shrubs ecosystem.

Tracer (13C and 15N) allocation were monitored between various pools (shoots, roots, soil, microbial biomass, CO₂) during the first five days after the label input with a one day frequency and an additional sampling was performed 15 days after the labelling. In particular, 13C and 15N dynamics were monitored in aboveground biomass by sampling leaves and leaf-respired CO₂. Branches were sampled separately and also analysed for 13C and 15N content. Aboveground pools were subdivided into structural pool and water soluble organic matter. Allocation of tracers to belowground was studied by sampling soil, roots and soil respired CO₂. Microbial biomass C and N were extracted and analysed for the tracers' content. Soil respiration and its $\delta^{13}C$ was determined by Keeling plot approach.

Such detailed sampling permitted to draw the functioning of this *C. monspeliensis* dominated shrubland community to warming and its related consequences on the C and N cycling in Mediterranean shrublands.

ID: 119

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Drought Effects on Forest Understory: Interactions between drought and land-use intensity

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Projections of climate change predict an increase in drought frequency and intensity for regions across the globe. The manifold impacts of drought on forest understory dynamics may lead to a positive or negative feedback depending on aboveground and belowground community resilience. Within the DFG funded Biodiversity Exploratories, our group investigates the potential feedback between intense drought conditions, forest management, understory plant and microbial communities and the response in soil organic matter hydrophobicity and site hydrology. We manipulate plots in the field and soil monoliths in the laboratory to address our hypotheses, a subset of which are: 1) drought alters the plant community physiology, which can be detected through the isotopic signature of transpiration, and 2) active belowground communities shift with drought, which we can detect via labeled phospholipid fatty acid derived from microbial cellular membranes. Finally, to detect changes in organic matter hydrophobicity between drought and control field plots, we use Diffuse Reflectance Infrared Fourier Transformed (DRIFT) spectroscopy. We present first year results and discoveries from the field and laboratory experiments.

ID: 236

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Effect of summer drought on monocultures and mixtures of temperate deciduous trees

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To be completed

ID: 198

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Primary and secondary effects of climate variability on carbon and water exchange in a managed subalpine Eucalyptus forest.

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Climate variability and change, ecosystem disturbance and land management operate over a large range of temporal and spatial scales and lead to variability in carbon and water fluxes. Diagnosing the climate controls over these fluxes is not simple but key to improving prediction and understanding of water and carbon cycle–climate interactions.

We use a novel technique to investigate the variability of the fluxes from daily to multiannual timescales; and demonstrate the controlling influence of climate on water use and carbon uptake directly (through changes in radiation, temperature, humidity) and indirectly (through disturbance triggered by changes in climate conditions). Direct climate impacts depend on the time scale under consideration but are generally strongest on the annual time scale.

To investigate the spatio-temporal variability of the impact of disturbance we use NDVI and albedo. They provide information on status and dynamics of the vegetation and we find that the whole area within the State Forest that was classified as native Eucalyptus forest (305.05 km²) was affected by the disturbance. The disturbance affected tree species differently, led to a reduced photosynthetically active leaf area, reduced stomatal conductance and hence photosynthetic capacity. The reduced carbon budget of the trees was evident as reduced biomass increment and increased mortality. We further find that the coherence between albedo and carbon and water exchange is strong on annual and multi-annual time scales. On multi-annual time scale, carbon and water fluxes are coherent with the multivariate El Niño index.

ID: 150

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Drought impact on vegetation in pre and post fire events in Iberian Peninsula

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In 2004/2005, Iberian Peninsula was stricken by an exceptional drought with a strong negative impact in vegetation dynamics (Gouveia et al., 2009). The impact of the exceptional 2004/2005 drought on vegetation was assessed for vegetation recovering from the extraordinary fire season of 2003 and on the conditions that contributed to the on setting of the fire season of 2005. The present work relies on remotely sensed data of vegetation dynamics and leaf moisture content, in particular monthly NDVI, NDWI and NDDI time series from 1999–2009, derived from VEGETATION dataset. Drought severity was estimated by the cumulative negative effect on photosynthetic activity (NDVI) and vegetation dryness (NDDI), with about 2/3 of Iberian Peninsula presenting vegetative stress and low water availability conditions, in spring and early summer of 2005. Furthermore, NDDI has shown to be very useful to assess drought, since it combines information on vegetation and water conditions.

Within the frame of the European Project FUME, we show that besides looking at the inter-annual variability of NDVI and NDDI, it is useful to evaluate intraannual changes, as indicators of change in vegetation greenness, allowing a detailed picture of the ability of the different land-cover types to resist to short-term dry conditions. In order to assess drought impact on post-fire regeneration, recovery times were evaluated by a mono-parametric model based on NDVI data (Gouveia et al., 2010, Bastos et al., 2011) and values corresponding to drought months were set to no value. Drought has shown to delay recovery times for several months in all the selected scars from 2003.

The analysis of vegetation dynamics and fire selectivity in 2005 suggests that fires tended to occur in pixels presenting lower vegetative and water stress conditions during spring and early summer months. Additionally, pre-fire vegetation dynamics, in particular vegetation density and water availability during spring and early summer, has shown to influence significantly the levels of fire damage. These results stress the role of fuel availability in fire occurrence and impact on the Iberian Peninsula (Gouveia et al., 2012).

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Gouveia C., Trigo R.M., DaCamara C.C (2009) "Drought and Vegetation Stress Monitoring in Portugal using Satellite Data". *Natural Hazards and Earth System Sciences*, 9, 1-11

Gouveia C., DaCamara C.C, Trigo R.M. (2010). "Post-fire vegetation dynamics in Portugal". *Natural Hazards and Earth System Sciences*, 10, 4, 673-684.

Gouveia C.M., Bastos A., Trigo R.M., DaCamara C.C. (2012) "Drought impacts on vegetation in the pre and post-fire events over Iberian Peninsula". *Natural Hazards and Earth System Sciences*, 12, 3123–3137, 2012.

ID: 219

Session 3: Feedback mechanisms from the biosphere to the climate system

Type of Contribution: Poster Presentation

Atmospheric constraints on Plant Water Use Efficiency drivers and patterns of changes since 1900

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Water Use Efficiency (WUE) controls the relationship between the ecosystem water and carbon balance. Because WUE responds to environmental changes it can be used as a metric to quantify the effect of climate change on ecosystems. The actual WUE_{Eco} is defined as a ratio of gross primary production and transpiration fluxes. On the leaf scale this is equal to the atmospheric WUE_{atm}, which is a function of the ambient and internal CO₂ concentration, the saturated specific humidity and relative humidity. Using observations and the JULES and HadCM3 models we explore on which temporal and spatial scales WUE_{Eco} and WUE_{atm} are equal, and how they respond to climate change.

Leaf level definitions are valid at site level, where annual WUE_{Eco} and WUE_{atm} simulated with JULES are equal and linearly increasing with atmospheric CO₂ concentration for a range of sites. For drier sites lower values of both were simulated. The simulated values are within the same range as values derived from eddy covariance observations.

Having shown the near equivalence between WUE_{Eco} and WUE_{atm} for specific sites, we can use the formula for WUE_{atm} to estimate the change in plant WUE over the 20th century, using observed climatological data and CO₂ concentrations. In general WUE is found to increase strongly with the CO₂ concentration, but this is offset by warming and drying that increases evaporative demand and therefore reduces WUE.

As a result we find complex spatio-temporal patterns of changes in WUE, resulting from the differing drivers of climate change and variation. For example, warming due to the reduction in atmospheric aerosol pollution since the late 1980s reduced WUE in some previously heavily-polluted regions despite the ongoing increase in atmospheric CO₂. We will describe the methods used to reconstruct WUE from observations, and discuss the spatial and temporal variation of WUE since 1900.

ID: 211

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Oral Presentation / Talk

Alternative drivers of carbon cycling under an extreme climate

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During heat and drought events, some of the common drivers of the carbon cycle, such as water from rain or snow, might play a minor role over an extended period of time. Instead, alternative drivers can control the processes of carbon cycling, some of which are less considered under regular conditions. Studies in ecosystems adapted to a more extreme climate showed that topsoil and aboveground plant litter desiccate quickly during prolonged dry and hot periods. During such events, decay and CO₂ production of plant litter and organic matter at the soil surface are controlled by alternative drivers rather than by common factors. Dry litter can quickly absorb water from dew and atmospheric vapor during frequent nights of high relative humidity, thus enabling microbial degradation. During day-time, litter exposed to high solar radiation and high temperatures in open terrain is abiotically degraded by photochemical and thermal processes that target lignin and other tissue compounds. During 4 months without rainfall, alternative processes caused up to 50% of the annual mass loss of litter in a Mediterranean shrubland. These factors could also drive decomposition of organic matter at soil surfaces exposed to atmospheric moisture, solar radiation and/or heat. Warmer and drier conditions as a consequence of climate change will result in enhanced drying of litter and topsoil also outside regions that are currently classified as drylands. In addition, extreme climatic events might trigger changes in vegetation types towards less woody cover and a more open landscape, which will extend drying of topsoil and litter, and will expose them to atmospheric moisture, high solar radiation and heat. Therefore, alternative drivers might play an increasing role globally in decomposition of organic materials and in CO₂ and other trace gases emitted during these processes.

ID: 139

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Warming effect on CO₂ fluxes in a Mediterranean shrubland

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The increased concentration of atmospheric GHG gases has increased the Earth surface temperature. These changes will influence the ecosystem carbon balance and its processes. Also in the Mediterranean basin the temperatures have shown a warming trend, but frequently the temperature is not seen as a limiting factor and the warming effect is often considered in terms of warming's influence on water availability. In order to investigate the warming effect on the CO₂ fluxes in a Mediterranean ecosystem, we manipulated the microclimate in a semi-deciduous shrubland in the Island of Sardinia by increasing the nighttime soil and air temperature. An automatic roof covered the vegetation inside 3 plots (20 m²) during nights, while other 3 plots were used as control (no roof cover).

Carbon dioxide exchanges were measured at leaf level and at ecosystem level. All measurements were carried out during the year 2010, after 9 years of treatment.

All the examined CO₂ fluxes (NEE, SR, TER, GPP) showed a strong temporal variation with the highest rates during the spring, when the high water content and the mild temperature supported both the photosynthetic and respiratory activities. The lowest rates were recorded during the hot and dry non-vegetative summer season. The autumnal rain events enhanced SR and TER more than GPP; when NEE contemporary reached minimum values.

The warming treatment increased the leaf photosynthesis during late spring - early summer, while at the canopy level there was only a positive effect during the period with lower temperatures and higher soil water content, when LAI levels were contemporary higher.

The increased CO₂ uptake might be related to the higher leaf N concentration found in the warming plots. The higher N mineralization found in a previous study in the warming plots corroborated this hypothesis.

ID: 149

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Impact of extreme weather events on microorganisms in soils

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Prolonged climate change as predicted in future climate scenarios, like extreme drought events during vegetation periods, will affect ecosystem functions in multiple ways. Increased frequencies of drought periods during spring and summer times lead to an increase in nutrient release due to physical disruption of soil aggregates and humic materials, and consequently, also affects soil microorganisms. Important soil functions, like nutrient turnover processes will be changed by both climate change scenarios. These factors are addressed in the EVENT-Experiment established at the Botanical Garden of the University of Bayreuth and focuses on natural grassland communities.

In this project, we hypothesise that under drought conditions hydrolytic enzyme activities will be reduced. Therefore, biochemical parameters such as soil potential extracellular enzymatic activities (PEEA) of MUF-labeled hydrolytic enzymes (e.g. phosphatase, chitinase, cellulases), changes in the carbon content and microbial biomass were measured. Further on soil microbial community will be affected as well due to the long lasting drought periods.

In three consecutive sampling years seasonal differences in potential extracellular enzyme activities between spring drought and summer drought treated soils were determined. Whereas after both treatments significantly decreased PEEA values were measured between drought treated and control soils, PEEA increased notably within two weeks after rewetting of summer drought treated soils due to a higher amount of available biomass. PEEA values of spring drought treated soils recovered only to the level of the control plots.

ID: 239

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Pine forest productivity under increasing drought stress during the last century and the ability of Orchidee to reproduce the observed trends.

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Mediterranean forests are affected by seasonal drought stress during summer. The photosynthetic activity decreases strongly during this period, limiting the productivity of Mediterranean forests. Future climate projections indicate increasing temperature and decreasing precipitations in the Mediterranean. Forest productivity is therefore assumed to decrease, although the increase in Co2 could counteract (part of) this effect. Global vegetation models (GVM) are widely used to model carbon fluxes and stocks for the biosphere. However, it is known that most of these models have problems to model seasonal drought stress conditions adequately. In this study we use a forest productivity dataset of a maritime pine (*P. pinaster*) forest in central Spain for the last 100 year. From this forest the standing biomass, wood harvest and biomass increment data were measured at a decadal time period. Precipitation has decreased over the area during the last century, with an increase in drought frequency during the last decades. We present here the analysis of the impact of increased drought stress on the forest productivity and the ability of Orchidee GVM to reproduce this century long productivity trends.

ID: 134

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Sensitivity of the global land carbon sink to climate variability, disturbance, and recovery

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Sensitivity of the global land carbon sink to climate variability, disturbance, and recovery

The atmospheric growth rate of CO₂ is sensitive to responses of the land surface to climate variability. Inherent in this variability is the recovery of ecosystems following disturbance of both natural and human origin. For example, the land carbon uptake was impacted by droughts in the Amazon in 2005 and 2010 and in the western U.S. in 2000-2004, and by the 2003 heat wave in Europe. Recovery dynamics following such events greatly influence the ecosystems carbon cycle and its vulnerability to future variability.

We analyse recovery dynamics in the JULES dynamic global vegetation model (DGVM) and investigate implications for the global land carbon sink. Two key components of the model are addressed: the individual plant functional types (PFTs) and the regrowth/disturbance time scales in the DGVM. First, we expand the number of PFTs in JULES and revise the parameters to represent observed relationships between leaf nitrogen and photosynthesis. Second, we address the time scales for regrowth and competition between the PFTs in the DGVM. These changes improve patterns of NPP on site-level and global scales. We compare the modelled interannual variability in the land carbon sink to estimates from atmospheric inversions, and identify further processes important in ecosystem recovery dynamics. The improved representation of natural disturbance/recovery cycles also improves simulations of recovery following anthropogenic disturbances.

ID: 235

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Carbon dynamics during induced lethal drought and carbon starvation

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Changes in precipitation patterns and more frequently occurring heat spells seem to be responsible for tree and forest mortality observed all over the globe. During drought, trees control water consumption by down-regulation stomatal conductance but this also narrows the pathway for diffusion of CO₂ into leaves and hence reduces carbon assimilation. During longer droughts, the carbon balance becomes negative and trees have to rely on stored carbon (non-structural carbohydrates, NSC). At the same time, drought potentially decreases phloem functioning by causing declines in plant water potential and this may interfere with carbon storage remobilization and use. Hence, drought not only influences carbon acquisition but also post-photosynthesis carbon storage dynamics. We are currently investigating carbon dynamics in trees subjected to drought in a field experiment and to drought and carbon starvation (partial CO₂ withdrawal from atmosphere) in a greenhouse experiment. Both drought and CO₂ withdrawal provoke a negative net carbon balance but the latter allows maintaining plant water potentials at adequate levels for carbon translocation. This approach will allow sorting out drought effects on carbon acquisition, remobilization and use.

Droughted trees died with NSC pools in needles and branches still charged while starch and sucrose in roots were strongly depleted. Moreover, we observed higher glucose and fructose concentrations in needles of droughted trees than in control trees. This discrepancy (enriched above-ground vs. depleted belowground carbon pools) indicates an interruption of carbon translocation across tree compartments during drought. Decreased phloem functioning seemingly prevented the transport of surplus carbon from needles to starving roots. This interpretation was confirmed by $\delta^{13}\text{C}$ measurements of the mobile carbon pool. A clear drought signal (higher $\delta^{13}\text{C}$) was observed in needles and branches but not in roots. Trees in the carbon starvation treatment survived longer when they were watered. Their NSC pools were almost completely depleted when death occurred while those of droughted trees were not. This observation underscores the importance of translocation for both carbon dynamics and tree survival during drought.

ID: 188

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Summer drought alters carbon allocation to roots and root respiration in mountain grassland

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In a future climate, extreme weather events such as summer droughts are considered to occur more frequently, with likely impacts on the carbon (C) balance of terrestrial ecosystems. Observational evidence suggests that drought affects ecosystem C source and sink activities to a different degree. However, little is known on the coupling between these two major components of the C cycle. Belowground carbon allocation is one of the most important processes in the terrestrial C cycle, linking the largest C fluxes, photosynthesis and soil respiration. Its dynamics and response to extreme weather events are not yet well understood.

We analysed drought effects on allocation of recently photoassimilated C to belowground plant organs on a mountain meadow (1820 m) in the Austrian Central Alps. We set up a rain exclusion experiment for eight weeks in the summer of 2010. After four weeks of treatment, when the soil water content in drought plots had decreased to values close to the permanent wilting point, we carried out a ¹³C pulse labelling on three control and three drought plots. During the subsequent two weeks fine roots were repeatedly sampled and root respiration rates, carbohydrate (starch, sucrose, glucose) concentrations and the C isotope composition of root respired CO₂ and of carbohydrate pools were measured.

Root respiration decreased during drought by up to 44 %, whereas sugar concentrations were doubled, suggesting strong osmotic adjustments. In contrast, starch concentrations remained largely unaffected by drought. The isotope ratio of root respired CO₂ after pulse labelling indicated that the amount of ¹³C in substrates of root respiration declined by ca. 40 % under drought conditions, closely reflecting the reduced photosynthetic C uptake after four weeks of reduced soil moisture. The dynamics of root respired ¹³C revealed that under drought conditions the mean residence time of ¹³C incorporated in respiratory substrates was doubled from 6 to 12 days, whereas the amount of ¹³C allocated to root sugars and starch increased. Notably, the allocation of tracer to root carbohydrates and respiration was distinctly delayed under drought.

These results suggest that in mountain grassland summer drought can alter the fate of newly assimilated C to and within roots, increasing its partitioning to osmotically active carbohydrates and storage pools, while decreasing its allocation to root respiration.

ID: 120

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Changes in microbial functionality and community structure due to drought in burned soils of a Mediterranean scrubland

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Climate change is projected to increase frequency and magnitude of drought in the Mediterranean region, which can affect also to fire frequency and extent. These factors can alter post-fire regeneration patterns, including changes in biogeochemical processes. Here, we used microbial and enzyme activities as indicator of soil functionality and ester linked fatty acid analysis to assess microbial community structural diversity in relation to fire and drought. In April 2009, an automated drought-manipulative experiment was setup on a Cistus-Erica scrubland in which annual precipitation was controlled by changing spring-summer rainfall, resulting in: environmental control (EC+), long-term historical average precipitation (HC+), moderate drought (MD+; 25% reduction of HC+ and 5 months without rain) and severe drought (SD+; 45% reduction of HC+ and 7 months without rain). In September 2009, the plots were burned to evaluate the joint effects of drought and fire. A set of unburned plots was kept without rainfall manipulation (EC-) and used as a burning control. Soil samples were collected after fire in order to evaluate seasonal pattern of the assayed variables. Our results show that there are clear differences in microbial community structure between burned and unburned soils which also resulted in differential nutrient pools and turn-over rates. Burned soils under drought conditions showed a slower nutrient turn-over (mineralization rates) which was also affected by seasonality. On the other hand no changes were observed in microbial community structure due to drought at short time. However, one year later, the implemented drought treatments resulted in a differential microbial structure.

