Direct evidence for modulation of photosynthesis by an arbuscular mycorrhiza-induced carbon sink strength

It has been suggested that plant carbon (C) use by symbiotic arbuscular mycorrhizal fungi (AMF) may be compensated by higher photosynthetic rates because fungal metabolism creates a strong C sink that prevents photosynthesize accumulation and down-regulation of photosynthesis. This mechanism remains largely unexplored and lacks experimental evidence. We report here two experiments showing that the experimental manipulation of the mycorrhizal C sink significantly affected photosynthetic rates of cucumber host plants. We expected that a sudden reduction in sink strength would cause a significant reduction in photosynthetic rates, at least temporarily. Excision of part of the extraradical mycorrhizal mycelium from roots, and causing no disturbance to the plant, induced a sustained (10-40%) decline in photosynthetic rates that lasted from 30 min to several hours in plants that were well nourished and hydrated and in the absence of growth or photosynthesis promotion by mycorrhizal inoculation. This effect was though minor in plants growing at high (700 ppm) atmospheric CO2. This is first direct experimental evidence for the carbon sink strength effects exerted by arbuscular mycorrhizal symbionts on plant photosynthesis. It encourages further experimentation on mycorrhizal source-sink relations and may have strong implications in large-scale assessments and modelling of plant photosynthesis. This article is protected by copyright. All rights reserved.
Methane emissions from tree stems: a new frontier in the global carbon cycle

Tree stems from wetland, floodplain and upland forests can produce and emit methane (CH$_4$). Tree CH$_4$ stem emissions have high spatial and temporal variability, but there is no consensus on the biophysical mechanisms that drive stem CH$_4$ production and emissions. Here, we summarize up to 30 opportunities and challenges for stem CH$_4$ emissions research, which when addressed will improve estimates of magnitudes, patterns, drivers and trace the potential origin of CH$_4$ emissions. We identified the need (i) for both long-term high frequency measurements of stem CH$_4$ emissions to understand the fine scale processes, alongside rapid large-scale measurements designed to understand variability across individuals, species and ecosystems; (ii) to identify microorganisms and biogeochemical pathways associated with CH$_4$ production; and (iii) to develop a mechanistic model including passive and active transport of CH$_4$ from the soil-tree-atmosphere continuum. Addressing these challenges would help to constrain magnitudes and patterns of CH$_4$ emissions, and would allow for the integration of pathways and mechanisms of CH$_4$ production and emissions into process-based models. These advances will facilitate upscaling of stem CH$_4$ emissions to the ecosystem level and quantify the role of stem CH$_4$ emissions for the local-to-global CH$_4$ budget. This article is protected by copyright. All rights reserved.
ambient Scandinavian early summer conditions (19/12 °C, day/night; 400 ppm CO₂). Around flowering a 10-day heatwave of 33/28 °C (day/night) was superimposed to all treatments. The lowest average grain yield was observed when the heatwave was superimposed onto the combined elevated temperature and CO₂ treatment. Here the yield decreased by 42% compared to no heatwave and 52% compared to ambient conditions. When the heatwave was superimposed onto ambient conditions the average grain yield decreased by 37% compared to no heatwave. There was no significant difference between the relative grain yield decrease caused by the heatwave in the ambient and future climate scenarios. In contrast, the vegetative aboveground biomass increased upon heatwave exposure, leading to a strong decline in the harvest index. Our results strongly emphasize the need to produce heatwave resilient cultivars.

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Ultrafine particles in inhabited areas in the Arctic - From very low to high concentrations
The Arctic is considered a pristine environment, where pollution mainly originates from global sources. The present study examines particle number concentrations (PNCs) and the main sources of airborne ultrafine particles (UFPs, d < 100 nm) in the town Sisimiut and two nearby settlements, Sarfangnit and Itilleq, in West Greenland. Measurements were carried out during three weeks in April and May 2016. Air temperatures during the measurements ranged from −4.4 to +8.7 °C. A portable condensation particle counter (P-Trak) was used for the measurements. Results showed that the lowest concentrations were found during days with high wind speeds, with the lowest PNC average of 72 ± 11 cm⁻³ (n = 9) (12 m/s). Background concentrations were usually low compared to more densely populated countries, with a couple of exceptions, where there was no clear cause for elevated PNCs in a background area East of Sisimiut. Measured PNCs in
the flue gas in the waste incineration plant in Sisimiut showed up to 334,976 cm$^{-3}$ and are expected to be higher in the gas after it is released through the chimney. Average PNCs up to 77,009 ± 43,880 cm$^{-3}$ (n = 26) were measured by a road located by the harbor in Sisimiut, while subsequent measurements at the same location showed much lower PNCs. The presence of heavy machinery elevated PNCs highly during two measurement events, giving PNCs up to 270,993 cm$^{-3}$ but dropping to 1180 cm$^{-3}$ 10 min later, after the vehicle had passed by. A measurement event in Sisimiut Airport while an aircraft landed and departed showed an average PNC of 44,741 ± 85,094 cm$^{-3}$ (n = 21). Two 24-h measurements resulted in average PNCs of 2960 ± 5704 cm$^{-3}$ and 3935 ± 10,016 cm$^{-3}$ respectively.