ID: 140

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Resistance and resilience of a mesic grassland to extreme heat waves and drought

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Climate extremes, such as heat waves and drought, are expected to increase in their frequency and intensity over the next century. We examined the resistance and resilience of a mesic tallgrass prairie ecosystem to two years of experimentally imposed climate extremes (heat and drought), followed by a recovery year. During 2010 and 2011, we reduced precipitation inputs to 33% of ambient rainfall (drought) resulting in a 50% reduction in soil moisture compared to a well-watered treatment (ambient rainfall plus supplemental irrigation). Under these contrasting precipitation regimes we imposed a two-week mid-summer heat wave (four temperature levels ranging from 0 to +11 degrees C above ambient). In 2012, all plots were provided ambient rainfall plus supplemental irrigation to insure that long-term average precipitation inputs were received. This design allowed us to examine the individual and combined effects of heat and drought on ecosystem structure (diversity) and function (aboveground net primary production, ANPP), evaluate the resistance and resilience to the climate extremes. While there were no direct or combined effects of the imposed heat waves, drought had significant impacts at the ecosystem and community levels, suggesting that water was the most important climate variable driving responses in this grassland. The extreme drought imposed in this experiment reduced total ANPP during the event by 60%, but full recovery in ANPP was measured in the year following drought. This recovery from drought occurred despite a major shift in community structure, which we attribute to different drought sensitivities and demographic responses among the dominant species.

ID: 217

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Anticipated climate change will significantly affect biogeochemical patterns of an acidified forested catchment

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The investigated Lysina catchment in the Czech Republic was affected by large anthropogenic acidification in the 20th century and it is undergoing chemical recovery for the last 20 years. Runoff for the year 2070 and annual streamwater chemistry for the period 1860–2070 were simulated by the models Brook90 and MAGIC, respectively. Based on annual data, runoff would change from 450 mm yr⁻¹ (1990–2006) to 320–402 mm yr⁻¹ for the year 2070 according to Brook90 simulations with bias-corrected regional climate model (RCAO) data with A2 emission scenario. Future streamwater SO₄ concentration would maintain at the current level of approximately 90 µeq L⁻¹ (2008–2009) in case of minimum or no change in runoff, or would increase by 10–30% as a result of projected runoff decrease. The runoff change would increase the concentration of base cations (Ca+Mg+Na+K) a similar magnitude compared to measured 160 µeq L⁻¹ (2008–2009). According to both scenarios, the effect of climate change on pH would be small and would lead to slight re-acidification of streamwater compared to measured 4.2 (2008–2009). The climate change influence to annual streamwater chemistry would be small compared to the influence of declining atmospheric acid deposition, but significant influence was modeled for summer/autumn months. Due to declining summer/autumn runoff, base cations concentration will increase significantly and stream pH will rise over 6.0. In winter where predicted runoff will be similar to present, base cations will be diluted and pH will stay acidic similarly to present conditions. Thus anticipated climate change will intensify seasonality of biogeochemical patterns.

ID: 218

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Extreme Drought-induced Trend Changes in MODIS EVI Time Series

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Extreme climatic events triggered by the global climate change increase significantly and, accordingly, the researches of vegetation's response and adaption are crucial on the evaluation of environmental risk. Yunnan province, locating in southwest China, experienced an extreme drought event (from autumn of 2009 to spring of 2010), with the lowest percentage rainfall anomaly and the longest non-rain days in the past 50 years. This study aimed to explore the characteristics and differences in the response to drought of four land cover types in Yunnan province, including forest, grassland, shrub, and cropland during the period 2001–2011. We used remote sensing data, MODIS-derived EVI (Enhanced Vegetation Index) to study the vegetation responses to this extreme drought event. The EVI time series were decomposed into trend, seasonal and remainder components using BFAST (Breaks For Additive Seasonal and Trend) procedure which accounts for seasonality and enables the detection of trend changes within the time series. The preliminary results showed that: (1) BFAST proved capable of detecting drought induced trend changes in EVI time series. (2) Changes in the trend component over time consist of gradual and abrupt change. Different spatial patterns were found for abrupt and gradual changes. Cropland due to their sensibility to severe drought exhibited an abrupt change while the forest seemed least affected by the extreme drought.

ID: 231

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Oral Presentation / Talk

Strong decadal trend in carbon uptake in a Beech forest: Response to extreme climatic events?

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The Danish beech forest near Sorø, Zealand, is among the few sites that show a significant decadal trend of increasing net CO₂ uptake. Model analyses showed that the trend was caused by physiological changes rather than by long-term climatic changes. We investigate the likelihood that the forest was in a state of recovery after an extreme climatic event right before the CO₂ flux measurements started.

Tree ring data showed significant growth reductions in 1996, the first year of the long-term flux observations. Climate data revealed that the winter 1995/1996 was cold and dry. We speculate that a longer snow free, severe frost period might have damaged the roots of the beech trees, which are known to be frost sensitive. Our hypotheses are: The dieback of some parts of the root system reduces both the tree internal carbohydrate and the N pools. Additionally the N uptake is reduced during the years of root damage. The consequently reduced N status limits the formation of enzymes in the photosynthetic apparatus of the leaves in the following years. The observed trend in photosynthetic capacity is a sign of recovery from this chain of events.

Apart from CO₂ fluxes and, thus, canopy photosynthetic capacities neither the direct nor the indirect hypothesised responses were measured in the first years of flux measurements at the site. We therefore developed an inverse approach to derive the dynamic parameters of the N-status from the multiannual course of CO₂ uptake rates. The N-status is then related to the tree internal N cycling and the necessary reduction in N uptake after the speculated frost damage event is estimated. From this we evaluate whether lagged responses to an extreme climatic event are the likely causes for the observed long-term trend in canopy photosynthesis.

ID: 192

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

EFFECTS OF RAIN PULSES ON CH₄ AND N₂O FLUXES OF A MANAGED GRASSLAND

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Future climate scenarios suggest an increase of extreme weather events over Central Europe. While the total amount of rainfall is projected to be rather constant, patterns of rainfall as well as the magnitude of rainfall events is most likely to change. This in turn can entail longer periods of dry weather, e.g. spring droughts. Such anticipated changes in seasonal precipitation will directly affect seasonal patterns of soil water conditions and therefore also related biological processes such as photosynthesis, respiration, methanogenesis, nutrient cycling and associated greenhouse gas fluxes.

However, the sensitivity of CO₂ fluxes in grassland ecosystems to changes in precipitation is still uncertain, not only in semi-arid and arid climates. Taking CH₄ and N₂O fluxes, expressed in CO₂-equivalents, into account further increases the uncertainty of a comprehensive greenhouse gas budget in grasslands. Thus, we investigated the importance of early morning rain pulses on magnitudes of soil CH₄ and N₂O fluxes in an intensively managed grassland in Switzerland, using static soil chambers and manipulating water inputs (control, 15 mm or 30 mm per week for three consecutive weeks, 15 mm or 30 mm per week every two weeks).

We found that soil CH₄ fluxes were much more susceptible to changes in soil water conditions than soil N₂O fluxes. Mean CH₄ uptake of upland soils decreased significantly with higher volumetric soil water contents. Consequently, we actually measured a release of CH₄ for the treatment with the highest water addition (up to 0.74 nmol m⁻² s⁻¹). On the other hand, mean soil N₂O emissions showed no clear trend in relation to water additions. The soil stayed a clear N₂O source, although with highly variable soil N₂O fluxes, probably due to small scale variations in soil properties. Thus, future more extreme rainfall events have the potential to completely alter the CH₄ sink/source relationships of upland soils.

ID: 133

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Oral Presentation / Talk

Ecosystem response to multiple extreme weather events and recovery after a subsequent terminal drought event

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Frequency and magnitude of extreme weather events are expected to increase. However, plant response to recurrent extreme events is rarely examined. We applied annually recurring extreme drought and heavy rainfall events for five consecutive years to constructed grassland communities in central Europe and measured 32 response parameters related to ecosystem functions such as primary production, nutrient cycling, carbon fixation, water regulation and community stability. Subsequently, we carried out a supposedly lethal drought event (duration: 104 days) to test for thresholds of ecosystem functions, memory effects concerning pre-exposure, and recovery.

Surprisingly, in the face of severe drought, above- and below-ground primary production remained stable across all years of the drought manipulation. Yet, drought significantly reduced below-ground biotic activity, affected plant ecophysiology and induced complementary plant–plant interactions. Drought further triggered shifts in flower phenology and primary consumer abundance. A drought manipulation for 104 days was lethal to aboveground biomass of almost all plants and effectively stopped soil biotic activity. We detected hints for a drought-memory in some species with individuals pre-exposed to drought being more resistant. Recovery after re-irrigation, however, was quick and strong. Re-sprouting occurred in most grassland species.

The results imply that primary productivity of temperate grasslands is surprisingly stable and the species are very resilient in response to recurrent extreme drought while several other response parameters show strong reactions. We propose that biotic interactions (diversity) and pre-exposure play important roles in stabilizing ecosystems.

ID: 228

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Decrease of carbon sequestration in China's terrestrial ecosystems caused by severe droughts in 2009

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In 2009, terrestrial ecosystems in China were hit by a series of droughts in different seasons. However, the degree at which carbon sequestration of terrestrial ecosystems was affected in China is not clear yet. In this study, the remote sensing driven process-based Boreal Ecosystem Productivity Simulator (BEPS) model was used to estimate decreases of net primary productivity (NPP) and net ecosystem productivity (NEP) in China's terrestrial ecosystems caused by the abnormal droughts in 2009. The BEPS model was first validated using NEP measured at typical flux sites and forest NPP measured at different regions. Then it was driven with leaf area index (LAI) inverted from the MODIS reflectance and land cover products and meteorological data interpolated from observations at 753 national basic meteorological stations to simulate NPP and NEP at daily time steps and a spatial resolution of 500 m from January 1, 2000 to December 31, 2010. Validations show that BEPS is able to capture the seasonal variations of tower-based NEP and the spatial variability of forest NPP in different regions of China. In 2009, annual NPP and NEP were lower than the averages over the period from 2000 to 2010 in most regions of China, especially in areas of southern China. The decrease of annual NPP in 2009 over southeast Tibet and southeast coastal areas was even more than $100 \text{ g C m}^{-2} \text{ yr}^{-1}$. Annual NEP in most areas of Yunan, Guangxi, Guizhou, and Hunan provinces decreased by more than $100 \text{ g C m}^{-2} \text{ yr}^{-1}$ relative to the means during the period from 2000 to 2010.

ID: 156

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Influence of summer drought on the structure and function of microbial community in alpine grassland ecosystems

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The recent IPCC report predicts an increase in the number of extreme weather events within the next decades with severe droughts in summer and heavy rainfall in winter. However, so far the influence of drought events on the microbial community in soils is largely unknown.

It was hypothesized that drought influences the structure and function of microbial communities to a large extent. To verify this hypothesis rhizosphere soil samples from two alpine grassland sites, which differed in their land use intensity were studied. To simulate drought, parts of the areas were covered with rain-out shelters which prohibited rainfall over a period of 9 weeks during summer. After the removal of the rain-out shelters the consequences of rewetting were studied for further 13 weeks. Samples of drought and rewetting as well as controls were taken at 8 different time points during the experiment. Soil water content, nitrate and ammonium contents were measured for all samples. Furthermore the abundances of different microbial communities involved in the microbial nitrogen cycle were determined based on the abundance of selected functional genes to investigate the impact of climate change on microbes involved in the nitrogen cycle. To analyze structural shifts in bacterial communities barcoded pyrosequencing of 16S rRNA gene amplicon libraries was carried out.

It could be shown that both sites differed in all measured parameters independent from the drought setting, with lower gene copy numbers and nutrient contents at the less managed site. An additional influence of the manipulation was mainly visible at the end of the drought period and during the first days of the rewetting period. Here also differences in the response pattern between the two sites were visible.

ID: 121

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Vulnerability of ecosystem productivity over Europe under past and future climate extremes

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Frequency and intensity of climate extremes, e.g. drought, heat and cold waves, have the potential to get stronger in future, and that would evoke the importance to know how terrestrial ecosystems will respond to those climate extremes, and how terrestrial ecosystems will change their feedbacks to climate system.

ORCHIDEE is used to estimate the potential influence by climate extremes under retrospective and future climate projections, composed of ERA40, WATCH, and REMO climate forcings (supplied by Dr. C. Beer, MPI) from 1901 to 2100. Vulnerability is here defined as an expectation of ecosystem productivity, e.g. E(GPP), E(NPP), and E(NEP), under extreme conditions, e.g. 5% percentile and 95% percentile of precipitation and temperature. We will show the results on those vulnerability estimations according to Dr. O. Marcel (CEH)'s proposal and our own definition. Estimation of vulnerability could be extended to other model's simulations contributed by other research institutes.

ID: 189

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Assessing the response of land-atmosphere CO₂ exchange to anomalous variability in climate through merging models with data

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Interannual variability in biosphere-atmosphere exchange of CO₂ is driven by a diverse range of biotic and abiotic factors. Replicating this variability thus represents the 'acid test' for terrestrial biosphere models. Although such models are commonly used to project responses to both normal and extreme variability in climate, they are rarely tested explicitly against inter-annual variability in observations.

Here, we present results using standardized data from the North American Carbon Program to assess the performance of 16 terrestrial biosphere models and 3 remote sensing products against long-term measurements of biosphere-atmosphere CO₂ exchange made with eddy-covariance flux towers at 11 forested sites in North America. Instead of focusing on model-data agreement we take a systematic, variability-oriented approach and show that although the models tend to reproduce the mean magnitude of the observed annual flux variability, they fail to reproduce the timing.

Observed interannual variability is found to commonly be on the order of magnitude of the mean fluxes. None of the models consistently reproduce observed interannual variability within measurement uncertainty. Underrepresentation of variability in spring phenology, soil thaw and snowpack melting, and difficulties in reproducing the lagged response to extreme climatic events are identified as systematic errors, common to all models included in this study. Further analysis using artificial neural networks and model-data fusion techniques reveals a complex tapestry of site and model specific sensitivity to extreme events.

ID: 210

Session 3: Feedback mechanisms from the biosphere to the climate system

Type of Contribution: Oral Presentation / Talk

Interannual variability in atmospheric CO₂ from generalized surface fluxes

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Interannual variability in atmospheric CO₂ can provide insight into the responses of terrestrial ecosystems to climatic variations. We investigated causes of interannual variability in atmospheric CO₂ using generalized surface fluxes as boundary conditions in a chemical transport model. We developed a set of surface fluxes by assuming a variety of functional forms for the imprint of temperature and precipitation anomalies on net primary production at monthly timescales. We also developed biomass burning emissions estimates by scaling satellite fire counts and burned area. These fluxes were prescribed in GEOS-Chem, which was run from 1997 to 2010 to simulate atmospheric CO₂. The simulation output was sampled at NOAA ESRL flask sampling sites, and both simulation and observations were aggregated in north-south zones. We examined correlations between the simulations and observations for each of these zones to determine the extent to which simplified fluxes captured the phasing and magnitude of observed variations. We also ran simulations to determine the influence of interannual variability in transport patterns on observed variability. Our results show that temperature, precipitation, and biomass burning covary in their influence on zonal anomalies in atmospheric CO₂ on interannual timescales. The relative importance of these three factors varies regionally, and these patterns of interannual variability may provide insight into future variability in terrestrial carbon fluxes under global climate change.

ID: 146

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Impact of climate change on greenhouse gas fluxes of (pre-) alpine grassland soils

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Due to cool and moist climatic conditions alpine grassland soils of moderate elevation (app. 1000m) are rich in soil organic carbon and associated nitrogen. In the framework of an in-situ climate change experiment we test the hypothesis that soil organic carbon and nitrogen are either volatilized (GHG emissions) or leached with seepage water due to increase in temperature. Field investigations are carried out in the (Pre-) Alpine TERENO Observatory covering several research sites in South-Bavaria, Germany. IMK-IFU has installed 36 lysimeters with undisturbed intact grassland soil cores (diameter 1m, depth 1.4m) and is operating them at three sites differing in altitude (Graswang 850m, Rottenbuch 750m, Fendt 600m). Lysimeters were partly translocated from higher elevation to sites at lower elevation and other soil cores still staying at the sites as controls. Along the altitudinal gradient mean annual temperature differences are $\delta 1.5^{\circ}\text{C}$ Graswang-Rottenbuch and $\delta 2.5^{\circ}\text{C}$ Graswang-Fendt and slightly lower mean annual rainfall with decreasing altitude. We will present the first full year datasets of soil CO_2 , N_2O and CH_4 emissions measured by manual as well as automatic chambers. Comparing emissions at the controls sites, and comparing the translocated soil cores, showed that the most significant differences were found for CO_2 and CH_4 fluxes and less for N_2O fluxes. Higher temperatures generally stimulated CO_2 and N_2O emissions and lead to increased uptake rates of atmospheric CH_4 . Different dynamics of snow pack formation at the three sites investigated, caused pronounced differences in frost-thaw driven N_2O emissions which significantly contributed to the annual budget.

ID: 197

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Interactive effects of UV radiation and drought on physiology, morphology and elemental stoichiometry in selected species of the mountain grassland

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The manipulation experiment focused on the evaluation of combined effects of UV radiation and drought was conducted in 2011-2012 on the grassland ecosystem at the experimental site Bílý Kříž (Czech Republic). The main objective of the experiment was to investigate the interactive effects of UV exclusion and drought on the changes in accumulation of UV-screening compounds (flavonols), photosynthetic parameters, C:N:P:Mg:Ca elemental stoichiometry, and morphology in selected herbs and grass species. The experimental plot was manipulated by the lamellar roofs enabling passing or excluding incident precipitation and UV radiation. In situ measurements of UV-screening compounds and physiological parameters were done at regular intervals (approximately 21 days) after drought induction.

Generally, UV and drought treatments had a similar effect on the accumulation of flavonols. UV exclusion resulted in a slight reduction of UV-shielding compounds under the conditions of ambient precipitation. Likewise, drought treatment caused a gradual increase in the accumulation of flavonols compare to the ambient conditions in all species studied. Thus, the drought treatment reduced the differences in flavonol contents between the UV treatments.

Under the UV exclusion, drought slightly decreased light saturated CO₂ assimilation rate (A_{max}). The presence of UV radiation caused the restoration of A_{max} to the values typical for plants grown at ambient precipitation. Among the morphological parameters, shoot length was mostly influenced by the UV and drought treatments.

Drought treatment caused slight changes in C:N:P:K:Mg:Ca stoichiometry, particularly in N:K ratio.