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**Variable O$_3$ episodes’ influence on yield and physiology in old and new wheat varieties under a climate change regime with elevated temperature and CO$_2$ levels**

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**Carbon Sequestration by Urban Trees**
Carbon dioxide (CO$_2$) is the most prominent component of anthropogenic greenhouse gas emissions, resulting mainly from fuel combustion in the built environment – for activities such as heating of buildings, urban mobility and cooking. The concentration of near-surface CO$_2$ in cities is affected by a range of factors, including traffic density and atmospheric stability. Plants have the capacity to sequester CO$_2$ through photosynthesis, and can therefore store carbon in plant biomass and in the soil. Green areas in the city may significantly affect local concentrations of atmospheric CO$_2$, as observed in urban-to-rural comparisons showing lower CO$_2$ concentration in the presence of vegetation. CO$_2$ sequestration over the ‘urban forest’ displays diurnal variation during the growing period, with uptake during daytime when plants are photosynthetically active, and nocturnal emissions in response to respiration. High atmospheric CO$_2$ concentrations represent a fertilizer for plants, promoting more efficient photosynthesis. However, urban plants often experience environmental stresses which compromise the photosynthetic apparatus, and in extreme cases may turn plants from carbon sinks into carbon sources. In this chapter, we review the most recent studies and highlight emerging
research needs for a better understanding of present and future roles of urban trees in removing CO2 from the atmosphere.

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**Langtidsmålinger viser overraskende resultat: Bøgeskov øger kulstofoptagelsen med tiden**

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**Long-term and realistic global change manipulations had low impact on diversity of soil biota in temperate heathland**
In a dry heathland ecosystem we manipulated temperature (warming), precipitation (drought) and atmospheric concentration of CO2 in a full-factorial experiment in order to investigate changes in below-ground biodiversity as a result of future climate change. We investigated the responses in community diversity of nematodes, enchytraeids, collembolans and oribatid mites at two and eight years of manipulations. We used a structural equation modelling (SEM) approach analyzing the three manipulations, soil moisture and temperature, and seven soil biological and chemical variables. The analysis revealed a persistent and positive effect of elevated CO2 on litter C:N ratio. After two years of treatment, the fungi to bacteria ratio was increased by warming, and the diversities within oribatid mites, collembolans and nematode groups were all affected by elevated CO2 mediated through increased litter C:N ratio. After eight years of treatment, however, the CO2-increased litter C:N ratio did not influence the diversity in any of the four fauna groups. The number of significant correlations between treatments, food source quality, and soil biota diversities was reduced from six to three after two and eight years, respectively. These results suggest a remarkable resilience within the soil biota against global climate change treatments in the long term.
**N2O emission from plant surfaces – light stimulated and a global phenomenon**

Nitrous oxide (N2O) is an important long-lived greenhouse gas and precursor of stratospheric ozone depleting mononitrogen oxides. The atmospheric concentration of N2O is persistently increasing; however, large uncertainties are associated with the distinct source strengths. Here we investigate for the first time N2O emission from terrestrial vegetation in response to natural solar ultra violet radiation. We conducted field site measurements to investigate N2O atmosphere exchange from grass vegetation exposed to solar irradiance with and without UV-screening. Further laboratory tests were conducted with a range of species to study the controls and possible loci of UV-induced N2O emission from plants. Plants released N2O in response to natural sunlight at rates of c. 20-50 nmol m⁻² h⁻¹, mostly due to the UV component. The emission rate is temperature dependent with a rather high activation energy indicative for an abiotic process. The prevailing zone for the N2O formation appears to be at the very surface of leaves. However, only c. 26% of the UV-induced N2O appears to originate from plant-N. Further, the process is dependent on atmospheric oxygen concentration. Our work demonstrates that ecosystem emission of the important greenhouse gas, N2O, may be up to c. 30% higher than hitherto assumed.
Advances in FACE and manipulation techniques

Experimental techniques to expose plants and ecosystems to elevated CO₂ have been around for decades, starting out with branch cuvettes, chambers and green houses and in the 90ies leading to the development of the FACE (Free Air Carbon Enrichment) technique, which has been and still is widely used. The FACE technique is used under field conditions and has been developed over the years to be applied for many types of ecosystems from low stature shrub, grass and arable lands to high stature forest trees. These experiments have provided extensive knowledge and data on CO₂ effects on individual plants and processes as well as whole terrestrial ecosystems. The ultimate goal of any experiment is to mimic future conditions and stress factors in a realistic and/or relevant way and to measure important and relevant responses at various spatial scales. FACE experiments are still facing some clear challenges when it comes to the experimentation or scenarios typically tested as well as the response measurements performed, challenges that limits our knowledge and understanding and need to be addressed and overcome in the future. With respect to the experimentation and scenarios, a significant constraint for FACE experiments is the cost of the CO₂ in such experiments which increases substantially with ring sizes and vegetation height as well as of course the number of replicates. FACE experiments can relatively easily be combined with other stress factors, but for every factor a full factorial combination doubles the costs. Consequently, very few combination studies exist and knowledge on interactions among CO₂ and other factors is still very limited, and especially interactions with extreme weather events are largely unknown. However, recent data suggests that such interactions are important and may not be easily forecasted from single factor experiments. With respect to response measurements, a key scientific question is how elevated CO₂ will affect the atmosphere-biosphere feedback. However, there are significant challenges associated with directly measuring the ecosystem carbon balance in FACE experiments, and despite numerous such experiments, there is a general lack of carbon feedback measurements.

A replicated climate change field experiment reveals rapid evolutionary response in an ecologically important soil invertebrate

Whether species can respond evolutionarily to current climate change is crucial for the persistence of many species. Yet, very few studies have examined genetic responses to climate change in manipulated experiments carried out in natural field conditions. We examined the evolutionary response to climate change in a common annelid worm using a controlled replicated experiment where climatic conditions were manipulated in a natural setting. Analyzing the transcribed genome of 15 local populations, we found that about 12% of the genetic polymorphisms exhibit differences in allele frequencies associated to changes in soil temperature and soil moisture. This shows an evolutionary response to realistic climate change happening over short-time scale, and calls for incorporating evolution into models predicting future response of species to climate change. It also shows that designed climate change experiments coupled with genome sequencing offer great potential to test for the occurrence (or lack) of an evolutionary response.
Concurrent elevation of CO$_2$, O$_3$ and temperature severely affects oil quality and quantity in rapeseed

Plant oil is an essential dietary and bio-energy resource. Despite this, the effects of climate change on plant oil quality remain to be elucidated. The present study is the first to show changes in oil quality and quantity of four rapeseed cultivars in climate scenarios with elevated [CO$_2$], [O$_3$] and temperature (T) combined and as single factors. The combination of environmental factors resembled IPCC’s ‘business as usual’ emission scenario predicted for late this century. Generally, the climate scenarios reduced the average amounts of the six fatty acids (FAs) analysed, though in some treatments single FAs remained unchanged or even increased. Most reduced was the FA essential for human nutrition, C18:3-ω3, which decreased by 39% and 45% in the combined scenarios with elevated [CO$_2$]+T+[O$_3$] and [CO$_2$]+T, respectively. Average oil content decreased 3–17%. When [CO$_2$] and T were elevated concurrently, the seed biomass was reduced by half, doubling the losses in FAs and oil content. This corresponded to a 58% reduction in the oil yield per hectare, and C18:3-ω3 decreased by 77%. Furthermore, the polyunsaturated FAs were significantly decreased. The results indicate undesirable consequences for production and health benefits of rapeseed oil with future climate change. The results also showed strong interactive effects of CO$_2$, T and O$_3$ on oil quality, demonstrating why prediction of climate effects requires experiments with combined factors and should not be based on extrapolation from single factor experiments.

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Bibliographical note
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Effects of gasification biochar on plant-available water capacity and plant growth in two contrasting soil types

Abstract Gasification biochar (GB) contains recalcitrant carbon that can contribute to soil carbon sequestration and soil quality improvement. However, the impact of GB on plant-available water capacity (AWC) and plant growth in diverse soil types still needs to be explored. A pot experiment with spring barley (Hordeum vulgare L.) was conducted to investigate the effect of soil amendment by 1% straw and wood gasification biochar (SGB and WGB), respectively, on AWC and plant growth responses under two levels of water supply in a temperate sandy loam and a coarse sandy subsoil. In the sandy loam, the reduced water regime significantly affected plant growth and water consumption, whereas the effect was less pronounced in the coarse sand. Irrespective of the soil type, both GBs increased AWC by 17–42%, with the highest absolute effect in the coarse sand. The addition of SGB to coarse sand led to a substantial increase in plant biomass under both water regimes: shoot growth by 40–165% and root growth by 50–57%. However, no positive effects were achieved by the addition of WGB. In the sandy loam, soil application of GB had no or negative effects on plant growth. Our results suggest that SGB has considerable potential for enhancing crop productivity in coarse sandy soils by increasing soil water retention and improving root development.

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Functional traits of urban trees: Air pollution mitigation potential

In an increasingly urbanized world, air pollution mitigation is considered one of most important issues in city planning. Urban trees help to improve air quality by facilitating widespread deposition of various gases and particles through the provision of large surface areas as well as through their influence on microclimate and air turbulence. However, many of these trees produce wind-dispersed pollen (a known allergen) and emit a range of gaseous substances that take part in photochemical reactions - all of which can negatively affect air quality. The degree to which these air-quality impacts are manifested depends on species-specific tree properties: that is, their "traits". We summarize and discuss the current knowledge on how such traits affect urban air pollution. We also present aggregated traits of some of the most common tree species in Europe, which can be used as a decision-support tool for city planning and for improving urban air-quality models.

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In the present study a set of 108 spring barley (H. vulgare L.) accessions were cultivated under predicted future levels of temperature and [CO2] as single factors and in combination (IPCC, AR5, RCP8.5). Across all genotypes, elevated [CO2] (700 ppm day/night) slightly decreased protein concentration by 5%, while elevated temperature (+5 °C day/night) substantially increased protein concentration by 29%. The combined treatment increased protein concentration across accessions by 8%. This was an increase less than predicted from strictly additive effects of the individual treatments. Despite the increase in grain protein concentration, the decrease in grain yield at combined elevated temperature and elevated [CO2] resulted in 23% less harvestable protein. There was variation in the response of the 108 accessions, which might be exploited to at least maintain if not increase harvestable grain protein under future climate change conditions.
Solar UV Irradiation-Induced Production of Greenhouse Gases from Plant Surfaces: From Leaf to Earth
During the past few decades it has been documented that the ultra-violet (UV) component of natural sunlight alone or in combination with visible light can instantaneously stimulate aerobic plant production of a range of important trace gases: CH$_4$, CO$_2$, CO, short-chain hydrocarbons/ non-methane volatile organic compounds (NMVOC), NO$_x$ and N$_2$O. This gas production, near or at the plant surface, is a new discovery and is normally not included in emission budgets (e.g. by the Intergovernmental Panel on Climate Change, IPCC) due to a lack of information with respect to validation and upscaling. For CH$_4$, it is known that the light dose controls emission under ambient and artificial light conditions, but the atmospheric gas composition and other environmental factors can influence gas production as well. Several plant components, including pectin and leaf wax, have been suggested as a precursor for CH$_4$ production, but underlying mechanisms are not fully known. For other gases such generating processes have not been established yet and mechanisms remain hypothetical. Field measurements of UV-induced emissions of the gases under natural light conditions are scarce. Therefore, realistic upscaling to the ecosystem level is uncertain for all gases. Nevertheless, based on empirical response curves, we propose the first global upscaling of UV-induced N$_2$O and CO to illustrate emission ranges from a global perspective and as a contribution to an ongoing quantification process. When scaled to the global level, the UV-induced emission of CO by vegetation surfaces amounts to up to 22 Tg yr$^{-1}$, which equals 11–44% of all the natural terrestrial plant sources accounted for so far. The total light-driven N$_2$O emissions amount to 0.65–0.78 Tg yr$^{-1}$, which equals 7–24% of the natural terrestrial source strength accounted for (range 3.3–9 Tg N yr$^{-1}$). In this review, we summarize current knowledge, based on experimental work with sunlight and artificial light, and estimate potential emission ranges and uncertainties, placing the available data into perspective. We discuss the state of the art in proposed mechanisms, precursors and environmental relationships, we consider the relevance of measured emission rates, and we also suggest a range of future research topics. Furthermore we propose and describe methods and techniques that can be used for future research.