ID: 174

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Invited Lecture

Ecosystem responses to extreme changes in precipitation: What have we learned from experiments in grasslands?

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Precipitation patterns and amounts are critical environmental drivers for most ecosystems and rainfall patterns are forecast to become more variable, with increased frequency of large rainfall events and extended inter-rainfall droughts as well as more extreme. We have been assessing the ecosystem consequences of these climate changes, using field-scale rainfall manipulation experiments to alter the timing of growing season rainfall events and to impose severe drought in intact grassland plots. Results indicate that there can be significant reductions in aboveground net primary productivity (ANPP) with altered rainfall patterns that included fewer but larger rain events and extended periods between rain events in more mesic grasslands. But this response has been variable among years. Moreover, in more arid grasslands experimental manipulations of precipitation regime resulted in responses in ANPP opposite those in mesic grassland. The size of individual rain events had a disproportionate effect on ANPP in these drier grasslands, with the positive effects of a few large events potentially offsetting the negative effects of reductions in precipitation amount. Results from extreme drought experiments in semi-arid grasslands were consistent with the conclusion that grassland responses to alterations in precipitation inputs may vary dramatically depending on the long-term hydrologic regime.

ID: 135

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Snow alters feedbacks from the biosphere to the climate system

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Climate warming can contrastingly affect winter soil conditions in northern ecosystems: Reduced snow cover leads to stronger soil frost in the still-cold boreal ecosystems, while in temperate ecosystems the warming eventually causes the complete loss of soil frost. Based on four field experiments, we explore feedbacks between winter warming and carbon dynamics in boreal and temperate ecosystems.

(1) Decomposition rates were reduced by 50% due to increased soil frost in consequence of snow removal in a boreal forest. (2) Continuous winter warming in a temperate grassland did not affect decomposition rates, due to decreased snow cover which led to no warming effect on soil temperature. (3) Stronger soil warming that avoided any soil frost, however, increased soil respiration during the warming phase by 291%. Plants increased nitrogen uptake during winter and biomass production (+31.5%) in the growing season. (4) Increased variability in winter temperature (warming pulses), however, decreased plant productivity despite increased N availability, and reduced litter decomposition in temperate grassland communities.

These findings emphasize the importance of snow for carbon dynamics. A reduction of snow cover leading to more variable soil temperatures can counteract increased carbon loss and positive feedback on global warming in boreal ecosystems. The same effect may occur transiently in the temperate zone, yet only until the cooling capacity of missing snow cover is exceeded. Plant response appears crucial with regard to nutrient leaching and carbon sequestration, as enhanced primary productivity may provide additional organic matter to compensate for increased decomposition.

ID: 177

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Impact of extreme weather events on the carbon budget of European croplands

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Extreme weather events like drought, heat waves or storms may have a strong impact on crop growth and can strongly affect the carbon cycle. Some of the effects can be compensated by adaptive management (e.g. drought effects by irrigation). In this study NPP and NEE of wheat are simulated for all of Europe to examine the impact of extreme weather events against a background of increasing atmospheric carbon dioxide concentration and climate change. Spatial data of the CarboExtreme project are used for soil, climate and land use and management is kept constant over time, based on management data from the NitroEurope project. A comparison of the results of the period 2070-2099 to 1970-1999 shows an increase of annual NPP over almost all of Europe. The NEE values react as a sink for most areas, and will be a stronger sink in the second period, apart from some areas in Spain. In 2003 several areas in Europe change to be a carbon source resulting from that severe Western European drought that year. In a comparison of 2003 with the period 1970-1999, NPP shows decreased values in Central Europe that can also be explained by the drought period 2003, while wide areas in East show an increase of NPP for 2003. The results show the impact of the drought 2003 on the primary production and the impact of the carbon sink capacity of cropland, which decreases during drought periods.

ID: 114

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Variability of atmospheric CO₂ over Indian region using satellite observations and model simulations: Implications for the sources and sinks

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Carbon dioxide (CO₂) is the most important anthropogenic greenhouse gas in the atmosphere and there is a serious concern that its continued increase would have an adverse climate effect [see, e.g., Intergovernmental Panel on Climate Change, 2007]. Variability of CO₂ is the result of superimposed both natural and anthropogenic mechanisms operating at different spatial and temporal time scales. Interannual variability is mainly due to natural variation in sink and source efficiency of terrestrial and oceanic systems induced by climate changes. The CO₂ behaviour exhibits also a short term variability that reflects the influence of the interplay between local or regional source and sink distribution and air-mass transport. The TransCom results showed a wide range of estimates with large error bars and highlighted the need for a better network of CO₂ stations to reduce this uncertainty, which is smaller in North America and Europe, and rather large over Tropical Asia due to poor coverage. Loss of the only Indian Station (flask data at Cape Rama, Goa), which has been discontinued since 2002, has further widened the data gap. Most of the models participated in the TransCom programme [Gurney et al., 2002] showed the large uncertainties over the Indian region due to poor coverage of data. The reliable predictions of the future atmospheric CO₂ concentrations and associated global climate change require an adequate understanding of the CO₂ sources and sinks. The sparseness of the existing surface networks limits the current knowledge about the global distribution of the CO₂ surface fluxes. The retrieval of CO₂ vertical columns from satellite observations is predicted to improve this situation. Such an application requires very accuracy and precision. The present work will mainly analyse the variability of CO₂ using the satellite observations and model simulations to study the estimation of sources and sinks.

Gurney, K. R., Law, R. M., Denning, A. S., Rayner, P. J., Baker, D., Bousquet, P., Bruhwiler, L., Chen, Y.-H., Ciais, P., Fan, S., Fung, I. Y., Gloor, M., Heimann, M., Higuchi, K., John, J., Maki, T., Maksyutov, S., Masarie, K., Peylin, P., Prather, M., Pak, B. C., Randerson, J., Sarmiento, J., Taguchi, S., Takahashi, T., and Yuen, C.-W. (2002) Towards robust regional estimates of CO₂ sources and sinks using atmospheric transport models, *Nature*, 415, 626–629.

Intergovernmental Panel on Climate Change (2007), *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, edited by S. Solomon et al., Cambridge Univ. Press, Cambridge, U. K.

ID: 159

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Resistance and resilience of soil respiration to recurring summer drought in temperate mountain grassland

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Mountain grasslands are highly sensitive to climatic changes and soil respiration (Rs) is their largest source for CO₂ emissions. As a contribution to the EU-project Carbo-Extreme and a national (FWF) project we studied how experimental summer drought and subsequent rewetting affects soil respiration over five subsequent years. The study site was a temperate mountain meadow at 1820m in the Austrian Central Alps. Drought was simulated with rain-out-shelters keeping off precipitation over a period of ca. 2 months of each year, which reduced the soil water content in the main rooting horizon to less than 20%vol (i.e. 20-30% relative extractable water). Rs measurements were performed with automated chambers and were complemented by episodic manual measurements on shallow and deep collars. Rs and its temperature sensitivity decreased at a soil moisture threshold of 20 – 30%vol, with the threshold increasing to higher values from the first to the last year of drought. Soil CO₂ efflux was strongly stimulated after rainfall following drought, where Rs exceeded the flux rates of the control plots. Post-rewetting Rs remained enhanced for weeks in the first three years of the experiment. In the fourth and fifth year rewetting caused only a short pulse of soil CO₂ emissions, after which Rs decreased below values in control plots for weeks. We conclude that recurring summer drought may alter the resistance and resilience of soil respiration in temperate grassland, with implications for its annual carbon balance.

ID: 187

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

2011 severe spring drought in France : vegetation and land surface model response

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The spring of the year 2011 has been exceptionally dry in Western Europe. Over France, May 2011 has been one of the driest over the last 50 years. This event had a marked impact on vegetation development leading to very low value of the Leaf Area Index (LAI) during the growing season . In contrast, July 2011 has been in general wet and cold allowing a new vegetation development. This extreme event, followed by higher than normal rainfall is an excellent case-study to evaluate the capacity of a land surface model to simulate the drought impact on vegetation, and vegetation recovery after a drought. In this study, we used the SURFEX land surface model, in its ISBA-CC (CC stands for Carbon Cycle) configuration. The ISBA-CC version simulates the vegetation carbon cycle, interactive LAI and the carbon accumulation in wood and in the soil organic matter. We performed 20-years simulations of SURFEX at high resolution (8 km) with atmospheric forcing from the SAFRAN dataset, an operational product over France. Following previous work that have confirmed a good simulation of the LAI inter-annual variability, this study investigates the ability of the model of reproducing the observed anomalies of LAI in 2011, in terms of timing and spatial patterns. We compare the simulated LAI with long time series (10 yr) of LAI derived from Earth Observation product derived GEOLAND2 BIOPAR project. We quantify the anomalies of energy, water and carbon fluxes. We investigate the robustness of these results and the impact of modifying several important sub-modules of the model: soil texture, photosynthesis, and rainfall interception.

ID: 111

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

The effects of UV radiation, litter chemistry, and drought on desert litter decomposition

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Recent studies suggest that litter decomposition in dryland ecosystems can be largely driven by abiotic factors such as UV radiation. The importance of photodegradation in litter decomposition appears to decline with precipitation, suggesting that the relative importance of photodegradation will increase given current projections of future increases in drought severity in the southwestern US. Several previous studies suggest that UV-B radiation is the most effective waveband in breaking chemical bonds forming organic material and that the complex nature of lignin makes it particularly susceptible to photodegradation. In this study, we tested the effects of pre-exposure UV radiation, litter chemistry (lignin and cellulose content), and drought on the rate of litter decomposition in a semi-arid ecosystem. To understand the effects of UV radiation on litter decomposition, we pre-exposed litter to three radiation treatments: control (no radiation), UV-A+visible, UV-A+UV-B+visible. Litter was exposed to the equivalent of three months of solar radiation in southern New Mexico. There were three litter types: basswood sheets (high lignin content), pure cellulose filter paper, and mesquite (*Prosopis glandulosa*) leaflets. Litter was placed in mesh litterbags that were buried within a large-scale precipitation manipulation experiment at the Sevilleta Long-Term Ecological Research site: control (ambient precipitation), elevated precipitation (x2 ambient precipitation), and drought (x0.5 ambient precipitation). We collected a subset of bags at 0, 1, 3, and 6 months and measured mass remaining and carbon (C) and nitrogen (N) content. After 6 months, mass remaining of filter paper and basswood sheets did not differ from the initial mass, but mesquite mass remaining declined over 30%. The pre-exposure UV effects had minimal influence on mass remaining after 6 months; however, precipitation had a strong positive influence on mass loss, especially in mesquite ($P < 0.001$). Nitrogen content was close to undetectable in high lignin proxy basswood sheet and pure cellulose filter paper. In mesquite, initial N content was approximately 2.5% in mesquite but declined below 1.8% after 6 months. On the other hand, initial C content was similar across the three materials (42-47%) and decreased to 30% in mesquite. Our results show that precipitation and litter N content may be more important than UV exposure on short-term litter decomposition in drylands. Our results suggest that limiting factors such as moisture availability and N content may be more important than UV radiation exposure in the early stage of dryland litter decomposition.

ID: 164

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Evaluation of ecosystem services in a future environment - a landscape scale study in an Alpine region

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Agricultural ecosystems are highly important to human well-being. In the light of global change, significant implications for related ecosystem services (ES) are expected. For our study site in the Stubai Valley in the Austrian Alps, we examined the relationship between agricultural activities and multiple ES in mountain regions from past to future. A set of ES considered of importance by experts and stakeholders were mapped for historical and future land-use/cover (LUC). Future LUC scenarios were based on stakeholder workshops, where LUC was mapped based on socio-economic- and climate scenarios. Whereas land-use intensity was reduced – especially on alpine meadows and pastures - in the past, future scenarios predict different developments. Although for certain socio-economic developments, farming will become more important and any suitable area should be managed, drought periods would excite an abandonment of farmland. Our results reveal that provisioning, regulating, and cultural services are linked to agricultural activities and future climate change. Furthermore, we found strong dependencies to topography for provisioning and regulating services. Optimization of forage provision leads to a decrease of regulating and cultural services. Abandonment and subsequent natural reforestation are valuable for regulating services but drop the aesthetic value. Trade-offs are strongly linked to land-use intensity and occur between all types of ES. We conclude that management of agricultural ecosystems is a suitable tool to ensure multiple ecosystem service delivery. Ecosystem services in mountain regions are closely linked to topographic and climatic conditions and a flexible system for financial support is needed to improve the farmers' options for reacting to climatic variations.

ID: 194

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

DOES C-USE CHANGE WITH DROUGHT IN AN EVERGREEN MEDITERRANEAN OAK COPPICE ?

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Partitioning products of photosynthesis toward biomass compartments is crucial for understanding the role that forests play as carbon sinks. This is particularly true with slow growing evergreen Mediterranean *Quercus ilex* with a ratio aboveground/belowground biomass close to one and drastically affected by water limitations. We analyzed the fate of GPP from a long-term dataset from a flux tower running continuously since 2001 and discrete measurements of litter fall and secondary growth. Leaf litterfall and APAR at early summer peak LAI has been used for derive leaf production. Flowers and acorns have been pooled to yield reproductive effort. An isometric relationship between stem and belowground biomass has been used to estimate perennial belowground growth.

Average values of yearly NEP, GPP and Reco were 281, 1259 and 978 g C m⁻². The corresponding ANPP components were 127.5, 26.4 and 63.8 g C m⁻² for leaves, reproductive effort and stems. Additional measurements of leaf dark respiration and stem respiration both upscaled at ecosystem level helped us to close C budget and derive an error analysis yielding likely values of autotrophic and heterotrophic respirations, NPP and CUE. Our CUE was close to those of other trees growing in Mediterranean-type ecosystems. NEP, GPP and Reco were largely impacted by water limitation. ANPP components were impacted by drought too, with a hierarchy of responses going from the more affected, the stem, to the less affected, the leaves. The acclimation of autotrophic respiration to drought we observed for leaves and stems supported CUE tended to increase slightly under water limitation, even under the very severe drought underwent in 2006.

ID: 190

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Ecosystem responses to the recent drought in Southwest China

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Climate extremes, including severe drought, can profoundly impact ecosystems and human welfare. As the frequency and intensity of drought events are expected to increase in the coming decades, there is a pressing need to advance our understanding of their ecological consequences. However, compared to the numerous studies examining ecosystem responses to changes in climatic means, research on drought is less common and biased towards a few regions (e.g., xeric ecosystems, the Amazon Basin). Southwest China, located in subtropical region with plenty of water, experienced a severe drought during 2009-2010, characterized by a prolonged period of particularly extreme precipitation and temperature anomalies. Given the severity and persistence of the recent drought episode, however, its impacts on terrestrial ecosystems are unclear. In this study, we used a couple of satellite-derived vegetation indices to investigate responses of vegetation growth to the drought event. We further assessed changes in components of carbon cycle and water cycle during the episode, based on remote-sensing observations and outputs from a number of process-based ecosystem models. The impact on crop yields of this region was also evaluated using inventory datasets. The severe drought in Southwest China during 2009-2010 provides a case study of how mesic ecosystems respond to drought stress, with important implications for ecosystem services in this populous and biodiverse region.

ID: 234

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

The transition of an upland spruce forest ecosystem through a catastrophic wind-fall event: measurements and simulation of the carbon balance

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Intact forests, especially in mid-latitudes, are generally large carbon sinks. However, stand-replacing (catastrophic) disturbance events like fires, insect-infestations, or severe wind-storms can shift an ecosystem from a net carbon sink to a source almost instantly, and keep it as such for an extended transition period. The duration of this transition is determined by the time scales involved in the development of competing vegetation types (e.g., trees vs. grass) as well as in the evolution of dead biomass carbon pools, and their contributions to net ecosystem exchange (NEE). However, with few exceptions, these transition processes are still largely unknown. The urgency to study carbon cycling through disturbance-transition periods is underlined by the recognition that extreme events leading to ecosystem disturbance are likely to increase in a warming world. A unique opportunity to study a major wind-fall event was caused by the winter-cyclone Kyrill in January 2007. Extreme winds in Kyrill caused a large wind-throw area (ca. 600 m diameter) in a mature upland spruce forest in the Bavarian Forest National Park (Lackenberg, 1308 m a.s.l., Bavaria, Germany). This wind-throw area is particularly notable, because dead-wood was not salvaged and remains on the ground.

Fluxes of CO₂, water vapor and energy have been measured by Eddy Covariance (EC) since 2009 in the center of the wind-throw area. In addition, we used an ecosystem model (MoBiLE, with dynamic vegetation) to simulate the behavior of the ecosystem through the wind-fall transition and to estimate the time evolution of relative contributions to gross ecosystem productivity (GEP) from trees and grass, as well as the partitioning between autotrophic and heterotrophic respiration. Observations from 2009-2011 were used to test and calibrate the model, and reconstruction of ecosystem and environmental drivers were used to extend simulations to before the wind-fall event.

For 2009 - 2011 EC-based estimates of annual NEE showed that the wind-throw remained a marked carbon source. However, during daytime on sunny and warm summer days, the wind-throw is already seen to act as a net carbon sink only two years after the wind-throw event, indicating the resilience of the ecosystem achieved by the few remaining trees and newly emerging vegetation (grass, sparse young spruce, etc.). Model simulations conformed well with measurements (2009-2011) and showed that the formerly mature forest shifted from carbon sink (NEE \approx -100gCm⁻²yr⁻¹) one year before the storm event to a marked carbon source (NEE \approx +500gCm⁻²yr⁻¹) afterwards. Model simulations indicate a rapid release of carbon from the soil in the first year after Kyrill. This emission was markedly reduced in the second year, but further decrease was slowed in subsequent years. The contribution of spruce to gross ecosystem productivity as well as respiration tends to increase, while the contribution of grass remains rather constant. We will use the model in short-term projections to estimate the time scale needed for the resilience of the forest ecosystem as a carbon sink.

ID: 155

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Role of extreme climate events in the temporal variability of atmospheric exchanges of CO₂, H₂O and energy from forest areas.

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The southwestern forest of « Les Landes de Gascogne » has been hit by two unprecedented storms in 1999 and 2009 and experienced severe soil droughts in 2002, 2005 and 2006 and heatwaves in 2003 and 2005. At two flux tower sites located in a young stand following clearcut and a mature stand respectively, the half-hourly fluxes of CO₂, H₂O vapour and energy as well as vegetation and soil stocks have been monitored for the same period, i.e. for 1997-2008 and 2001-2011.

Using these data and geographic information regarding changes in the regional vegetation cover, forest inventories and river runoff, we analysed the impact of these events on the time series of forest canopy exchanges and its interaction with management. Clearcutting following wind storms reversed the ecosystem from a net sink to a source of C-CO₂ and the carbon loss were still not offset ten years after tree logging. Soil drought impacted also severely mature forests through stomatal closure, ground vegetation yellowing and leaf shedding, zeroing their annual carbon balance. Tree growth was however not affected in the same proportion. Drought affected also dramatically the net carbon and water balances of fallow and young stands regrowing after clearcut. However, in the juvenile regrowing stand, the effects of successive management operations (stump crushing, ploughing, ground vegetation burial) overtook climate effects. In the mature stand, thinning operations had much lesser effects on ecosystem flux. In both stands, the CO₂ gross downward flux created by photosynthesis, GPP, was more sensitive to climate and management than the upward flux linked to the ecosystem respiration, RE.