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Solar UV irradiation-induced production of N$_2$O from plant surfaces - low emissions rates but all over the world
Nitrous oxide (N$_2$O) is an important long-lived greenhouse gas and precursor of stratospheric ozone depleting mono-nitrogen oxides. The atmospheric concentration of N$_2$O is persistently increasing; however, large uncertainties are associated with the distinct source strengths. Here we investigate for the first time N$_2$O emission from terrestrial vegetation in response to natural solar ultra violet radiation. We conducted field site measurements to investigate N$_2$O atmosphere exchange from grass vegetation exposed to solar irradiance with and without UV-screening. Further laboratory tests were conducted with a range of species to study the controls and possible loci of UV-induced N$_2$O emission from plants. Plants released N$_2$O in response to natural sunlight at rates of c. 20-50 nmol m$^{-2}$ h$^{-1}$, mostly due to the UV component. The emission rate is temperature dependent with a rather high activation energy indicative for an abiotic process. The prevailing zone for the N$_2$O formation appears to be at the very surface of leaves. However, only c. 26% of the UV-induced N$_2$O appears to originate from plant-N. Further, the process is dependent on atmospheric oxygen concentration. Our work demonstrates that ecosystem emission of the important greenhouse gas, N$_2$O, may be up to c. 30% higher than hitherto assumed.

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The fundament of food, crop protein production, is threatened by climate change

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A 10-day heatwave at flowering superimposed on climate change conditions strongly affects production of 22 barley accessions

Extreme climate events are projected to be among the future most challenging constraints to plant development. Heatwaves as well as floods and droughts cause acute changes in the growth environment determining our primary production (Collins et al., 2013). Europe experienced extreme heatwaves in 2003 and 2006. In 2003, a 21 % decrease in the French wheat production was found from temperatures up to 6 °C above long-term means and precipitation being less than 50 % of the average (Ciais et al., 2005). One strategy to mitigate this decrease from heatwaves is to identify resilient cultivars and incorporate them in breeding programs.

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A 10-days heatwave around flowering superimposed on climate change conditions significantly affects production of 22 barley accessions

Extreme climate events as heatwaves, floods and storms cause acute changes in season variability influencing primary production and are very likely to increase in magnitude and/or frequency (IPCC, AR5, WGI). In the present study 22 primarily Nordic barley accessions were grown in four basic climate treatments of 1) 19/12°C (day/night) and 400 ppm carbon dioxide concentration \([\text{CO}_2]\) mimicking ambient South Scandinavian summer conditions, 2) elevated temperature (+5°C day/night), 3) elevated \([\text{CO}_2]\) at 700 ppm and 4) the combination of elevated temperature and \([\text{CO}_2]\). Temperature and \([\text{CO}_2]\) were at levels representing a worst case scenario (~RCP8.5, IPCC) at the end of the 21st century. A 10 day-heatwave of 33/22°C (day/night) was superimposed around the time of flowering on the basic climate treatments.

The superimposed heatwave decreased overall grain yield in all combinations, however, vast variation in response was identified among accessions. In the two-factor treatment the decrease in grain yield varied from 2-80%. The heatwave caused the strongest overall effect in the treatment of elevated \([\text{CO}_2]\) decreasing grain yield by 48% and the least effect (35%) was observed under elevated temperature suggesting elevated temperature to have a priming effect. In all heatwave treatments allocation of biomass was changed, increasing aboveground vegetative biomass and decreasing grain yield as previously reported.

The treatment with the combination of elevated temperature, \([\text{CO}_2]\) and the superimposed heatwave may best represent a future climate scenario since more than one climate factor most likely will change at a time. From the basic ambient treatment to the two-factor treatment including heatwave, grain yield decreased 52%. Our study emphasizes the need for assessing the effects of extreme events under climate change conditions on numerous accessions in order to select appropriate genotypes for breeding future cultivars that can secure the primary production.

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Assessing the air pollution distribution in busy street of Copenhagen in the further development of a street pollution model
The EU Air Quality Directive requires Member States to perform Air Quality Monitoring in order to assess ambient air quality for compliance checking with air quality limit values (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:152:0001:0044:en:PDF). This monitoring needs to include areas with the highest concentrations to which the population is exposed, but also areas which are representative for the exposure of the general population; in both cases for the protection of human health as well as for protecting biodiversity in ecosystems. The current project aims at obtaining a detailed dataset for the spatial air pollution distribution in a very busy street, H.C. Andersens Boulevard in Copenhagen; a street where a monitoring site has already been in place for many years. The dataset will be established for the further development of the Operational Street Pollution Model (OSPM) developed at AU; the revised version OSPM includes new features like inhomogeneous distribution of the traffic on different lanes, slope of the street etc (see e.g. Ottosen et al. (2015)). An additional goal for the project is to explore the applicability of low-cost electrochemical sensors for describing pollution distributions in busy streets. The focus of the project is on nitrogen dioxide (NO_2) for which concentrations in recent years have been exceeding EU limit values. The EU limit values have been exceeded since a change of lanes in the street moved traffic closer to the monitoring station. In order to get more detailed information about the traffic flow and its diurnal pattern, manual traffic counts have been performed over 24 hours. In addition a video camera has been installed on the roof of a building next to the street during the monitoring campaign. Measurements are carried out using passive samplers from Radiello.
For weekly measurements and devices based on electrochemical sensors from Alphasense with high temporal resolution. Data from the devices based on electrochemical sensors and the passive samplers will be carefully compared with high quality data obtained from the existing monitoring station (which is also operated by AU).

References

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Genome-wide association study of production and stability traits in barley cultivated under future climate scenarios

Future barley cultivars will have to produce under the constraints of higher temperature in combination with increased concentrations of atmospheric carbon dioxide and ozone as a consequence of climate change. A diverse set of 167 spring barley genotypes was cultivated under elevated levels of temperature (+5 °C) and [CO2] (700 ppm) as single factors and in combination as well as under elevated [O3] (100–150 ppb) as single factor. The setting in general resembled changes projected by IPCC (AR5) to take place at the end of this century. A genome-wide association study (GWAS) was performed to identify markers for increased primary production under climate change conditions and reveal possible genes of interest. Phenotyped traits included grain yield, number of grains, number of ears per plant, aboveground vegetative biomass, harvest index and stability of the production parameters over the five applied treatments. The GWAS encompassed 7864 SNP markers (Illumina iselect), a compressed mixed linear model with the GAPIT package, and conservative validation of markers. A total of 60 marker-trait associations [−log10(P value) 2.97–5.58] were identified, e.g. grain yield under elevated temperature on barley chromosome 2H, static stability of grain yield on 7H, sites for exploitation of elevated [CO2] on 4H and 7H and associations under the two-factor treatment. Marker-trait associations identified from single-factor treatments were not retrieved, when elevated [CO2] and temperature were combined emphasizing the need for multifactor experiments. This GWAS study identified markers and chromosome regions to be targeted in breeding for development of climate resilient cultivars.

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GWAS of Barley Phenotypes Established Under Future Climate Conditions of Elevated Temperature, CO2, O3 and Elevated Temperature and CO2 Combined

Climate change is likely to decrease crop yields worldwide. Developing climate resilient cultivars is one way to combat this production scarcity, however, little is known of crop response to future climate conditions and in particular the variability within crops. In Scandinavia, barley is widely cultivated, but yields have stagnated since the start of this century. In this study we cultivated 138 spring barley accessions in a climate phytotron under four treatments mimicking forecasted levels of temperature, carbon dioxide concentration ([CO2]) and ozone ([O3]) at the end of the 21st century. The ambient control had 19/12°C (day/night) and [CO2] at 385 ppm. Three single-factor treatments had elevated temperature +5°C day/night, [CO2] at 700 ppm or [O3] at 120 ppb, and in a two-factor treatment the combination of elevated temperature and [CO2] was applied. Treatment effects were assessed on grain yield, grain protein concentration, grain protein harvested, number of grains, number of ears, aboveground vegetative biomass and harvest index. In addition, stability of the production was calculated over the applied treatments for the assessed parameters. In the climate scenario of elevated temperature and [CO2] the grain yield of barley decreased 29% and harvested grain protein declined 22%. Vast variation was identified among the individual barley accessions, which should be exploited by plant breeders in the development of climate resilient cultivars. A genome-wide association study (GWAS) of recorded phenotypes and 3967 SNP-markers identified 60 marker-trait associations (-logp > 2.95). Markers were found associated with grain yield under all three single factor treatments temperature, [CO2] and [O3], as well as with stability over treatments. To our knowledge, this is the first study that evaluates numerous barley accessions under future climate conditions and identifies candidate markers for abiotic stress tolerance - markers that could be used in the development of cultivars to secure future primary production.

Impacts of Climate Change on Terrestrial Ecosystem Functioning – An Overview

CLIM4TTE - background
The concentration of CO₂ in the atmosphere is increasing, global temperatures are increasing, and local precipitation patterns are changing with increases in the intensity of rain events and drought periods. This is expected to affect the structure and functioning of terrestrial ecosystems (IPCC, 2013) with major impacts on natural environments as well as ecosystems used for agriculture or forestry. Over the past three decades, major efforts have been devoted to understanding and predicting such impacts of climate change on ecosystem processes and functioning in order to understand the urgency of the changes as well as the possibilities for ecosystem adaptation or climate change mitigation. These efforts have included observations of past changes, monitoring of ongoing changes, observations across environmental gradients (space for time substitution), ecosystem manipulation experiments mimicking future climate changes, and dynamic ecosystem modelling (Beier, 2004; Rustad, 2008). Each of these approaches has its forces and drawbacks, but across all a general limitation is that observations and experiments have focused on on single climate factor. For example, observations across gradients can hardly combine simultaneous and ideal differences in two or even three climate factors at the same time to provide a multi-factor response picture. Ecosystem experiments, which could do it, often limit themselves to one factor for practical reasons or because of lack of resources, since inclusion of one extra factor doubles
the number of experimental units and the demand for resources in a classic experimental design. Therefore, very few multi-factor climate change experiments exist. Instead the underlying assumption has been that if the individual responses are known based on single factor experiments, then dynamic ecosystem or global models can predict the responses of the combined factors. This approach may seem reasonable but is constrained by at least two problems, which CLIMAITE specifically aimed to overcome: 1. When several factors act together, they may interact, and these interactions among the different climate change factors may not be linear and/or predictable. Computer models may predict some of these interactions relatively well (e.g. resource limitations due to increased growth), while other interactions may be unpredictable. 2. Even when models do predict the interactions, we still need multifactor experiments to train and test the models in order to know if the predictions are correct. Another inherent problem related to climate change and experimentation is the time scale. Climate change acts over decades, meaning that climate change experiments running for 2-4 years only highlight short term and transient effects on the ecosystems, while lacking the ability to inform about long term and more stable effects. The "long term" perspective of climate change was therefore another important rationale for the CLIMAITE experiment. The "long term" perspective of climate change calls for long term experiments, which for decades has been argued from the scientific community, was therefore another important rationale for the CLIMAITE experiment. The VILLUM FOUNDATION provided a very rare opportunity to pursue this in reality. In summary, the CLIMAITE experiment was driven by two major rationales: 1) a need for realistic experiments involving combinations of the main climate change drivers and 2) the long term perspective of climate change.