The Bowen ratio of the clearcut stand was strongly enhanced and evapotranspiration decreased leading to a dramatic increase in water runoff and in the peak flows from the watersheds damaged by the windstorm. A direct projection of these data through a simple model and gridded data at high resolution allowed to estimate the impact of the successive storms and droughts on the regional CO₂, heat and water vapour fluxes at the subregional scale.

This research was co-supported by the Carbo-Extreme European and GHG-Europe projects.

ID: 152

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Stand structure and tree age modulate last century tree growth decline in response to increasing drought frequency in a Mediterranean pine ecosystem

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Primary drivers of tree growth under climate change are poorly understood as they may differ across biomes and forest types. In the Mediterranean basin - one of the most vulnerable regions according to climatic change scenarios - there are experimental and modelling evidence of both positive and negative tree growth responses to warming temperatures. These discrepancies highlight the need of long-term information of direct tree growth measurements as well as historical knowledge of drought events. Moreover factors such stand structure and tree age can be also key drivers of tree growth and need to be considered. In this study we examine last century tree growth trends in an Iberian Mediterranean pine ecosystem (Barrens-like pinelands) through decadal direct measurements of stem volume increments recorded in trees belonging to a variety of forest stands and diameter classes since 1920. Two drought indices were assessed based on the Standardized Precipitation and Evapotranspiration Index (SPEI): (i) drought frequency (DF), as the relative number of years with $SPEI < 0$ on one hand, and (ii) the average SPEI. We also included in the analyses stand structure -estimated as forest stand basal area (m^2/ha)- and tree age -estimated by the number of tree-rings. Results of a Generalized Linear Mixed Model suggest that Drought Frequency is a good predictor of forest growth decline although both tree age and stand structure can modulate such trends, i.e. the negative impacts of increasing drought frequency are disproportionately higher in younger trees under high competition. Thus the bottleneck for forest productivity in the coming decades might be more pronounced in forests at an early developmental stage rather than in mature forests. Thus our results highlight the importance considering demographic processes and tree age in current ecosystem models aiming to predict changes in forest productivity in response to climate change.

ID: 243

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Field studies on the interaction of drought or heat stress and elevated atmospheric CO₂ concentrations on growth and yield of C₄ and C₃ crops

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Recent modeling studies addressing the effect of future climate change on crops revealed that drought stress and heat stress will substantially impair yield stability of crops. Currently it remains open if and to what extent these stresses will be modified in the future by the concurrent increase of atmospheric CO₂ levels (eCO₂). While the physiological basis of interactions between drought stress or heat stress and eCO₂ is largely known at the leaf level, there are hardly any studies testing these interactions in the field. Research activities at our institute comprise large-scale field facilities to test drought stress (rain shelter) and heat stress (infra red heaters) interactions with free air CO₂ enrichment (eCO₂ = FACE). Drought x eCO₂ studies with different sorghum genotypes and maize clearly showed that eCO₂ enhanced water use efficiency and increased growth of these C₄ plants under drought conditions, but not under well watered conditions. Model algorithms for the assessment of heat stress effect on biomass and grain growth of cereals like wheat are currently based exclusively on studies from growth chambers or greenhouses. Heat stress x eCO₂ studies under field conditions have not yet been done. We started heat stress experiments in the field where the stress is applied during specific heat sensitive developmental stages of different wheat genotypes. The presentation will show the experimental layout of the different field studies and selected results from the vegetation periods 2008-2012 including the C₄ crops and preliminary tests of infrared heaters for warming the wheat canopies.

ID: 215

Session 3: Feedback mechanisms from the biosphere to the climate system

Type of Contribution: Poster Presentation

Surface-atmosphere exchange at a disturbed forest site in the Austria Alps

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Forest disturbance regimes can cause long-lasting changes in ecosystem structure and function over large spatial scales, significantly altering both biogeochemical and biogeophysical forest-atmosphere interactions. Research on this topic has grown over the last decade, with a number of research groups demonstrating the significant changes in ecosystem carbon, water and energy dynamics and the potential positive and negative climatic feedbacks associated with stand replacing disturbance events. However, a full understanding of disturbance effects on forest-atmosphere exchange is still limited by a lack of empirical data from certain forest types in both their intact and disturbed states. We therefore began a micrometeorological investigation at a 29ha forest site in the Northern Calcareous Alps of Austria recently disturbed by windthrow and subsequent bark beetle infestations. The issue of forest disturbance is particularly relevant within the context of the Austrian Calcareous Alps, where due to widespread stand instability, windthrow and bark beetle events are currently increasing in both frequency and intensity. Furthermore, with an increase in storm events a likely consequence of climate change, this trend looks set to continue. During the vegetation periods of 2011 and 2012, measurements of both turbulent and radiative surface-atmosphere exchange were conducted to investigate energy partitioning and net ecosystem exchange at our disturbed site. Turbulent fluxes of carbon dioxide, water vapor, and sensible heat were determined using the eddy covariance method, while double pyrrometers and double pyranometers were installed to measure net radiation and short-wave radiation exchange, respectively. The "Climate Extremes and Biogeochemical Cycles in the Terrestrial Biosphere: Impacts and Feedbacks Across Scales" conference thus represents an ideal forum, where our initial flux data could be presented.

ID: 214

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

The contribution of soil respiration to net ecosystem exchange after forest disturbance – a case study from the Austrian Alps

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Disturbance regimes such as windthrow and bark beetle attacks can significantly affect the carbon balance and fluxes of a forest, potentially switching the entire ecosystem from a carbon sink to a distinct carbon source. Such shifts in net ecosystem exchange result from a decrease in gross primary production and an alteration in ecosystem respiration. As soil respiration represents the main component of the latter, a respective alteration is likely controlled by soil carbon efflux.

To reveal the contribution of soil respiration to net ecosystem exchange after forest disturbance we observed these carbon fluxes during the vegetation periods of 2011 and 2012 at a forest site in the Northern Calcareous Alps of Austria, recently disturbed by windthrow and subsequent bark beetle events. Soil respiration was monitored continuously by means of an automatic soil respiration chamber system, while net ecosystem exchange was measured using the eddy covariance method. Furthermore, to address explicitly the effects of the disturbance regime on the soil carbon efflux, soil respiration was measured discontinuously at a high spatial resolution at the windthrown site as well as in an adjacent unaffected forest stand.

Soil respiration was the main contributor to ecosystem respiration at the disturbed site, thus heavily influencing net ecosystem exchange of carbon dioxide, mainly by its heterotrophic respiration component. Temperature standardized soil respiration rates were significantly higher in the unaffected stand, but considering a higher soil temperature and an altered soil moisture regime at the disturbed site, soil respiration was almost of the same magnitude as in the stand.

This study is part of the INTERREG Bayern-Österreich 2007 -2013 project 'SicAlp – Standortssicherung im Kalkalpin' which is funded by the European Regional Development Fund (ERDF) and national funding.

ID: 201

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Oral Presentation / Talk

Frost drought: how timberline conifers survive winter embolism

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Water transport plays a crucial role in plant hydraulics. For growth and survival, sufficient hydraulic efficiency and hydraulic safety (i.e. resistance to the formation of xylem embolism) is required. Plant water transport is based on a metastable process and drought as well as freeze-thaw cycles can induce embolism. Most tree species were found to operate near their hydraulic limits and thus at a high risk of embolism, which blocks water transport and thus the water supply of distal tissues.

We present data of a long-term study (more than ten years) on embolism formation in conifers growing at the timberline. *Picea abies* can suffer from up to 100% loss of conductivity in branch xylem and also show a decrease in needle conductivity during winter. Frost drought as well as the high number of freeze-thaw events were found to be the cause for hydraulic failure, whereby small trees were more affected than large specimens. Only young trees are protected by the snow cover.

Timberline trees were found to survive even excessive embolism by repair of the transport system. Refilling starts already in late winter when the soil and stem base are still frozen. The mechanisms is unknown but probably based on active processes and an uptake of water over the crown surface. A better understanding of embolism formation and repair processes is needed to estimate effects of climate change on future development of timberline forests.

ID: 165

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Winter CO₂ fluxes in a sub-alpine grassland in relation to environmental variables

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We measured carbon dioxide (CO₂) emissions over a period of 3 years at the sub-alpine Swiss CARBOMONT site Rigi Seebodenalp. The results indicate that winter respiration contributes larger than expected to the annual CO₂ budget at this high altitude, rich in belowground organic carbon grassland (7–15% C by mass). Cumulative winter respiration determined over a 6 month period from 15th of October until 15th of April contributed 23.3 ± 2.4 and $6.0 \pm 0.3\%$ to the annual respiration during the years under observation, respectively. The insulation effect of snow and a lowering of the freezing point caused by high concentrations of soil organic solutes prevented the soil from freezing, favoring higher soil temperatures resulting in relatively high respiratory losses. The duration of snow cover and micrometeorological conditions determining the photosynthetic activity of the vegetation during snow-free periods influenced the size and the variability of the winter CO₂ fluxes. Losses of CO₂ from the snow-covered soil were highest in winter 2003/2004. These high losses were partially explained by higher temperatures in the topsoil, caused by higher air temperatures just before snowfall. Thus, losses are not a consequence of higher soil temperatures registered during the summer heat wave 2003. However, water stress during the summer heatwave in 2003 might have caused an increment in dead organic matter in the soil providing additional substrate for microbial respiration in the following winter, suggesting that time lags and hysteresis effects may be more important for understanding winter respiration than concurrent environmental conditions in most ecosystems of comparable type.

ID: 137

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Relationship between North Atlantic Oscillation and burned area in Europe

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Modeling the relationship between climate and disturbances on terrestrial ecosystem is one major challenge in earth system modeling since the carbon and nutrients cycling on land are fundamentally linked to cycles of disturbance and recovery.

In this contribution, an analysis of modeled and observed relationship between burned area and atmospheric circulation in Europe will be presented. The analysis is focused on the relationship between North Atlantic Oscillation (NAO) anomalies and burned area in time and space.

We used an alternative definition of the NAO index based on the empirical orthogonal function analysis of the sea-level-pressure field (SLP): the leading eigenvector (i.e. the first Principal Component, PC1) computed from the time variation of the SLP field. The PC1 was preferred to the commonly used NAO index because is able to capture better the link existing between atmospheric dynamics and surface processes in particular in spring and summer .

Model simulations of burned area were conducted with a modified version of the Community Land Model, specifically optimized for its application in Europe.

Observations of burned area are derived from the Global Fires Emissions Database (GFEDv3).

The first part of the analysis was aimed at characterizing the spatial correlation between NAO and burned area. The grid cell-wise Pearson's correlation coefficients between PC1 and burned area anomalies simulated by CLM and reported in GFED were computed.

The second part of the analysis was aimed at characterizing the correlations between burned area and NAO at different time-scales. The time series of burned area and PC1 were partitioned in sub-signals (long-term signals, annual cycle and high frequency components) by using the singular spectral analysis (SSA) decomposition technique. Then, for each 5° x 5° grid-cell the cross-relationships between decomposed time-series were explored on a range from intra to interannual time scales, and for a variety of lags between PC1 and burned area.

Preliminary results show a significant correlation between burned area and NAO in Iberian Peninsula (positive correlation observed in the western Iberian Peninsula), Mediterranean area (Italy and Balkan regions), and in the Baltic region (positive correlation). The spatial patterns of correlation are similar for CLM and GFED. However, the higher correlation coefficients obtained by using modeled burned area suggests that the effect of NAO is over-weighted by CLM.

In the second analysis, episodes of high local coherence (in time/space) between NAO and burned area are observed, in particular for the Iberian Peninsula and the Baltic region. For Iberian Peninsula, anomalies in burned area observed during heat-waves are correlated with atmospheric circulation anomalies at different time-scale and with different lags (from few-weeks to half-year). In particular, burned area anomalies are correlated with NAO at the temporal scales that caused drought and anomalous temperatures in 2 different heat-waves events (2003, 2005), and that caused higher precipitation during the winter-spring in 1996. These results may open interesting perspectives toward the use of NAO to develop simple empirical models to identify regions potentially subjected to an extreme fire season with lead time of about half-year.

ID: 209

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Impact of organic matter quality on permafrost carbon vulnerability

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About 1600 Gt of organic C (OC) is stored in permafrost-affected soils, representing 21 to 27% of the world's OC. Facilitated permafrost thawing and active layer thickening in pan- and subarctic environments will likely cause the release of formerly stabilized C and positive feedbacks on global warming. We hypothesize that the response of permafrost-affected tundra soils to climate change will strongly depend on the quality of the organic matter (OM) stored in different horizons (e.g., active layer, cryoturbated horizons, permafrost). In this study we focus on the turnover and composition of OM in permafrost-affected, cryoturbated tundra soils of the Siberian subarctic. Soils were sampled along a North-South gradient near the Kolyma river in Eastern Siberia. In each tundra type ('grass', 'tussock grass' and 'moss-shrubby' tundra), we analyzed the contribution of particulate vs. mineral-associated OC in all main soil horizons following density fractionation with sodium polytungstate (1.6 g cm⁻³). Organic matter in each fraction was characterized by stable isotope composition (¹³C, ¹⁵N) and the lignin (CuO oxidation) and neutral sugar content (acid hydrolysis). The apparent age of OM in these fractions was determined by AMS-¹⁴C dating and the potential OM decomposability by aerobic incubation. The information about the functional and molecular composition of OM was related to apparent and potential turnover rates, providing new evidence about the role of abiotic (temperature, moisture) versus structural parameter on C vulnerability in this sensitive ecosystem.

ID: 163

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Assessment of carbon and nitrogen cycling in arable systems under climate extremes: An Analysis of a regional greenhousegas emission inventory from arable soils for Saxony from 1998 to 2100

Saul Molina, Steffen Klatt, David Kraus, Rüdiger Grote, Edwin Haas, Ralf Kiese, Klaus Butterbach-Bahl

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IPCC SRES climate projections up to 2100 predict an increase in climate extremes. Up to now, the feedback of the terrestrial biosphere (plant growth, carbon and nitrogen turnover) to these climate extremes is unknown or very uncertain. Experimental approaches to gain knowledge is very limited such than ecosystem modelling and simulation will provide a feasible approach to assess ecosystem behaviour to climate extremes on the relevant time scales.

The ecosystem model LandscapeDNDC is a process based model for carbon, nitrogen and water cycling within terrestrial ecosystems (forest, arable and grasslands) which can be used on site as well as regional scale. All processes and states are considered in a variable and flexible vertically structured one dimensional column that reaches from any given soil depth to the uppermost canopy height. The model was successfully evaluated for its capability to simulate ecosystem C and N cycling and biosphere-atmosphere-hydrosphere exchange of C and N compounds across all ecosystem types (forest, grassland, arable) using field observations at a series of sites across Europe.

In this study, using LandscapeDNDC, we analysed the ecosystem responses of agricultural systems in terms of yield, N and C trace gas emissions, changes in soil C and N stocks as well as nitrate leaching to climate extremes for the state of Saxony. As climate scenario for the years 1998-2100 we used the IPCC SRES A1B ECHAM data downscaled to 1 kilometer resolution. Climate extremes (temperature stress, drought and increase in intense precipitation) for specific years were defined as a deviation from the running average by at least 33%. We will present results with regard to simulated arable ecosystems responses to climate change and climate extremes at regional as well as grid scale.

ID: 222

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Oral Presentation / Talk

The role of changing temperature and rainfall in controlling post-fire Mediterranean shrublands

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Understanding how climate affect Mediterranean vegetation response to fire is important in a changing climate. After fire, some species recover by germinating from the soil-seed bank, while others resprout. These two contrasting strategies could make them differentially sensitive to climate variability and change. Here I present results from several experiments aimed at understanding how variations in temperature conditions and water availability affect the germination of several species dominant in Mediterranean shrublands. A gradient approach is used, covering the North and South of the Iberian Peninsula, or sites across the whole Mediterranean. Results show that, in general, there is not a relationship between germinability and on-site environmental conditions, and that idiosyncratic response is most common. Additionally, field studies with experimental fires show that post-fire recruitment differs among species in response to rainfall patterns. In general, the establishment window is very short and virtually restricted to the first year after fire. In dry years following fire, rainfall-sensitive species can miss this opportunity. Resprouters, by contrary, were much less sensitive. Finally, I use examples from an experiment in which a shrubland is been subjected to experimental manipulations of rainfall total and timing during four years, including one year before fire. Data show that species also differ in their response. While resprouters were less sensitive, seeders response was more variable. Overall, climate variability and change will affect Mediterranean shrublands although the exact way in which this will occur depends largely on the species.

ID: 107

Session 3: Feedback mechanisms from the biosphere to the climate system

Type of Contribution: Oral Presentation / Talk

Desertification and Extreme events decrease the Land C Sink over the last two decades.

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Previous studies have suggested an increase in the global land carbon sink over the last 20 years. However, ecosystem level studies and a recent modelling study on trends in the land carbon sink suggest that some regions are losing their ability to capture carbon dioxide. This has been attributed to several processes such as fire, insect plagues and climate change. In this work we show evidence that there is a close link between these “decreasing sinks”, water availability and the occurrence of drought. For this we analyse trends in net primary productivity and net biome productivity from 9 dynamic global vegetation models and evapotranspiration trends from satellite derived data and process-based models over the 1986-2005 period.

Our results show a broad agreement between modelled and observed evapotranspiration trends, and between the evapotranspiration, NBP and NPP trends. Two categories of regional aridification were identified: 1) decreasing C sink trends that display a constant decrease in evapotranspiration in already dry ecosystems, e.g. grasslands and shrublands 2) areas with a decreasing C sink and increasing mean evapotranspiration; linked to forest ecosystems, where the NPP and NBP decrease due to the extreme weather events (i.e. trends are dominated by ecosystem response to extreme events). We conclude that drought –both in terms of a steady decline in precipitation and due to extreme event- are the mainly responsible for regional reductions in the land C sink.

ID: 175

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

European-scale intercomparison of water and carbon fluxes as simulated by a set of LSMs and DGVMs

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Terrestrial ecosystems currently act as a carbon sink by absorbing about one third of the anthropogenic CO₂ emissions. However, there are large uncertainties concerning the fate of this carbon sink under a changing future climate. Extreme events such as droughts and heat waves are expected to become more frequent and severe, which may reduce the terrestrial carbon sink and may even turn it into a source in some regions. A better understanding of the processes controlling these land-atmosphere CO₂ exchanges is therefore crucial in order to better constrain the carbon cycle response to future climate change.

Past and future terrestrial CO₂ fluxes were analyzed based on a set of Land Surface Models (LSMs) and Dynamic Global Vegetation Models (DGVMs) used in the framework of the CARBO-EXTREME and TRENDY projects. This study focuses on the interactions between water and carbon fluxes particularly during drought. Our results suggest decrease in the terrestrial carbon sink over Europe but the role of soil moisture changes and variability on terrestrial CO₂ fluxes is still uncertain.