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Jagten på fremtidens planter - ændringer i klimaet udfordre produktivitet og kvalitet
Med avanceret teknologi, der efterligner fremtidens klima, undersøger forskere på DTU og KU, hvordan planter reagerer på cocktailen af forhøjet temperatur, CO₂, ozon og ekstreme hedesøjler.

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Optimal stomatal behaviour around the world

Stomatal conductance (gs) is a key land-surface attribute as it links transpiration, the dominant component of global land evapotranspiration, and photosynthesis, the driving force of the global carbon cycle. Despite the pivotal role of gs in predictions of global water and carbon cycle changes, a globalscale database and an associated globally applicable model of gs that allow predictions of stomatal behaviour are lacking. Here, we present a database of globally distributed gs obtained in the field for a wide range of plant functional types (PFTs) and biomes. We find that stomatal behaviour differs among PFTs according to their marginal carbon cost of water use, as predicted by the theory underpinning the optimal stomatal model1 and the leaf and wood economics spectrum2,3. We also demonstrate a global relationship with climate. These findings provide a robust theoretical framework for understanding and predicting the behaviour of gs across biomes and across PFTs that can be applied to regional, continental and global-scale modelling of ecosystem productivity, energy balance and ecohydrological processes in a future changing climate.

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Organisations: Department of Chemical and Biochemical Engineering, Ecosystems Programme, Macquarie University, Western Sydney University, University of Technology Sydney, University of Lleida, CSIRO Ecosystem Sciences
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Plants increase laccase activity in soil with long-term elevated CO₂ legacy

Actively growing plants can stimulate mineralization of recalcitrant soil organic matter (SOM), and increased atmospheric [CO₂] can further enhance such plant-mediated SOM degradation. Laccases are central for recalcitrant SOM decomposition, and we therefore hypothesized that plants and elevated [CO₂] stimulate laccase activity. We incubated soil exposed to seven years of elevated or ambient field [CO₂] in ambient or elevated [CO₂] chambers for six months either with or without plants (Deschampsia flexuosa). Elevated chamber [CO₂] increased D. flexuosa production and belowground respiration. Interestingly, plants also grew larger in soil with an elevated [CO₂] legacy. Plants stimulated soil microbial biomass, belowground respiration and laccase activity, and the plant-induced laccase stimulation was particularly apparent in soil exposed to long-term elevated [CO₂] in the field, whereas laccase activity was unaffected by short-term chamber [CO₂]. Hence, actively growing plants can stimulate laccase activity, but the potential for plant-induced laccase production appears to depend on the laccase production potential of the soil. Further, initial differences in laccase production potential prevailed during the six months experimental period independent of current [CO₂], although plant production increased at elevated [CO₂] during this period. Taken together, these findings suggest that although laccase activity depends on plant presence, the laccase production potential does not respond fast to increased plant production.

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Organisations: Department of Chemical and Biochemical Engineering, Rise National Laboratory for Sustainable Energy, Department of Environmental Engineering, Ecosystems Programme, University of Copenhagen
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Responses of enchytraeids to increased temperature, drought and atmospheric CO$_2$: Results of an eight-year field experiment in dry heathland

In a long-term field trial we investigated the responses of enchytraeids to simulated future climatic conditions predicted for Denmark. At a semi-natural Danish heathland site we exposed 9.1 m$^2$ plots to elevated atmospheric CO$_2$ concentration (510 ppm), extended summer drought and passive night-time warming. Treatments and all possible combinations of treatments were replicated 6 times. The enchytraeid community was assessed after 8 years of treatment. Atmospheric CO$_2$ did not have any significant effect on the enchytraeid community even though root biomass was increased in plots with elevated CO$_2$. The warming treatment had a modest effect on soil temperatures (0.3 $^\circ$C at 5 cm depth) and did not have significant effect on abundance or biovolume of enchytraeids. However, the individual body size of Chamaedrilus chlorophilus (= Cognettia sphagnetorum partim.) was negatively correlated with soil temperature in spring 2013, perhaps indicating that warming stimulates fragmentation (reproduction) rates at this time of the year. Increased drought in MayeJune 2012 did not have lasting effects on abundance or biomass 3 months after the termination of drought treatment. However, comparison with earlier assessments of enchytraeids in the CLIMAITE experiment shows that the severity of drought and the time elapsed since the last drought is the best predictor of the biovolume (or biomass) of enchytraeids. Moreover, species richness was significantly impacted by the average soil water content experienced by enchytraeids during the 8-year study. It seems, therefore, that the most important factor for enchytraeid abundance and species diversity in the projected future climate conditions is soil water content.
The response in production parameters to projected future levels of temperature, atmospheric carbon dioxide ([CO₂]), and ozone ([O₃]) was investigated in 138 spring barley accessions. The comprehensive set of landraces, cultivars, and breeder-lines, were during their entire life cycle exposed to a two-factor treatment of combined elevated temperature (+5 °C day/night) and [CO₂] (700 ppm), as well as single-factor treatments of elevated temperature (+5 °C day/night), [CO₂] (700 ppm), and [O₃] (100–150 ppb). The control treatment was equivalent to present average South Scandinavian climate (temperature: 19/12 °C (day/night), [CO₂]: 385 ppm). Overall grain yield was found to decrease 29% in the two-factor treatment with concurrent elevation of [CO₂] and temperature, and this response could not be predicted from the results of treatments with elevated [CO₂] and temperature as single factors, where grain yield increased 16% and decreased 56%, respectively. Elevated [O₃] was found to decrease grain yield by 15%. Substantial variation in response to the applied climate treatments was found between the accessions. The results revealed landraces, cultivars, and breeder-lines with phenotypes applicable for breeding towards stable and high yield under future climate conditions. Further, we suggest identifying resources for breeding under multifactor climate conditions, as single-factor treatments did not accurately forecast the response when factors were combined.
Conclusions and perspectives