ID: 157

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Impact of extreme events on the global land carbon cycle during the 20th century

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Future climate is expected not only to change in the mean value of temperature or precipitation, but also to shift in the variance or the shape of probability distributions of these climatic variables, which means some climate extremes may become more frequent, including more common and severer drought, flood, heatwave and cold snap. Terrestrial ecosystem is sensitive to such climate change, which is widely observed in last few decades and is corroborated by results of field experiments. However, most of these studies focused on few observational sites or one single event, and the responses of ecosystem to climate extremes at regional to global scale during a long period still remain uncertain. In this study, we used process-based ecosystem models to estimate the impacts of different extreme events on ecosystem carbon cycle during last century. We investigated the changes in ecosystem net primary productivity (NPP) and ecosystem respiration (Re) under various extremes, and tried to figure out the sensitivity of NPP and Re to the intensity and duration of extreme events. Model results are also validated by satellite observations of the fraction of absorbed photosynthetically active radiation (FPAR) and normalized difference vegetation index (NDVI). Accurately representing the response of terrestrial ecosystems to climate extreme events is crucial to better understand the future climate-carbon feedback.

ID: 108

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Oral Presentation / Talk

Impact of extreme drought and heat events on grasslands communities: sensitivity during the growing season, recovery potential, and loss of resistance upon successive exposure

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This contribution summarizes the results of three large experiments on simulated climate extremes in temperate grasslands, conducted at the University of Antwerp from 2008-2010. The experiments focused on drought and heat extremes in a full-factorial design, using rainout shelters to exclude precipitation and controlled infrared irradiation in free-air conditions in the field to simulate heatwaves. We addressed the following questions:

- (1) Which type of extreme is more critical, drought or heat?
- (2) How does impact vary with timing during the growing season of extreme events?
- (3) How fast do grasslands recover?
- (4) Do successive events weaken the resistance?

Generally, heatwaves had only limited impact, with infrared imaging showing little heat stress because of transpirational cooling. If heatwaves were combined with drought, however, negative effects observed in single factor drought treatments were exacerbated through intensified soil drying, and heat stress in summer. Grasslands indeed proved more sensitive during summer compared with spring and autumn. Yet in some years we also observed little impact of summer drought and heat, especially when the extremes induced only mild changes in soil moisture. Recovery after single extremes was usually rapid. In several years, end-of-season community biomass after exposure was even greater than in unexposed controls. This increase originated exclusively from stimulated root growth and was accompanied by greater whole-plant nitrogen stocks, indicating increased net mineralization or stimulated root exploration under the influence of "mid-season drought". Finally, we exposed plant communities to multiple extreme climatic events, from the viewpoint that the probability of successive extremes increases under climate change. A preceding extreme might decrease the resistance to a subsequent event if the recovery period is too short or the resilience too poor, but the resistance might also increase if preceding extremes bring acclimation. In our experiments, a preceding heat+drought event lowered the resistance to a subsequent heat+drought event if the recovery period was 2 weeks, even though the leaves had completely recovered during that interval. With longer delays between extremes, the resistance remained intact.

We conclude that the timing of extreme events is critical to their impact. Temperate grassland communities are especially affected by combined heat and drought, but effects on end-of-season biomass are not necessarily negative. While recovery in grasslands is thus typically fast, recurrent climate extremes with short time intervals can weaken the resistance.

ID: 229

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Oral Presentation / Talk

Effects of antecedent precipitation, stand age, and fire on the response of ecosystem functioning to drought in arid and semi-arid ecosystems of North America

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Long-term measurements of soil moisture, climatic conditions, and disturbance are used to analyze the controls on net CO₂ exchange, evapotranspiration, and LAI. Long-term eddy covariance measurements in the chaparral of Southern California and the deserts of Baja California Sur, Mexico near La Paz are used to investigate the interactive effects the timing and pattern of rainfall and its interaction with other forms of disturbance including fire and tropical storms. Antecedent conditions appear to play a major role on the effect, depth, and severity of drought on net CO₂ flux, evapotranspiration, survival, and other key biophysical parameters. Three sites in the chaparral at the SDSU Sky Oaks Biological Field Station, representing different ages since fire, and one site in the Larrea-cardon desert on the CICESE ecological reserve near La Paz, BCS are compared and contrasted over >10 years including periods of fire, drought, and flooding.

ID: 169

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Dynamic Global Vegetation Models: parameterization challenges in a changing world

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Dynamic Global Vegetation Models (DGVMs) are widely used for analyzing forest growth dynamics and possible biophysical and biogeochemical feedbacks to climate. Their performance has been typically tested against flux tower and forest inventory observations and by model intercomparison studies. In the present analysis the parameterization of LPJ-GUESS, a state-of-the-art ecosystem model, was evaluated by performing a global sensitivity analysis. We show that simulated carbon fluxes and pools are highly sensitive to parameters related to photosynthesis. At the same time, the sensitivity to parameters controlling plant water relations was found to be low even in relatively dry conditions. Both of these results are in contradiction with recent evidence showing that photosynthesis is not the primary driver of plant growth while plant-water relations are significant. In addition, we investigate how parameter variability, justified by plant acclimation and evolution, is translated into uncertainties of model realizations. This is achieved by presenting an ensemble of global-scale simulations based on a simple “perturbed biophysics” experiment. Because the aim of DGVMs is often long term, climate non-stationary projections, we argue that significant amendments are needed in their structures rather than in their parameterizations. A more mechanistic representation of plant water relations and carbon trans- and allocation are likely to provide more robust simulations of the terrestrial carbon cycle.

ID: 129

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Oral Presentation / Talk

Extreme rainfall events as biogeochemical hot moments for the hydrologic soil carbon export in mountainous watersheds

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The hydrologic export of soil organic carbon via dissolved and particulate organic carbon (DOC; POC) constitutes a crucial link between land and water in the global C cycle. Storm C pulses can account for a substantial portion of the annual soil C increment in mountainous watersheds, but little is known about the relative importance of DOC and POC pulses during extreme rainfall events and their fate in rivers and sediment deposits. Storm pulses of DOC and POC were investigated using both hourly sampling and in-stream C analyzer in a mountainous forested watershed in Korea during five summer monsoon periods to evaluate the relative importance of DOC and POC losses in soil C budgets. POC concentrations were consistently lower than DOC concentrations during baseflow and small events, but increased drastically with rising discharge during intense storms, with response magnitudes dependent upon storm characteristics. While the bulk of the annual DOC export occurred under prevailing low-flow conditions, stronger responses of POC to intense storms resulted in a disproportionately large export of POC during a few intense or extreme events. Analyses of C and N stable isotopes and lipid biomarkers in suspended and deposited sediment pointed to varying sources of POC during storm events and the evolution of chemical characteristics along sediment transport pathways. Despite stochastic occurrence, erosion-induced pulses of POC during extreme rainfall events can translocate large amounts of soil C from mountain slopes to downstream rivers and sediment deposits, in which the fate of the exported C remains poorly understood.

ID: 145

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Drought effects on post-fire recovery of species with different regeneration strategies in a Mediterranean shrubland

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Climate change is projected to increase the frequency and intensity of droughts in the Mediterranean region, as well as the occurrence of large fires. Therefore, it is likely that post-fire recovery of vegetation occurs under drought conditions. In that case, the post-fire regeneration strategy of each species (seeders vs resprouters) could play a key role.

Here, we present a study in which a Mediterranean shrubland of central Spain was experimentally burned and subjected to rainfall manipulations by mean a system of automatic rainout shelters with irrigation facility. Four treatments were implemented: environmental control (EC+; natural rainfall), long-term historical average precipitation (HC+; 600 mm/year, two months drought), moderate drought (MD+; 450 mm/year, five months drought) and severe drought (SD+; 325 mm/year, seven months drought). Moreover, a set of unburned plots without rainfall manipulation (EC-) was used as a burning control. The regeneration of main species in the community was monitored during the first three post-fire years. The results showed that the key period for vegetation recovery was the first year post-fire, especially for species with a seeder regeneration strategy. Furthermore, the recruitment and vigor of these seeder species, e.g. *Cistus ladanifer*, were significantly affected by drought treatments. By contrast, resprouter species were hardly affected by the drought, as was the case of *Phillyrea angustifolia*.

ID: 244

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Ecological Consequences of Climate Extremes: Impacts of Drought-Induced Tree Mortality on Carbon Sinks

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One of the greatest uncertainties in global climate change is forecasting changes in feedbacks between the biosphere and the atmosphere. Terrestrial ecosystems and, in particular, forests exert strong controls on the global carbon cycle and influence regional hydrology and climatology directly through water and surface energy budgets. Recent studies indicated that forest mortality caused by rising temperature and drought from around the world have unexpectedly increased in the past decade and they collectively illustrate the vulnerability of many forested ecosystems to rapid increases in tree mortality due to warmer temperatures and more severe drought. Persistent changes in tree mortality rates can alter forest structure, composition, and ecosystem services (such as albedo and carbon sequestration). Quantifying potential impacts of tree mortality on ecosystem processes requires research into mortality effects on carbon, energy, and water budgets at both site and regional levels. Despite recent progress, the uncertainty around mortality responses still limits our ability to predict the likelihood and anticipate the impacts of tree die-off. Studies are needed that explore tree death physiology for a wide variety of functional types, connect patterns of mortality with climate events, and quantify the impacts on carbon, energy, and water flux. In this presentation, I will highlight recent research progress, and identify key research needs and future challenges to predict the consequence and impacts of drought-induced large-scale forest mortality on carbon sinks. I will focus on three main forest ecosystems (tropic rainforest in Amazon, temperate forest in Western USA, and boreal forest in Canada) as detailed case studies.

ID: 170

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

The water sourcing strategy of drought affected temperate grasslands

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In Central Europe, temperate grasslands are agroecosystems of high agricultural, ecological and economic importance. Growth, distribution and yield of this vegetation type depend strongly on the sufficiency of water supply in late spring/early summer. Until now, water has never been considered as a limiting factor. However, climate models project a change in the future precipitation patterns: until 2070, a reduction in summer precipitation of about 20% (compared to 1961-1990) is projected for northeastern Switzerland. In addition, the frequency of extreme drought periods is likely to increase.

The aim of this study was to investigate if herbaceous grassland species adapt their water sourcing to (simulated) drought by exploring deeper soil layers to compensate the decreasing soil moisture. Summer drought was simulated by using transparent shelters (3 m x 3.5 m) at three different Swiss sites along an altitudinal gradient (400 m to 2000 m). Water of soil and plant root crown (xylem) samples was cryogenically extracted. Soil, plant and precipitation waters were analyzed for $\delta^{18}\text{O}$ using isotope ratio mass spectrometry. Standing belowground biomass was sampled regularly to determine possible shifts in the root mass distribution.

The $\delta^{18}\text{O}$ values of drought affected plants differed significantly from those of control plants, and often were similar to those of upper soil layers, although upper soil layers were very dry. This pattern occurred at the three sites and during three years in different intensity. Particularly, in the recovery periods, i.e., about 4 weeks after removing the shelters, a very strong relationship with the $\delta^{18}\text{O}$ value of precipitation could be found. Our results were confirmed by an additional evaluation with a Bayesian calibrated mixing model. Belowground biomass distribution supported the results based on the stable isotopes approach: Under drought stress, a strong increase of root mass was observed in the top soil. Thus, in contrast to the hypothesized drought adaption to deeper rooting patterns, temperate grassland species shifted root growth and water uptake to the top soil, supposedly towards the next most likely water source: the next precipitation event.

ID: 132

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Managed land and the carbon cycle: Might oversimplification lead to large underestimations of impact?

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It is widely accepted that anthropogenic land-use change has substantially altered fluxes of carbon between the terrestrial biosphere and the atmosphere. The impacts on carbon fluxes are both immediate, through the clearing of natural vegetation, and sustained, through modifications of long-term land-atmosphere exchange. Yet only relatively recently has anthropogenic land-use change been explicitly and widely represented in global Earth-system models, and the sensitivity of different approaches is not well explored. Typically such models represent all crops and pasture land (~35% of global land area in 2000) using a grass plant functional type. However many crops differ greatly from grass in their phenology, productivity and bioclimatic limits. In addition to the resulting instantaneous differences in fluxes, the response of crops to changes in climate mean and variability will also differ relative to grass. Thus, differences between grasses and crops may be strongly dependant on the driving climate. Using the dynamic global vegetation model LPJ-GUESS we investigate the sensitivity of net ecosystem exchange of carbon to the treatment of managed land in the model. We show the differences in accumulated terrestrial carbon fluxes during 1850-2100 between simulations that treat crops as grasses, and simulations that include 13 major crops. By driving LPJ-GUESS with the most extreme climates in the CMIP5 ensemble, we elucidate the importance of the climate in driving these differences. We discuss the significance of these differences in terms of the global carbon cycle, and identify important features of managed land for inclusion in Earth system models.

ID: 162

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Extremes in tree ring widths: Coincidences with climate and net primary productivity

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Here we propose a method to evaluate Dynamic Global Vegetation Models (DGVMs) such as LPJmL for their capability to simulate the response of the European carbon cycle to extreme climatic events. Observed tree ring widths are contrasted with simulated net primary productivity (NPP) from LPJmL and the climatic forcing variables in order to evaluate ecosystem responses to extreme heat and drought events. Our basic data sets are measured tree ring widths, climatic forcing variables (e.g. temperature and precipitation) and simulated NPP from LPJmL at 363 locations throughout Europe. Our goal is to find coincidences between extreme events in climate, NPP and tree ring width time series that are very unlikely to arise by chance alone and, hence, point towards a possible causal relationship. One main advantage of our method is that by determining a window of potential overlaps of coincidences we can also account for lag effects, e.g. a delayed response to an extreme event that occurs in the year after the event. Our method allows for a scale-independent model evaluation, i.e. simulated NPP and tree ring widths can be directly compared. Our results will help to improve simulations of the European carbon cycle and thus lead to a deeper understanding of potential impacts of extreme events on ecosystem productivity.

ID: 220

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

A climate data set of reduced variability and conserved long-term mean

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Variability of climate is projected to increase in many regions of the world during the next century. Potentially, such change in climate variability will have a great impact on terrestrial ecosystem functions. Factorial experiments using a process-oriented biosphere model allow disentangling the effects of a change in climate variability from effects of a change in the mean climate on land-atmosphere exchanges of carbon and energy. Such factorial experiments require climate data sets with conserved long-term mean but different

short-term variability. Parameters of a distribution transformation function are estimated for individual climate variables to match such criteria. The resulting European climate data set holds similar long-term means but reduced variability. We estimate parameters such that variability is reduced on purpose because that method ensures the altered climate space being a subspace of the control dataset. The transformation also conserves the number of rainy days

within a month and the shape of the distribution. The median absolute difference between daily data of both data sets is about 5 to 20 \%. Fitting generalized extreme value (GEV) distribution functions to annual min/max values shows that mean extreme values are reduced by about 15 \% with interestingly a latitudinal gradient in Europe.

ID: 227

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Incremental impacts of precipitation, temperature, and cutting frequency on biogeochemical processes in grassland ecosystems

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Grasslands comprise more than one-third of the Earth's land surface and support a majority of the world's livestock, which provides essential nutrients to a growing population. Changes in climate and management, separately, have had significant impacts on biogeochemical processes in grasslands. However, only a few modeling studies have incorporated management impacts on biogeochemical cycling with various Earth system components and the potential feedbacks from these landscapes. The Regional Hydro-Ecologic Simulation System (RHESSys) is a process-based hydrologic model that couples water and nutrient cycling and conducts processes at relevant spatial scales using a hierarchical approach. We use this model to conduct an incremental analysis of the impact of precipitation, temperature, and cutting frequency in grassland areas and convey how these changes affect biogeochemical processes.

Our hypothesis is that incremental changes in precipitation, temperature, and cutting frequency display potential thresholds and/or system linearities among biogeochemical processes in grasslands. Correspondingly, linearities can be utilized to scale processes over large spatial areas with ranges of climatic variability and management conditions. Using RHESSys, we examine relationships between the aforementioned abiotic factors and a variety of biogeochemical processes, such as net primary productivity (NPP), nitrification, denitrification, mineralization, nitrogen uptake, and streamflow nitrates. Plotted results indicate whether these processes reach thresholds or show monotonic relationships along abiotic gradients with extreme values as well. For example, NPP displays a threshold at intermediate cutting frequency with decreases at too low or high defoliation levels.

RHESSys was selected to conduct this gradient analysis of abiotic factors due to the integrated nature of the model structure. This work will contribute to a regional Earth system modeling project, BioEarth, at Washington State University by providing scaling strategies for small-scale biogeochemical processes.

ID: 172

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Terrestrial Carbon Variability in the CMIP5 Models

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The response of vegetation and terrestrial carbon fluxes to climate change is uncertain; CMIP5 models produce a broad range of changes in net biome production in response to climate change. Inter-annual variability can be used to understand the different behaviours of the CMIP5 models. We use carbon variability in the CMIP5 simulations to quantify a significant change in carbon fluxes, to explain differences in model results and to constrain uncertainty in projected changes.

Quantifying the magnitude of natural variability in terrestrial carbon fluxes provides a benchmark against which to measure changes in carbon fluxes caused by climate change and land use change. Understanding why carbon variability is different in each model will help explain the ranges of response seen on longer timescales. Finally, there is some observational evidence of variability in carbon fluxes, comparing models' responses to these observations will help constrain the uncertainty in the projected changes.

In each model, the locations of greatest natural variability in terrestrial carbon fluxes are identified. Differences in these locations and in the magnitude of variability are explained by differences in climate conditions and mean vegetation distribution. Remaining differences must then be due to differences in the carbon cycle components of the models. This approach identifies which of these three factors is causing differences between the models and hence which should be the focus of further research.

ID: 141

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Varying drought intensity in a C4 grassland: modeling the effects on carbon fluxes at annual and decadal scales

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Global climate models (GCMs) project changes to climate means and extremes by the end of the 21st century. In water-limited systems, such as C4 grasslands, alterations to precipitation patterns and amounts may significantly impact biogeochemical cycling. There is consequently a growing need to understand the sensitivities of such ecosystems to long-term reductions in mean precipitation (press-drought) versus short-term, extreme drought (pulse-drought). While a variety of field experiments have addressed drought responses, their temporal and spatial extents are limited by logistical challenges. Here we use a modeling approach to examine the long-term effects of pulse- versus press-droughts in a C4 grassland using the Community Land Model version 4.0 (CLM). CLM was calibrated to energy flux, soil moisture, and productivity data from the Konza Prairie Long-Term Ecological Research Station in Kansas, USA. Experimental climate inputs were derived from station and reanalysis data, and manipulated to represent varying levels of annual drought. Climatologies were assembled into three ten-year treatments: control, pulse-drought, and press-drought. While drought dynamics differed substantially, the two drought treatments received the same total decadal rainfall.

During drought years, annual NPP was reduced by 20% in the press-drought and 53% in the pulse-drought treatment. However, by the end of the ten-year simulation, the press-drought treatment displayed a greater reduction in total ecosystem carbon (-3.1% vs -1.5%). This is likely due to the quick recovery and lack of “ecological memory” in years following extreme drought. Results suggest that while extreme drought events strongly impact short-term carbon dynamics, more subtle but prolonged precipitation reductions may decrease long-term carbon storage to a greater degree. Future work will use projected future climates and assess responses to community composition.