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Key Indicators of Air Pollution and Climate Change Impacts at Forest Supersites

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Latest Achievements on Climate Change and Forest Interactions in a Polluted Environment
The COST Action FP0903 “Climate Change and Forest Mitigation and Adaptation in a Polluted Environment (MAFor)” involved 29 countries and created a platform for information exchange with experts from different fields, with the following main objectives: 1) to increase understanding of the state and potential of forest mitigation and adaptation to climate change in a polluted environment and 2) to reconcile process-oriented research, long-term monitoring and applied modelling at comprehensive forest research sites. In particular, MAFor translated the existing European knowledge on climate and air pollution dynamics into prospects for forest research and monitoring, with focus on the carbon, ozone, nitrogen and water budgets. The aim of this paper is to summarize scientific activities and achievements of MAFor: the creation of a meta-database for highlighting the available data and integrating the information from European forest research/monitoring networks; the development of a new concept of forest sites for research and monitoring (Supersites); the identification of the main knowledge gaps; and the definition of priorities for forest adaptation to climate change in a polluted environment. The action also increased European capacity building in this sector by organizing five conferences, granting 84 short-term scientific missions, organizing four training schools and publishing more than 100 papers.

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Organisations: Department of Chemical and Biochemical Engineering, Ecosystems Programme, Institute for Plant Protection, Finnish Meteorological Institute, Norwegian Forest and Landscape Institute, Institute for Agricultural and Forestry Systems in the Mediterranean, Technische Universität München, Austrian Federal Office and Research Centre for Forests, Thunen-Institut, Czech Academy of Sciences, Istanbul University, Regione Toscana via di Novoli, Institute of
Leaf surface wax is a source of plant methane formation under UV radiation and in the presence of oxygen

The terrestrial vegetation is a source of UV radiation-induced aerobic methane (CH$_4$) release to the atmosphere. Hitherto pectin, a plant structural component, has been considered as the most likely precursor for this CH$_4$ release. However, most of the leaf pectin is situated below the surface wax layer, and UV transmittance of the cuticle differs among plant species. In some species, the cuticle effectively absorbs and/or reflects UV radiation. Thus, pectin may not necessarily contribute substantially to the UV radiation-induced CH$_4$ emission measured at surface level in all species. Here, we investigated the potential of the leaf surface wax itself as a source of UV radiation-induced leaf aerobic CH$_4$ formation. Isolated leaf surface wax emitted CH$_4$ at substantial rates in response to UV radiation. This discovery has implications for how the phenomenon should be scaled to global levels. In relation to this, we demonstrated that the UV radiation-induced CH$_4$ emission is independent of leaf area index above unity. Further, we observed that the presence of O$_2$ in the atmosphere was necessary for achieving the highest rates of CH$_4$ emission. Methane formation from leaf surface wax is supposedly a two-step process initiated by a photolytic rearrangement reaction of the major component followed by an α-cleavage of the generated ketone.
Towards supersites in forest ecosystem monitoring and research.

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**UV-induced N2O emission from plants**
Nitrous oxide (N\textsubscript{2}O) is an important long-lived greenhouse gas and precursor of stratospheric ozone-depleting mononitrogen oxides. The atmospheric concentration of N\textsubscript{2}O is persistently increasing; however, large uncertainties are associated with the distinct source strengths. Here we investigate for the first time N\textsubscript{2}O emission from terrestrial vegetation in response to natural solar ultra violet radiation. We conducted field site measurements to investigate N\textsubscript{2}O atmosphere exchange from grass vegetation exposed to solar irradiance with and without UV-screening. Further laboratory tests were conducted with a range of species to study the controls and possible loci of UV-induced N\textsubscript{2}O emission from plants. Plants released N\textsubscript{2}O in response to natural sunlight at rates of c. 20 e 50 nmol m\textsuperscript{-2} h\textsuperscript{-1}, mostly due to the UV component. The emission response to UV-A is of the same magnitude as that to UV-B. Therefore, UV-A is more important than UV-B given the natural UV-spectrum at Earth's surface. Plants also emitted N\textsubscript{2}O in darkness, although at reduced rates. The emission rate is temperature dependent with a rather high activation energy indicative for an abiotic process. The prevailing zone for the N\textsubscript{2}O formation appears to be at the very surface of leaves. However, only c. 26\% of the UV-induced N\textsubscript{2}O appears to originate from plant-N. Further, the process is dependent on atmospheric oxygen concentration. Our work demonstrates that ecosystem emission of the important greenhouse gas, N\textsubscript{2}O, may be up to c. 30\% higher than hitherto assumed.