ID: 160

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

European ecosystem vulnerability to extreme events: The ecosystem perspective

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Extremes of meteorological events may but do not have to cause damages in ecosystems. Climate change is expected to have a strong impact on the productivity and stability of ecosystems worldwide. So far, the impacts of extreme drivers on ecosystems have generally been studied regardless of the extremeness of the ecosystem response.

We base our analysis on a Probabilistic Risk Assessment concept of Van Oijen et al. quantifying the vulnerability of vegetation dynamics in relation to the extremeness of meteorological drivers such as temperature or precipitation. Here, the definition of extreme, hazardous weather conditions is based on the ecosystem response. Hence, instead of searching for extreme meteorological events, we define extreme ecosystem responses in terms of threshold levels of carbon uptake, and search for the meteorological conditions responsible. Having defined hazardous events in this way, we quantify the vulnerability of ecosystems to the such hazards.

We apply this approach on results of the dynamic process-based vegetation model LPJmL using climatic input for Europe from the WATCH-ERA-REMO climate scenario with the SRES A1B emission scenario. Our results show that under current climatic conditions, the southern part of Europe already suffers severe heat and drought stress which is reflected in our approach by vulnerability values being high for precipitation, relatively high for the SPEI index, moderately high for temperature and quite high for the consecutive dry days. Thus, hazard occurrence is frequent enough to determine ecosystem vulnerability but this depends on the definition of the threshold of hazardous ecosystem responses.

ID: 176

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Oral Presentation / Talk

Summer extreme climatic event in the future: impact on the net CO₂ and water fluxes of an upland grassland and buffering impact of elevated atmospheric CO₂

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Extreme climatic events are expected to be more frequent and intense in a few decades, but they will also occur in a climatic context different from the current one. In the Montpellier Ecotron, we studied the response of intact grassland monoliths (1m², 60 cm deep) sampled in an upland grassland of the French Massif Central. The first year the grasslands were acclimated to the average climatic conditions of the years around 2050 (+ 4 °C and – 56 mm for summer precipitations). The second year, the same climate was maintained but in half of the experimental units we imposed a summer drought and heat wave (50 % reduction of precipitations for a month and then 100 % precipitation reduction combined with a 3,4 °C increase in temperature for two weeks). A CO₂ treatment (520 vs 380 μmol/mol) was crossed with the climatic treatment.

Net CO₂ fluxes were measured continuously during the second year of the experiment. The extreme climatic event induced a total senescence of the canopy whatever the CO₂ treatment. The interactive effect of elevated CO₂ with the drought treatment was significant at the onset of the drought and particularly large in the fall after the recovery period, with a net photosynthesis twice as high in the (extreme climate+ CO₂) treatment compared to the control. Integrated over the year, elevated CO₂ totally buffered the impact of the extreme climatic event on net CO₂ exchanges. These results are discussed together with the evapotranspiration and soil humidity data.

ID: 127

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Effects of extreme weather events on plant-soil dynamics: Coupling the carbon and water cycle

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Extreme weather events such as heat and drought are increasing globally. However, our scientific understanding on how extreme events affect ecosystem functioning is still limited, and a better process understanding of plant and soil responses is needed to reduce uncertainties in model predictions.

Our study aims therefore to identify and quantify combined heat and drought effects on the carbon and water balance of the plant-soil system. In more detail, our objectives are: I) to identify the link between plant water stress and C fluxes, such as assimilation, respiration and allocation, II) to study combined heat and drought effects on the soil system, including autotrophic vs. heterotrophic respiration, III) to investigate the extend of the coupling of above- with belowground under heat and drought conditions, and IV) to estimate carry-over effects to the following year and multi-year heat/drought effects.

The study takes place in a modern, state-of-the-art greenhouse facility in Garmisch-Partenkirchen, allowing to control for environmental conditions, such as temperature and humidity. The experimental set-up consist of two tree species, Douglas-fir and black locust planted in large, 70 cm deep pots equipped with soil moisture and temperature probes, as well as with mesh cylinders to exclude root and mycorrhizal in-growth. The pots are insulated and additionally equipped with a cooling system to mimic close to ambient soil temperatures during the experimental phase. The response of the plant-soil system to heat, under well watered and drought conditions will be compared to a control treatment at ambient temperature under comparable moisture conditions. Plant water status will be inferred from water potential and sap flow measurements and related to C gain (photosynthesis) and C loss (respiration, above- and belowground). Heterotrophic respiration measurements allow us to estimate microbial activity under extreme conditions. Moreover, to quantify C allocation patterns and above-belowground coupling, a ^{13}C pulse-labeling will be carried out and the ^{13}C signal followed within plant compartments and soil. The study will be continued in the second year, to estimate carry-over effects of extreme heat and drought in the following year, as well as multi-year heat and drought effects.

ID: 179

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Recent changes in forest structure across Boreal, cool Temperate and Mediterranean forests: climatic trends may constrain the carbon sink potential of European forests

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Forests can act as both carbon sinks and sources, having a prominent role in the global carbon cycle, but also in other ecosystem processes and services. European forests have a large potential for mid-term carbon sequestration and an increase in carbon storage during the second mid of 20th century has been consistently reported. However, recent biomass changes in European forests and the key drivers underpinning these changes are poorly understood. Here we use plot-level forest inventory data from Spain, Germany and Finland to examine variation in stand basal area, growth and mortality roughly during the last two decades. We use linear mixed-effects models to identify the main correlates underlying these patterns. Cool temperate biomes exhibited the highest net stand basal area increments, relative growth and mortality rates. In contrast Mediterranean and northern Boreal forests exhibited lower, or even negative, values of net basal area changes. Stand structure (mean d.b.h. and stand basal area) and climate (water availability and minimum temperatures) strongly affected stand basal area changes and strong interactions between stand structure and climate were found. Recent climatic trends -i.e., increased temperature or decreased precipitation between national forest inventories surveys with respect to the reference period - significantly constrained stand basal area increments. We conclude that climatic warming might further limit the mid-term carbon sink role of European forests, particularly in Mediterranean regions, and that these changes can be exacerbated or ameliorated depending on current stand structure.

ID: 202

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

An Ice Storm Manipulation Experiment in a Northern Hardwood Forest.

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Ice storms are an important natural disturbance within forest ecosystems of the northeastern United States. Current models suggest that the frequency and severity of ice storms may increase in the coming decades in response to changes in climate. Because of the stochastic nature of ice storms and difficulties in predicting their occurrence, most past investigations of the ecological effects of ice storms across this region have been based on case studies following major storms. Here we report on a novel alternative approach where a glaze ice event was created experimentally under controlled conditions at the Hubbard Brook Experimental Forest, New Hampshire, US. Water was sprayed over a northern hardwood forest canopy during February 2011, resulting in 7 to 12 mm radial ice thickness. Although this is below the minimum cutoff for ice storm warnings (13 mm of ice) issued by the US National Weather Service for the northeastern US, this glaze ice treatment resulted in significant canopy damage, with 142 and 218 g C m⁻² of fine and coarse woody debris (respectively) deposited on the forest floor, a significant increase in leaf-on canopy openness, and increases in qualitative damage assessments following the treatment. This study demonstrates the feasibility of a relatively simple approach to simulating an ice storm, and underscores the potency of this type of extreme event in shaping the future structure and function of northern hardwood forest ecosystems.

ID: 138

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Effects of recurring summer droughts on ecosystem photosynthesis and respiration in a mountain grassland

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Climatic changes in mountain regions play a key role in current and future grassland ecosystem processes. It is currently expected that droughts and heatwaves will become more frequent in a changing climate. All around the world mountain regions have been labelled as sensitive zones, where declining water availability and increasing temperature are expected to increase the vulnerability of these ecosystems. However, the effects of such extreme events on ecosystem carbon (C) fluxes and their coupling in temperate and so far non-water limited Alpine grasslands are not yet well understood. We studied effects of recurring summer drought on the C dynamics of a mountain meadow at 1820 m and an abandoned grassland at 2000 m in the Austrian Central Alps. The aim of the study was (1) to analyse the multiannual effect of drought on net ecosystem CO₂ exchange (NEE) and its major component processes, i.e. gross primary productivity (GPP) and ecosystem respiration (Reco), and (2) to trace drought effects on the use of recent C in soil respiration. We tested the hypothesis that drought reduces NEE, GPP and Reco and the ratio of GPP / Reco and causes a reduction in the use of recent photoassimilates in belowground respiration. At each study site, exclusion of rainfall was achieved by establishing rain-out shelters for a period of two months (June, July), while control plots remained exposed to natural precipitation. To trace the fate of recent C from assimilation to respiration ¹³CO₂ pulse-labelling was carried out at the meadow site, and the carbon isotope composition of soil respired CO₂ was continuously monitored with an open dynamic-chamber system coupled with a quantum cascade laser. Our results showed that at both sites NEE, GPP and Reco showed a consistent reduction with reduction in soil water level. Drought reduced ecosystem respiration to a lesser extent than photosynthesis. We observed memory effects on all flux processes after 3 years of recurring drought on the mountain meadow, which was likely due to shifts in the abundance of dominant species. Within the first 30 days after labelling, the contribution of recent C to the main component process of ecosystem respiration (soil respiration) was slightly reduced in the drought plots. We conclude that 1) a summer drought may potentially alter the carbon balance of mountain grasslands towards decreasing photosynthesis and assimilation area, whereas 2) repeated drought may lead to adaptation of the ecosystem which reduces the drought response of C fluxes, and 3) summer drought may reduce the contribution of recent C to belowground respiration.

ID: 147

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Small-scale feedbacks and large-scale impacts

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Biogeochemical processes are affected by environmental conditions, and heterogeneity within the canopy or soil can cause these environmental conditions to vary locally. Biogeochemical processes themselves contribute to these variations (e.g., by altering within-canopy or soil concentrations of O₂ or CO₂, or by changing leaf temperatures), and thereby exhibit a local feedback, which can be of importance for the large-scale response of ecosystems.

I will discuss the importance of such feedbacks for the simulation of biogeochemical processes in global models. Whereas the descriptions of biogeochemical processes in these models are often derived from small-scale observations and process understanding, global models tend to ignore the heterogeneity and feedbacks at these scales, and simulate the responses based on large-scale climatic conditions. In this way, small-scale feedbacks are often ignored, and their consequences for future environmental conditions remain unknown.

ID: 103

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Drought-induced reduction in uptake of recently photosynthesized carbon by springtails and mites in alpine grassland

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Universität Innsbruck, Austria

We tested whether experimental summer drought affects the transfer of recently photosynthesized carbon from plants to soil mesofauna in a subalpine meadow. From day one after ^{13}C pulse-labelling of the plant canopy, roots, collembolans and mites were enriched in $\delta^{13}\text{C}$ in control, but not in drought plots. However, as the difference in $\delta^{13}\text{C}$ between roots and soil animals was not affected by the drought treatment, we conclude that drought affects the tight linkage between photosynthesis and soil mesofauna primarily via functional responses of plants rather than via changes in the mesofauna.

ID: 245

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Invited Lecture

Biosphere-climate interactions: Extreme events, modelling, and climate change projections

Sonia Isabelle Seneviratne, Edouard L. Davin, Lukas Gudmundsson, Benoit Guillod, Martin Hirschi, Ruth Lorenz, Heidi Mittelbach, Brigitte Mueller, Boris Orłowski, Rene Orth

ETH Zurich, Switzerland

The land biosphere affects climate through its impact on evapotranspiration, surface albedo, and land carbon uptake. This presentation will focus on drought-biosphere-climate feedbacks and their impacts on temperature extremes (e.g. Seneviratne et al. 2010, Hirschi et al. 2011, Mueller and Seneviratne 2012). In particular, the identification of suitable metrics to quantify these feedbacks and validate them in climate models will be discussed. In addition, compound effects with land cover feedbacks, soil moisture memory impacts and large-scale circulation forcing will be presented. Finally, the importance of these feedbacks in the context of seasonal forecasting (e.g. Quesada et al. 2012) and climate change projections (e.g. Seneviratne et al. 2012) will be addressed.

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ID: 232

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Assessment of photosynthetic activity with field spectroradiometry in a Mediterranean oak woodland: seasonal and interannual dynamics

João M. N. Silva, Sofia Cerasoli, Ana Rodrigues

Forest Research Centre, School of Agriculture, Technical University of Lisbon, Portugal

Carbon assimilation by vegetation is mainly related to the fraction of the absorbed photosynthetically active radiation (FAPAR) and the light use efficiency (LUE). Field spectroradiometry and satellite data have been used for monitoring photosynthetic activity and as inputs to models of primary productivity. Application of those models is challenging to complex Mediterranean oak woodlands, which are composed of several layers – trees (cork oak), shrubs and grasses – and are subject to large seasonal and interannual climate variability. The goal of this study is to use in situ spectroradiometry data to track photosynthetic activity in those three co-existing layers, and to quantify the contribution of each layer to the overall gross primary productivity.

Field measurements of reflectance with a Fieldspec 3 (ASD Inc.) have been made twice a month since April 2011 in the three layers. Simultaneous measurements of the maximum efficiency of photosystem II (Fv/Fm) and quantum yield were performed by a pulsed light fluorometer (MiniPAM, WALZ).

The three layers showed very different annual trends of the normalized difference vegetation index (NDVI). Grasses showed a strong seasonality, in consequence of summer senescence. NDVI values of cork oak, an evergreen oak, exhibited a little change and the semi-deciduous shrubs showed an intermediate behaviour. Trends of the photochemical reflectance index (PRI) revealed two important features: the renewal of cork oak canopy in spring and a marked difference among the vegetation layers during summer stress conditions, when cork oak maintains high values comparing to shrubs and grasses. A significant linear relationship was found between PRI and Fv/Fm, which is indicative of the ability of this index to track photosynthetic capacity. A good relationship between NDVI and FAPAR was obtained in shrubs and showed similar coefficients to the ones reported in literature.

ID: 191

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Invited Lecture

Ecological consequences of climate extremes vs. extreme climatic events: a framework and future directions

Melinda D. Smith

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Climate extremes, such as severe drought, heat waves and periods of heavy rainfall, can have profound consequences for ecological systems and for human welfare. Global climate change is expected to increase both the frequency and intensity of climate extremes and there is an urgent need to understand their consequences for ecosystems. Major challenges for advancing our understanding of the ecological consequences of climate extremes include 1) having sufficient knowledge of systems so that extreme ecological responses can be identified and 2) being able to attribute a climate extreme as the driver of an extreme response, defined as an extreme climatic event (ECE). Although the occurrence of ECEs may be common in observational studies, studies in which climate extremes have been experimentally imposed often do not result in ecosystem responses outside the bounds of normal variability of a system. Thus, ECEs likely occur much less frequently than their potential drivers and even less frequently than observational studies suggest. Future research is needed to identify the types and timescales of climate extremes that result in ECEs and the potential for interactions among different types of climate changes and extremes. There also a need to set climatic and ecological baselines to facilitate determination of ECES. These research priorities require the development of alternative research approaches to impose realistic climate extremes on a broad range of ecosystems.

ID: 186

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Extreme European summer heatwaves: can we catch them with our models?

Annemiek Irene Stegehuis, Robert Vautard, Philippe Ciais

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The variability of European summers is expected to increase in the next century, probably leading to more frequent and more severe heatwaves. Heatwaves are known for their impact on humanity but also heavily impact ecosystems, such as forests, and their carbon cycle. Although recently an increasing amount of research has been done on heatwaves and their impacts, it remains unclear whether present climate models are able to simulate the most extreme events, and thus their impact on ecosystems.

In this study the regional climate Weather Research and Forecast model (WRF) will be analyzed on its ability to simulate the extreme summer event of 2003 and its associated land-atmosphere feedbacks against observations such as temperature, heat fluxes, and soil moisture. A second phase of this research is to study the impact of extreme heatwaves on forests and their carbon cycle with a process based biosphere model, ORCHIDEE, forced with the climate variables simulated by WRF.

Preliminary results suggest that there is an underestimation of temperature during the hottest days of the 2003 heatwave over central and southern Europe. If climate models are not able to simulate current extreme events, the question remains whether they will be able to simulate future, perhaps even more extreme events with the right magnitude. Furthermore, their impact on forest and the c-cycle might then be underestimated.

With this study we hope to shed light on the ability of current generation climate models to simulate the most extreme heatwaves in order to increase knowledge on possible future scenarios.

ID: 247

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Carbon dynamics in a boreal forest under 15 years of soil warming

Monika Strömberg, Sune Linder

SLU, Sweden

The boreal forest is expected to experience the greatest warming of all forest biomes, raising concern for the fate of the large quantities of stored soil carbon. The effects of a changing climate on the C balance in these ecosystems are still, however, poorly understood. We studied how soil warming affected carbon dynamics in irrigated (I) and irrigated-fertilised (IL) stands of 40-year-old Norway spruce in Flakaliden, Northern Sweden. From May to October, heating cables were used to maintain the soil temperature in warmed plots (Ih and ILh) at 5 °C above the soil temperature in non-heated control plots (Ic and ILc). Fertilisation started in 1987 and soil-warming commenced in 1995. Stem volume production was followed annually 1994-2011 and soil-surface CO₂ fluxes 1998-1999 and 1997-2011.

We found that soil-warming initially increased stem wood production in Ih and ILh plots, with a peak after five years, but after 10-15 years returned to levels slightly above or levels similar to non-heated plots. The increase can be explained by an initial increase in nitrogen mineralisation, which has thereafter decreased to ambient levels. This was supported by an increase in 15N in the needles on warmed plots, which suggested mineralisation of older soil organic matter.

After 13 years, soil-warming increased annual soil-surface CO₂ fluxes as an effect of higher daily fluxes, longer growing season, and a larger root litter production. The increase was, however, much lower than expected, since warming decreased both temperature sensitivity (Q₁₀) and basal respiration. For any specific soil temperature, the soil-surface CO₂ fluxes on warmed plots were significantly lower than on non-heated plots. These results indicate that there must be an acclimation and/or adaptation of soil-surface CO₂ fluxes to temperature and emphasise that extrapolation of data collected under current ambient conditions may be inappropriate to extrapolate to a warmer climate.

ID: 148

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Gross nitrogen fluxes in intact beech-soil-microbe systems under simulated climate change

Javier Tejedor¹, Michael Dannenmann¹, Silvija Bilela², Rainer Gasche¹, Silvia Gschwendtner⁴, Martin Leberecht⁵, Carolin Bimüller³, Ingrid Kögel-Knabner³, Andrea Polle Polle⁵, Michael Schlöter⁴, Heinz Rennenberg²

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The vulnerability of beech forests of Central Europe to projected climate change conditions is a current matter of debate and concern. In order to investigate the response of N cycling in a typical beech forest to projected climate change conditions, we transplanted small lysimeters with intact beech-soil systems from a slope with N-exposure (representing present day climate conditions) to a slope with S exposure (serving as a model climate for future conditions). Lysimeter transfers within the N exposure served as control. After an equilibration period of 1 year, three isotope labeling/harvest cycles were performed: (1) comparison between N and S slopes under ambient conditions; (2) comparison between N and S slopes after intensified drought at S exposure; (3) rewetting after the drought period. Homogenous triple isotope labeling (¹⁵N/¹³C glutamine, ¹⁵NH₄⁺, ¹⁵NO₃⁻) in combination with ¹⁵N tracing and -pool dilution approaches as well as molecular analyses of nitrogen cycling genes and mycorrhiza morphotyping allowed to simultaneously quantify all N turnover processes in the intact beech-soil-microbe system.

First results show a dramatic attenuation of microbial gross nitrate production from 252±83 mg N m⁻² day⁻¹ for the control treatment to 49±29 mg N m⁻² day⁻¹ for the climate change treatment and associated strong declines in nitrate uptake by microorganisms and beech, which could not be compensated by uptake of ammonium or glutamine. Hence our data provide a mechanism to explain nutritional limitations of beech under higher temperatures and drought and raise questions about the sustainability of such forests under projected climate change conditions.

ID: 158

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Influence of climate variability on future fire regimes and vegetation-fire interaction in Europe

Kirsten Thonicke¹, Susanne Rolinski¹, Werner von Bloh¹, Ariane Walz^{1,2}, Anja Rammig¹

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Climatic fire risk is projected to increase with future climate change, as temperatures increase, but precipitation decrease in many fire-prone areas in Europe. Recent analyses of fire statistics and other fire-related data have shown that climate fire risk is not always linearly related to area burnt or fire severity. This means that vegetation productivity, i.e. fuel production, or landscape fragmentation, e.g. through land-use and transportation routes, influence fire spread. Drier climate negatively impacts vegetation productivity, thus leading to less fuel load which further limits fire spread despite similar fire risk. The sensitivity of the affected vegetation also influences fire effects and post-fire mortality. Increasing agriculture or urbanization limit the continuity of the fuel bed. More urban population changes the use of fire in landscape management and affects fire ignitions, thus area burnt. Climate variability additionally contributes to the non-linearity of these processes, which is likely to change under future climate conditions. All these factors point to important feedbacks between vegetation and fire, which can be investigated using dynamic process-based vegetation-fire models such as LPJmL-SPITFIRE.

We apply LPJmL-SPITFIRE to future climate change scenario, 1) the WATCH-ERA-REMO climate scenario which was run for the SRES A1B emission scenario to Europe and 2) the same climate scenario but with reduced climate variability. Here, we investigate the effects of climate variability and CO₂-fertilization on future fire regimes, vegetation dynamics and associated biome shifts. It is hypothesized that climate variability influences vegetation-fire interactions along biome borders, especially in Eastern Europe. Mediterranean countries are most likely to face fuel limitation, leading to a reduction in fire towards the end of the century. Transitions in vegetation composition leading to both types of trajectories will be examined.

ID: 153

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Model-Data-Fusion with a generic biosphere model using ecosystem manipulation data from a Danish heathland

Tea Thum¹, Philippe Peylin², Andreas Ibrom³, Leon van der Linden^{3,4}, Claus Beier³, Cédric Bacour⁵, Diego Santaren², Philippe Ciais²

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In ecosystem manipulation experiments (EMEs) the ecosystem is artificially exposed to different environmental conditions that aim to simulate circumstances in future climate. At Danish EME site Brandbjerg the responses of a heathland to drought, warming and increased atmospheric CO₂ concentration are studied. The measurements include control plots as well as replicates for each three treatment separately and in combination. The Brandbjerg heathland ecosystem is dominated by heather and wavy hairgrass.

These experiments provide excellent data for validation and development of ecosystem models. In this work we used a generic vegetation model ORCHIDEE with Model-Data-Fusion (MDF) approach. In MDF we are using observations from the site to optimize the model parameters. This enables us to assess the modelling errors and the performance of the model for different treatments. This insight will inform us whether the different processes are adequately modelled or if the model is missing some important processes. We used a genetic algorithm in the MDF.

The data available from the site included measurements of aboveground biomass, heterotrophic soil respiration and total ecosystem respiration from years 2006-2008. All three data streams were used simultaneously in the MDF. In most cases, the model originally overestimated the aboveground biomass and the heterotrophic respiration before the MDF, and the MDF improved the model performance for all different data streams. The results suggest that a new plant functional type needs to be developed to ORCHIDEE in order to successfully simulate the Brandbjerg.

ID: 184

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

The sequence of short-term extreme drought and inundation events determines riparian plant performance

Yasmijn van der Knaap, Rien Aerts, Peter van Bodegom

VU University Amsterdam, Netherlands, The

Climate change scenarios predict an increasing number of extreme climatic events. Previous research concerning extreme events focused mainly on plant performance. Plant performance may partly be determined by its traits, or trait plasticity. Species that have appropriate traits to withstand extreme events, or are able to adapt their traits, may increase their chances of survival and eventually their competitive advantage. The aim of this study was to test whether multiple extreme events can trigger trait plasticity in plants and if that improves plant performance. We performed a greenhouse experiment where 25 wet to drought tolerant plant species (grasses and herbs) were subjected to single and double 10-day drought and inundation stress, and all combinations thereof. We measured plant performance (biomass, plant length, evapotranspiration and relative growth rates) and multiple plant traits (root porosity, leaf thickness, specific leaf area, leaf nitrogen content and leaf phosphorus content) to test species responses to these events. Our results show that plants are not able to adapt their traits to these fast changing conditions. However, the extreme events and their sequence had major effects on plant performance, especially the Drought-Drought and Inundation-Drought treatments affected plant performance. These effects depended on both the moisture preference and the growth form (grass or herb) of the species, where wet tolerant species were more negatively affected than drought tolerant species, and grasses were more sensitive to these events than herbs. The results indicate that multiple short-term extreme events may lead to qualitatively and quantitatively different impacts than single events and that it is difficult to predict those impacts beforehand. A better understanding of how plant species respond to the sequence of short-term extreme events is clearly needed to make predictions for a future climate.

ID: 185

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Impact of past and future climate variability and extreme events on carbon loss in European arable agriculture

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Predictions of climate models generally suggest an increase in climate variability and an increased probability in the occurrence of extreme weather events during this century. The expected increase in variability of meteorological variables such as temperature and precipitation will impact the productive functions as well as ecosystem services agricultural systems provide, including the storage of soil organic carbon.

Here we use a methodology and improved climate dataset that is being developed in the EU FP7 CARBO-Extreme project to analyse the effect of increased climate variability on arable agriculture in Europe with a focus on crop production and carbon storage.

We will investigate whether the impact of extreme events on soil organic carbon loss from agricultural soil in Europe has changed over time by analysing the period from 1961-2100, and quantify the impact of the most extreme events (defined by the 90th and 95th percentile) on carbon dynamics in agricultural systems. This will allow us to determine whether extreme events will increasingly affect crucial carbon components in agricultural systems such as biomass production and soil organic carbon in the future compared to the past, or not.

The effect of CO₂ fertilization on crop growth, as well as the capacity of agricultural management options to mitigate negative impacts will be investigated.

ID: 116

Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Impact of climatic extremes on the C-cycle in European vegetation: Analysis of uncertainties and risks

Marcel Van Oijen¹, Christian Beer², Haythem Ben Touhami¹⁰, Nuno Carvalhais², Philippe Ciais⁹, Wolfgang Cramer³, Jaime González⁸, Tomomichi Kato⁹, Matthias Kuhnert⁷, Raphaël Martin¹⁰, Anja Rammig⁴, Markus Reichstein², Susanne Rolinski⁴, Sonia Seneviratne⁵, Pete Smith⁷, Jean-Francois Soussana⁶, Kirsten Thonicke⁴, Nicolas Viovy⁹, Ariane Walz⁴, Martin Wattenbach¹¹, Miguel Zavala⁸

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We analyse how climate change may alter risks posed by extreme

weather events to primary productivity of European ecosystems. The approach follows the protocol for risk analysis that was developed in project Carbo-Extreme. In this approach, risk is quantified as the product of hazard probability and ecosystem vulnerability. The latter terms are calculated from the input-output relations of process-based ecosystem models. This risk analysis is carried out for ~22000 grid cells of 0.25 x 0.25 degrees across Europe and for different types of ecosystem. We identify which parts of Europe are at increasing risk of droughts and heat waves and whether that is mainly due to increases in the frequency of extreme events or to increases in the vulnerability of the ecosystems. We also show to what extent uncertainty about model parameter values and model structure affects the conclusions.

ID: 173

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Oral Presentation / Talk

How a hurricane disturbance influences extreme CO₂ fluxes and variance in a tropical forest

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A current challenge is to understand what are the legacies left by disturbances on ecosystems for predicting response patterns and trajectories. This work focuses on the ecological implications of a major hurricane and analyzes its influence on forest gross primary productivity (GPP; derived from the moderate-resolution imaging spectroradiometer, MODIS) and soil CO₂ efflux.

Following the hurricane, there was a reduction of nearly 0.5 kgC m⁻² yr⁻¹, equivalent to ~15% of the long-term mean GPP (~3.0 ± 0.2 kgC m⁻² yr⁻¹; years 2003–8). Annual soil CO₂ emissions for the year following the hurricane were >3.9 ± 0.5 kgC m⁻² yr⁻¹, whereas for the second year emissions were 1.7 ± 0.4 kgC m⁻² yr⁻¹. Higher annual emissions were associated with higher probabilities of days with extreme soil CO₂ efflux rates (>9.7 μmol CO₂ m⁻² s⁻¹). The variance of GPP was highly variable across years and was substantially increased following the hurricane. Extreme soil CO₂ efflux after the hurricane was associated with deposition of nitrogen-rich fresh organic matter, higher basal soil CO₂ efflux rates and changes in variance of the soil temperature. These results show that CO₂ dynamics are highly variable following hurricanes, but also demonstrate the strong resilience of tropical forests following these events.

ID: 223

Session 3: Feedback mechanisms from the biosphere to the climate system

Type of Contribution: Oral Presentation / Talk

Assessment of proposed heatwave amplifying mechanisms over Europe using ECA indices of extremes and high-resolution AGCM model data

Anne Verhoef, Pier Luigi Vidale, Emily Black

The University of Reading, United Kingdom

We assess the importance of mechanisms that have been identified as contributors to the development and persistence of European heatwaves. These include the effects of local and Mediterranean rainfall deficit on a large number of 'indices of extremes', for various European domains. Data were obtained from the European Climate Assessment & Data database, ECA&D, for the period 1959-2011. Correlation analyses between Standard Precipitation Index (SPI3, either MAM or JJA) as the independent variable and the summer-average indices as the dependent variables, shows that local and to a lesser extent Mediterranean region spring-time hydrological preconditioning have been possibly overvalued in recent studies of heatwave triggering or re-inforcing mechanisms. A higher correlation was found between local summer rainfall and the various indices, albeit simply as a result of interactions between the water- and energy balance. Next, when we contrasted heatwave years against non-heatwave years, the link between a drier SPI3_MAM for the Mediterranean region (not so for SPI3_JJA), and increased European temperature indices in particular, was considerably amplified, but circulation patterns rather than hydrological preconditioning are likely to be the driving mechanism.

Concurrent analysis of high-resolution AGCM model outputs (capable of reproducing atmospheric blocking) for similar indices of extremes show that our observational findings are robust over a number of domain and index combinations.

ID: 110

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Effects of warming and soil drought on competition between invasive and native plant species

Maya Verlinden, Ivan Nijs

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The introduction and spread of alien plant species has become a global ecological and conservation crisis as these species can dramatically affect native ecosystem composition and functioning. An emerging concern is that the impacts of plant invasions will be aggravated by climate change and synergies between these two global changes have been identified as a possible new threat to biodiversity. However, to date, studies on such synergies are rare. We therefore conducted an experimental study into the effects of climate warming and associated soil drought on alien compared to native plant species.

We tested the effect of simulated climate warming on the competition between highly invasive plant species (*Senecio inaequidens* and *Solidago gigantea*) and dominants of the invaded native vegetation, grown together or in monocultures in unheated and heated (+3 °C) chambers. In a first experiment, all plants received optimal water, while in a second experiment, the plants received natural precipitation to allow for summer soil drought. In the absence of soil drought, warming reduced the dominance of *S. inaequidens* but stimulated the suppressed *S. gigantea*. When warming was associated with soil drought, the competitive superiority of *S. inaequidens* was increased, while the competitive ability of *S. gigantea* was not affected relative to its native counterpart. Our results suggest that the extent to which invasive plants can cope with periods of soil drought is important regarding their competitive success in a future warmer world.

ID: 122

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Oral Presentation / Talk

Synthesizing effects of precipitation manipulation on plant production and soil respiration – results and challenges

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We compiled a database containing data from over 70 experimental sites where precipitation was manipulated. These experiments cover different biomes (mainly tropical forests, temperate forests and grasslands, temperate and Mediterranean shrublands), but the majority of experiments was performed in the temperate zone. From these experiments, we collected (among others) available data for plant biomass and biomass production, leaf gas exchange, leaf and soil chemistry and soil respiration. Because experiments differed largely in the timing, duration and magnitude of the manipulation, our aim was to first quantify the manipulation and bring all experiments to a common denominator reflecting the (plant) available water. The data needed for such quantification of the manipulation are, however, available for very few experiments. Analyses that go beyond a meta-analytical approach (in which the magnitude of the manipulation is typically neglected) are therefore hampered.

In order to avoid problems related to the magnitude of the manipulation, we focussed the analyses of soil respiration (R_{soil}) on within-experiment trends. We tested whether a simple temperature-soil moisture-model that fits well to the R_{soil} measurements of the control plots can be used to predict the R_{soil} measurements for the treatment plots. For several experiments we found that low predictability was not only related to extrapolation beyond the range of SWC in the control plots. Apparently, the manipulation had altered the response of R_{soil} to temperature and/or SWC in the treatment plots to a degree which was not predictable from the controls.

Besides R_{soil} , we also analyzed responses of ANPP to reduced precipitation. A mixed effects modelling approach (which accounts for clustering of observations from sites with multiple years of data and/or multiple manipulations) revealed that ANPP was mainly determined by the site mean annual precipitation (MAP). Additional variation was explained by actual annual precipitation (either natural or experimentally reduced). The effects of annual precipitation on ANPP did not vary across the studied range of MAP, and the database fails in providing evidence of differential effects of experimental drought across sites with contrasting precipitation regime.

ID: 193

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

On the treatment of soil water stress in LSM simulations of vegetation function

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Reliable estimates of ecosystem responses to climate variability and weather extremes depend on a realistic description of land surface-atmosphere feedbacks in environmental (weather and climate) prediction models. These comprise coupled photosynthesis–stomatal conductance (A–gs) sub-models, embedded in land surface models (LSMs), to estimate terrestrial fluxes of energy, water and carbon. LSMs incorporate parameterisations of environmental limitations, enabling realistic feedbacks; soil moisture limitation of plant function is a primary control on feedbacks, particularly in sub-tropical to temperate ecosystems. The representation of this process differs greatly among LSMs.

Following Egea et al. (2011), we have implemented higher levels of biophysical complexity in the A-gs model embedded in the JULES LSM, by allowing root zone soil moisture to limit plant function via three individual routes (biochemical, stomatal conductance and mesophyll conductance) and combinations thereof. We performed land surface climate simulations over a large European domain for the period 1990 to 2009.

We show that current approaches to the treatment of soil water stress in LSMs fail to credibly simulate vegetation response across the typical range of European weather and climate variability, including recent climate extremes. Vegetation models retaining stomatal and mesophyll mechanisms in the imposition of soil water stress on plants are better able to discriminate the responses of water-limited versus radiation-limited regions. A higher simulated water use efficiency in Southern Europe (with ~20% less soil water depletion for equivalent photosynthetic rates) supports vegetation recovery within a year of each extreme summer, in agreement with observations, unlike the standard (biochemical route) LSM.

ID: 151

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Expert options on potential adaptations in ecosystem management to meet changing magnitude and frequency of climate extremes

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Climate change is expected to lead to changing magnitude and frequency of extreme meteorological events over the coming decades. These changes will have impacts on terrestrial ecosystems worldwide and associated carbon cycles, which again might have a positive feedback with global climate change. Questions arise also for the management of European ecosystems:

How vulnerable are European ecosystems to changing magnitude and frequency of extreme meteorological events? What are the associated risk with respect to reduced Carbon sequestration rates and losses in carbon stocks? Is there a need to adapt ecosystem management to meet these challenges? If so, what are appropriate measures?

In this contribution a two-step procedure is suggested: First, pan-European vulnerability and risk maps of ecosystems to meteorological extremes, namely droughts and heat waves, are presented. These outcomes are the results of a variety of simulations by multiple process-based ecosystem models covering several climate change scenarios according to IPCC AR4 to meet model and scenario based uncertainties. With vulnerability and risk, the principle output indicators intend to directly reveal their meaning for policy and decision making in practical ecosystem management, which could, for instance, be used to estimate the potential effects on emission reduction commitments.

In a second step, these maps and potential policy recommendations are presented to and discussed with experts in carbon management from local to European level. One first goal is to discuss the appropriateness of the chosen indicators for practical decision-making in order to improve the principle output indicators. The second goal is to collect first reactions on the possible necessity to adapt to the changing pattern of drought and heat waves occurrence, and identify different ways to realise such adaptations. This information helps to better understand the rational of actual ecosystem managers and potentially include them into further research of climate change-adapted system. Finally, the feedback to initial policy recommendations from the practical ecosystem managers will be incorporated to more elaborate versions of policy recommendations and increases both their robustness and acceptance.

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Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Effects of drought on forest ecosystems carbon cycle in China during 2001-2010

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Drought, which is expected to increase in frequency, extent and severity with climate change, affecting the structure, function, process of forest ecosystems. The interaction between extreme climate events and forest ecosystem help us to better understand the biodiversity and vulnerability of ecosystems. However, there is still wide concern about how forest ecosystems respond to extreme drought under climate change. In this study, we used drought index (standard precipitation index, SPI) and a process-based model (Boreal Ecosystems Productivity Simulator, BEPS) to characterize the spatial-temporal pattern of drought conditions in China and explore the impacts on forest ecosystem carbon cycle over the last decade. At the national scale, there was no significant change in drought conditions for entire China during 2001-2010. However, the southwestern area showed increased drought intensity, resulting in significant decreases in NPP. In northern China, particularly in the northeast of China, the area behaved NPP increased consistently with its drought intensity declines. Furthermore, the responses of NPP to drought for different forest types have been also considered. Extreme climate events like drought should be considered in estimating the carbon balance of forest ecosystem.

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Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

CASA modeling of carbon budgets across Europe and Russia with 1km resolution

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Most biogeochemical models work on 1, 0.5, or 0.25 degree resolution (roughly 100x100, 50x50, or 25x25 km). With CASA, 1 km resolution modeling is possible. CASA model is capable of simulating the main terms in carbon budget, NPP and NEE, with very high resolution.

In this talk, I will briefly describe the study including NPP/NEE calculation and parameters optimization, the gridding system for 1km x 1km pixels, conversion of coordinate systems between MODIS tile and conventional Latitude/Longitude, calibration against MODIS and Fluxnet data, and the spatial and temporal results.

The study has a monthly temporal resolution, performed for the time period 2000-2011. Carbon fluxes due to land use change during this period will also be discussed.

This study combines several data sets from different sources and fits them into 1km x 1km pixels. MODIS products are used for NPP and NEE calculation, including MOD15A2 for fPAR, MOD16 for PET, and MCD12Q1 for land cover. High resolution meteorological data from MPI-Jena (0.25 x 0.25 degree) and lower resolution (1.5 x 1.5 degrees) data from ECMWF are employed for modeling Europe and Russia, respectively. For calibration purpose, MODIS MOD17 for GPP and Fluxnet sites data are also used.

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Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Evaluating the effect of soil drought on inner-alpine coniferous trees based on sap flow measurements

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Climate simulations anticipate a clear increase of mean summer temperature with synchronous decrease in summer precipitation during the course of the current century in Central Europe. As a consequence, transpiration of forest trees and stands may be altered along with soil water availability. A dry inner-alpine open *Pinus sylvestris* forest (*Erico-Pinetum typicum*; *Pinus sylvestris* 60%, *Picea abies* 20% and *Larix decidua* 20%) within the inner Alpine dry valley of the Inn River in Tyrol, Austria provides ideal conditions for studying the effect of predicted enhanced soil drought to conifers. For enhancing soil drought we installed a transparent roof construction above the forest floor to prevent precipitation to reach the soil. The roofed area covered 240 m² and included 10 trees. A respective number of 11 trees served as controls in the absence of any manipulation. In 2011 withholding of precipitation caused a continuous decline in soil water availability down to < 0.05 m³ m⁻³. As a consequence sap flow density (Qs) for all studied tree species declined compared to the control trees. The decline was most pronounced in evergreen *Pinus sylvestris* followed by *Picea abies* and was least pronounced in deciduous *Larix decidua*. Regression analysis between normalized Qs and environmental parameters showed the strongest correlation with photosynthetic active radiation (PHAR). This strong correlation independent of species and treatment highlighted the overall importance of solar radiation on tree transpiration.

ID: 246

Session 2: Large-scale observations and modeling

Type of Contribution: Invited Lecture

Biospheric Feedbacks from Climate Extremes and Disturbances

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Climate extremes and disturbances can profoundly alter the structure and function of ecosystems and initiate significant feedbacks to climate with sometimes long-lasting consequences. This presentation will highlight latest examples and compare and contrast the unique feedback legacies following severe droughts, hurricanes, fires, insect outbreaks, and harvest disturbances. With an emphasis on carbon and albedo impacts across North America, we will examine the frequency of each disturbance type over recent decades, and explore their trends and interannual variability. An attempt will be made to synthesize how these agents of change combine to influence the global biosphere and climate system.

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Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Response of ecosystem carbon and water dynamics to spring drought in Switzerland

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During the past decade, Europe has experienced several exceptional weather events such as severe summer droughts and heat spells in 2003 and 2010, which heavily disturbed the carbon and water balances of terrestrial ecosystems. Regional climate models have predicted more intense and frequent extreme events for the future. While the understanding of the impact of summer drought on ecosystem carbon and water dynamics has progressed recently, our knowledge on the effects of spring drought on ecosystem fluxes is still very limited.

In Switzerland, spring 2011 was among the warmest and driest since start of meteorological measurements, resulting in a pronounced spring drought (March till May). We synthesized data from the regional eddy covariance network Swiss FluxNet (3 grassland, 2 forest and 1 cropland sites) to assess the effects of this drought on ecosystem carbon dioxide and water vapour fluxes. The objectives of our synthesis study were to (1) evaluate the phenological development of the vegetation, (2) assess the range and magnitude of ecosystem carbon and water vapour fluxes, (3) quantify ecosystem carbon and water budgets, and (4) investigate potential carry-over effects of this spring drought in Switzerland.

Our results show an earlier phenological development during 2011, reductions in gross primary productivity (GPP), reduced evapotranspiration (ET), along with enhanced water use efficiency (WUE) in forest ecosystems but not in grassland systems during spring drought. Overall, our study indicates a diverging response of ecosystem carbon and water dynamics in grasslands and forests.

ID: 199

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Climate change increases the frequency and severity of episodes of streamwater acidification: an analysis of the 40-year data record from Birkenes, Norway

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Acidification of surface waters is often characterised by chronically low pH and acid neutralising capacity (ANC) due to deposition of sulphur and nitrogen compounds. Superimposed on the chronic acidification are acid episodes driven by high flow, drought, seasalt deposition and snowmelt. Acid episodes cause most of the biological damage, especially in streams. The 40-year record of streamwater chemistry from Birkenes, Norway, consisting of >2500 water chemistry samples (mostly weekly) shows 105 episodes below the threshold of ANC $-50 \mu\text{eq/l}$. The frequency, severity and duration of episodes have diminished since about 1990 due to chemical recovery following reduced deposition of sulphur. In particular SO_4 -driven episodes have become less frequent, whereas episodes driven by climate (wind, high flow) continue. The data provide the basis for empirical relationships between strength of the driver, degree of chemical recovery, and severity of ANC depression. These can be used together with output from acidification models such as MAGIC and downscaled global climate models to predict the future frequency, severity and duration of episodes given scenarios of acid deposition and climate change.

ID: 205

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Modelling the decadal trend of ecosystem carbon fluxes in a temperate deciduous forest demonstrates the important role of functional changes

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Temperate forests are globally important carbon stocks and sinks. Trends (1997-2009) in net ecosystem exchange (NEE) have been observed in a Danish beech forest, Sorø and this trend cannot be entirely attributed to the direct climatic effects. This study sought to clarify the mechanisms responsible for the interannual variability in NEE, using an ecosystem model (CoupModel) and model data fusion (MDF) with multiple constraints and modelling experiments. The model was able to simulate the observed data well at diurnal and seasonal time scales but did not reproduce the long-term observed trends in NEE, when global parameter estimates were used. Annual parameter estimates were able to reproduce the decadal scale trends; the yearly fitted posterior parameters (e.g. the light use efficiency) indicated a role for ecosystem functional change. A potential influence of nitrogen demand during mast years was also shown in the posterior parameter sets. The dynamics in the biological parameters is fundamental for the long-term simulation of ecosystem carbon balance in the investigated forest. Increasing weather variability and more frequent occurrence of extreme events are likely to stimulate ecosystem functional change. The cause and consequence of such changes are therefore important subjects that need further investigation.

ID: 143

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Response of vegetation structure to extreme climate events in Europe: Analysis from fire regime perspective

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Climate change significantly affects terrestrial ecosystems in terms of vegetation structure and functionality. Extreme climate events will likely intensify this effect (atop of climate trends). In our study, which was part of the FUME project, we assess uncertainties and sensitivities of future fire regimes and ecosystem response by investigating the effect of climate change, changes of population density and CO₂ concentration on burned area, vegetation dynamics, and ecosystem carbon cycling in European forests. The dynamic global vegetation model LPJ-GUESS (Smith, Prentice, and Sykes 2001), with an enhanced prognostic wildfire module (Knorr et al., in preparation) is applied to simulate changes in vegetation phenology, productivity, relative cover and population structure. The model represents forest vegetation by 22 plant function types (PFTs) that can be mapped to dominant tree species (Hickler et al. 2012; Arneth et al. 2008). Simulations compare effects of the presence or absence of fires in terms of the ecosystem response to climate, CO₂ and human population changes. We will assess vegetation biomass, PFT composition and net primary production (NPP) as important indicators for changes, including ecosystem recovery after extreme events.

ID: 225

Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Oral Presentation / Talk

N deposition effects on ecosystem structure and function are regulated by climate extremes

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N deposition has changed ecosystem structure and function significantly across the world. However, the impacts of climate extremes on these changes are rarely studied. This knowledge is particularly needed with the increase of climate extremes. Based on 6 years of study, we found that N addition increased community productivity, except in 2008 (extremely wet) and 2010 (extremely dry). N addition exhibited no significant effect on community productivity in 2008, because inorganic N was lost through eluviation resulting from extremely high precipitation rates. However, N addition decreased community productivity in 2010. As species richness was higher in low N addition rate treatments than in high N addition rate treatments, the community in low N addition rate treatments could achieve higher productivity by compensatory effects under extreme drought. Extreme drought also affected community structure significantly. We found that N addition decreased dominant species representations, while promoted opportunistic species in the first 3 years. However, extreme drought in 2009 and 2010 reversed this trend. While extreme drought killed most other species, the dominant species survived, and they recovered quickly when the rain returned. Our results indicate that the effect of N addition on ecosystem structure and function was strongly regulated by climate extremes.

ID: 181

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Response of vegetation production to more extreme precipitation regimes across biomes from remote sensing measurements

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Precipitation regimes are predicted to shift to more extreme patterns that are characterized by more intense rainfall events and longer dry intervals, yet their ecological impacts on vegetation production remain uncertain across biomes in natural climatic conditions. This in situ study investigated the effects of novel climatic conditions on aboveground net primary production (ANPP) by combining a greenness index EVI from MODIS measurements and climatic records during 2000 to 2009 from 11 long-term experimental sites in multiple biomes and climates. Results showed that extreme precipitation patterns decreased the sensitivity of ANPP to total annual precipitation (PT), at the regional and decadal scales, leading to a mean 20% decrease in rain-use efficiency across biomes. Relative decreases in ANPP were greatest for arid grassland (16%) and Mediterranean forest (20%), and less for mesic grassland and temperate forest (3%). The co-occurrence of more heavy rainfall events and longer dry intervals caused greater water stress that resulted in reduced vegetation production. A new generalized model was developed to improve predictions of the ANPP response to changes in extreme precipitation patterns by using a function of both PT and an index of precipitation extremes. These findings suggest that extreme precipitation patterns have more substantial and complex effects on vegetation production across biomes, and are as important as total annual precipitation in understanding vegetation processes. With predictions of more extreme weather events, forecasts of ecosystem production should consider these non-linear responses to altered precipitation patterns associated with climate change.

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Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Oral Presentation / Talk

Strong resistance of an Asian subtropical forest to extreme droughts: leaf, tree and ecosystem level mechanisms contributing to homeostasis of water and carbon balances

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The frequency and strength of droughts are predicted to increase in many areas of the world, while how terrestrial ecosystems may respond remains unclear. In order to understand the eco-physiological mechanisms controlling the responses of subtropical forests to rainfall anomalies, we studied leaf physiology, tree water use and growth, leaf area index, canopy conductance, ecosystem carbon exchange, and soil water status of a primary Asian subtropical forest during normal dry seasons and the 2010 “once in a century” drought. Interestingly, trees in the forest were not water-deficient even during the driest period of the 2010 rainfall anomaly (predawn leaf water potentials > -0.4 MPa), and midday leaf water potentials did not differ between the 2009 and 2010 dry seasons. The homeostasis in midday water potential in 2010, despite a substantial decrease in soil water content and the substantial lowering of the water table, was a consequence of decreased stomatal and canopy conductance. Notably, down-regulation of transpiration incurred a small cost in carbon uptake at leaf and ecosystem levels; although net ecosystem CO₂ assimilation decreased from that of the 2009 dry season by 1.59 mol m⁻² month⁻¹ in the last month of the 2010 dry season, the forest was still a large carbon sink (4.74 mol m⁻² month⁻¹). Our results provide evidence that some Asian subtropical forests can buffer the effects of extreme rainfall shortages by using soil and ground water storages, by lowering transpiration, and by increasing water use efficiency. The considerable carbon gain by the forest during the dry season and the rainfall anomaly also partially explains the dominance of evergreen trees in the subtropical forests of Southwest China and implies a large contribution of Asian subtropical forests to the global carbon cycle.

ID: 112

Session 2: Large-scale observations and modeling

Type of Contribution: Poster Presentation

Evaluating the extreme drought impact on vegetation condition and productivity in the Southwestern China using MODIS data

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Abstract: Drought, as a recurring extreme climate event, affects the structure, function, process of terrestrial ecosystems. Southwestern China experienced the most severe drought in the past decade which prolonged from autumn 2009 to spring 2010. Our aim is to characterize drought conditions in the southwest of China and explore the impacts on vegetation condition and terrestrial ecosystem productivity. Standard precipitation index (SPI) was used to characterize drought area and intensity and a LUE model was used to explore the effect of drought on the terrestrial ecosystem productivity with MODIS data. The 10-year period of this study included both "normal" precipitation years and an severe drought in 2009-2010. The SPI at different scales captured the major drought events in the Southwestern China during the study period. Vegetation greenness (NDVI and EVI) both showed wide spread declines in the 2010 year but not 2009, which indicated that there were 4-6 months lag between drought events and maximum declines in vegetation greenness. Meanwhile, annual NPP in Southwestern China declined by an average of 8% in 2010 compared to mean value in the period 2001-2008.

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Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Poster Presentation

Climatic drivers of temporal variability in forest ecosystem NEE

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Forest ecosystems are an important sink for atmospheric CO₂ due to their ability to take up large amounts of carbon for wood growth. Yet, it is still unclear how net ecosystem exchange (NEE = Gross primary productivity (GPP) – total ecosystem respiration (TER)) of forest ecosystems will respond to large climatic variabilities associated with climate change.

Explaining inter- and intra-annual variabilities of forest NEE was shown to be challenging although weak links (often $r^2 < 0.25$) have been reported between climatic variables and NEE measured in the field with the eddy covariance technique. Furthermore, it is likely that lagged ecosystem responses in terms of carbon dioxide loss and/or uptake to climatic anomalies (i.e., deviations from the long-term mean, 30 yrs) obscure stronger relationships.

15 years of eddy flux data from the Swiss Fluxnet site Davos Seehornwald were used to investigate current and previous year climatic drivers of inter-annual NEE variability. Spring conditions of the current year were consistently identified as important drivers of this spruce forest ecosystem, limiting GPP by increasing TER. Moreover, previous year climatic variables also affected NEE, but less consistently among years.

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Type of Contribution: Oral Presentation / Talk

Extreme weather event impacts ecosystem functioning more than net Carbon uptake in the Arctic tundra

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Increasing temperature tends to enhance plant productivity and CO₂ uptake in northern ecosystems, while water limitation has the opposite effect. The results of this study show that during an extremely warm and low precipitation summer (2007), the combination of high radiation and low water availability strongly depressed moss photosynthesis, while not negatively affecting vascular plants. To understand the impact of this extreme weather conditions, we compared this atypical summer (2007) to the "typical" cooler and wetter previous summer (2006). Ecosystem respiration (Reco) was constantly higher during the warm and dry summer 2007. Gross primary production (GPP), was much higher early in summer 2007 and consistent with an earlier activation of the ecosystem that started uptaking C right after the snow melt. However, later in the season, GPP presented lower values and the C accumulation rates were much lower in summer 2007 than what observed in the previous summer.

No matter these differences, during the extreme summer (2007), the net ecosystem CO₂ uptake (NEE) was similar and even slightly higher than the ones observed in summer 2006. This ecosystem scale result was consistent to the observed higher C uptake in summer 2007 over the entire North Slope of Alaska estimated using CarbonTracker. Importantly, even if similar net C assimilations were observed under these very different conditions which would suggest the resilience of this ecosystem to extreme weather events, we observed substantial necrosis of the moss mat in summer 2007. This implies that negative impacts to certain vegetation components (e.g. mosses) and possibly biodiversity loss, might be undetected by larger scale studies, making essential the coupling of large and small scale studies.

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Session 2: Large-scale observations and modeling

Type of Contribution: Oral Presentation / Talk

Significant global reduction of carbon uptake by water-cycle driven extreme vegetation anomalies

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Understanding the role of climate extremes is increasingly in the focus of Earth system sciences and highly relevant to climate change assessments [1]. In particular, we need a precise understanding of the impact of extreme events on the terrestrial biosphere in order to quantify the relevance for, and feedbacks with, the climate system. Previous studies have shown that climate extremes may have severe regional effects on the carbon cycle, but a state-of-the-art global impact assessment is still lacking. Hence, here we quantify large spatiotemporal contiguous extreme anomalies in global gross primary productivity (GPP). Using a definition of less than 5% chance of occurrence [1], we estimate that the 100 largest negative extreme events in GPP over the last 30 years are responsible for a decrease in carbon uptake of about 40 Pg C. Moreover, our results demonstrate that the decrease in carbon uptake due to negative extremes is much higher than the increase in uptake due to positive extremes (up to 25%). We find that most of the negative extremes are best explainable by phases of water scarcity in the ecosystems. An analysis of the results from the "Coupled Model Intercomparison Project Phase 5" (CMIP5) reveals that the magnitude of extremes in GPP tends to increase. However, if the magnitude of these extremes is related to the total converted GPP, their relative impact rather decreases in the course of the century. We conclude that ecosystems might be more resilient against climate change than previously thought.

[1] Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, IPCC SREX report, 2012 (eds C. B. Field et al.)

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Session 1: Ecosystem responses to climate variability and weather extremes

Type of Contribution: Oral Presentation / Talk

Grassland root system resistance and recovery to a summer extreme in actual and future climate

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Maintenance of root system activity during period of severe drought is critical for terrestrial ecosystems in order to resist and thereafter to recover from this stress. When upper soil layers dry one major acclimation of plant roots is to colonize deeper soil layers and to maintain living roots to uptake nutrients and water. Thus in future climate conditions with more severe summer heat wave, plant roots are of prime importance for maintenance of ecosystem services.

Root system of an upland grassland was studied in field conditions during two years using minirhizotrons to understand its response to a summer extreme. In addition grassland was subjected to actual and future climate treatments to test the hypothesis that acclimatized plants to future climate show higher recovery. These treatments corresponded respectively to (1) application of long-term weather conditions of the site (control) and (2) precipitation reduction in summer and autumn with rainout shelters (curtains) and night-time soil warming (passive warming with curtains). The first year a summer extreme was applied in both climate treatments. It corresponded to two months precipitation reduction combined with two weeks active warming. The second year both extreme treatments received same conditions as actual and future climate treatments. In total four climate treatments were applied combined with two cutting frequencies, frequent (six cuts per year) and infrequent (three cuts per year).

Our results showed that in summer growth rate of roots localized at soil surface decreased in response to the extreme, whereas roots growing in deeper soil layer were not affected. In autumn and one year after, root growth recovered from the application of the extreme. More precisely, an over-production of roots was observed in deep soil layer for grassland subjected to future climate (+24%), and for roots grown at surface soil layer for actual climate (+20%). The root response to future climate changed according to cutting frequency: in frequent cut root over-production occurred at soil surface (+44%); in infrequent cut this trend was observed in deep soil layer (+21%). In addition root lifespan of the extreme treatments was higher than in the control treatment, indicating a decrease of root system turnover. Finally grassland root system recovered from the summer extreme, by producing more roots but this compensatory process was not sufficient to sustain aerial biomass production to the level of the control treatment. These results suggest asymmetric response of above and below-ground compartments of grassland in future climate scenario including summer extreme. Furthermore infrequent cut was a better practice than frequent cut for adapting grassland to future climate including summer extreme.