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**Antagonism between elevated CO2, nighttime warming, and summer drought reduces the robustness of PSII performance to freezing events**
Plant responses to warming, elevated CO2, and changes in summer precipitation patterns involve complex interactions. In this study we aim to reveal the single factor responses and their interactive effects on photosystem II (PSII) performance...
during an autumn-to-winter period. The study was carried out in the CLIMAITE multifactor experiment, which includes the combined impact of elevated CO2 (free air carbon enrichment; CO2), warming (passive nighttime warming; T) and summer drought (rain-excluding curtains; D) in a temperate heath ecosystem. PSII performance was probed by the effective quantum yield in light, Fv′/Fm′, using the pulse amplitude methodology, and the total performance index, Pittotal, which integrate changes of the chlorophyll-a fluorescence transient including the maximal quantum yield in darkness, Fv/Fm′. Decreasing temperature during autumn linearly reduced Pittotal, both in the wavy hair-grass, Deschampsia flexuosa, and in the evergreen dwarf shrub common heather, Calluna vulgaris, and following freezing events the Pittotal and Fv′/Fm′ were reduced even more. Contrary to expected, indirect effects of the previous summer drought reduced PSII performance before freezing events, particularly in Calluna. In combinations with elevated CO2 interactive effects with drought, D×CO2 and warming, T×D×CO2, were negatively skewed and caused the reduction of PSII performance in both species after occurrence of freezing events. Neither passive nighttime warming nor elevated CO2 as single factors reduced PSII performance via incomplete cold hardening as hypothesized. Instead, the passive nighttime warming strongly increased PSII performance, especially after freezing events, and when combined with elevated CO2 a strongly skewed positive T×CO2 interactive effect was seen. This indicates that these plants take advantage of the longer growing season induced by the warming in elevated CO2 until a winter frost period becomes permanent. However, if previously exposed to summer drought this positive effect reverses via interactive D×CO2 and T×D×CO2 effects immediately after freezing events, causing the full combination of TDCO2 not to differ from the control. In a future warmer climate with high CO2 and summer drought, the occurrence of freezing events thus seem highly decisive for reducing PSII performance in the autumn-to-winter period. Such a reduced robustness of PSII performance may be highly decisive for the magnitude of the late season photosynthetic carbon uptake and reduce the growing season length in these temperate heath plants.

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**Biomass burning in eastern Europe during spring 2006 caused high deposition of ammonium in northern Fennoscandia**

High air concentrations of ammonium were detected at low and high altitude sites in Sweden, Finland and Norway during the spring 2006, coinciding with polluted air from biomass burning in eastern Europe passing over central and northern Fennoscandia. Unusually high values for throughfall deposition of ammonium were detected at one low altitude site and several high altitude sites in north Sweden. The occurrence of the high ammonium in throughfall differed between the summer months 2006, most likely related to the timing of precipitation events. The ammonia dry deposition may have contributed to unusual visible injuries on the tree vegetation in northern Fennoscandia that occurred during 2006, in combination with high ozone concentrations. It is concluded that long-range transport of ammonium from large-scale biomass burning may contribute substantially to the nitrogen load at northern latitudes. © 2013 Elsevier Ltd. All rights reserved.

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Can barley (Hordeum vulgare L. s.l.) adapt to fast climate changes? A controlled selection experiment

The projected future climate will affect the global agricultural production negatively, however, to keep abreast of the expected increase in global population, the agricultural production must increase. Therefore, to safeguard the future crop yield and quality, the adaptive potential of crops to environmental change needs to be explored in order to select the most productive genotypes. Presently, it is unknown whether cereal crops like spring barley can adapt to climate stressors over relatively few generations. To evaluate if strong selection pressures could change the performance of barley to environmental stress, we conducted a selection experiment over five plant generations (G0–G4) in three scenarios, where atmospheric [CO2] and temperature were increased as single factors and in combination. The treatments represented the expected environmental characteristics in Northern Europe around year 2075 [700 ppm CO2, 22/17 C (day/night)] as well as a control mimicking present day conditions (390 ppm CO2, 19/12 C). Two different barley accessions, a modern cultivar and an old landrace, were evaluated in terms of yield and biomass production. In all treatments representing future environmental scenarios, the G4-generation of selected plants did not improve its reproductive output compared to the G0-generation, as G4 produced less seeds and had a lower yield than unselected plants. These results indicate that barley might not respond positively to rapid and strong selection by elevated [CO2] and temperature, contrary to previous results from oilseed rape. The two barley accessions analyzed presented almost the same response pattern in a given treatment, though the modern cultivar had the highest yield in the climate scenarios, while the landrace was superior in yield under present day climate conditions.

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Contributors: Alemayehu, F. R., Frenck, G., van der Linden, L., Mikkelsen, T. N., Bagger Jørgensen, R.
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Improving the performance of infrared reflective night curtains for warming field plots

Infrared reflective (IR) curtains have been widely used to obtain passive nighttime warming in field ecosystem experiments in order to simulate and study climate warming effects on ecosystems. For any field installation with IR-reflective curtains in an ecosystem the achieved heating effect depends on the heat gain determined by the stored energy during daytime (incoming radiation can be used as a proxy) the heat conservation determined by the IR-reflective effect of the curtains (cloudiness can be used as a proxy) and the heat loss determined by convective heat loss (wind speed can be used as a proxy). In this study, we demonstrate some feasible avenues for improving the achieved temperature increase (ΔT) when using IR-reflective curtains at field scale by attacking the three main factors determining the efficiency of the curtains: (i) improving the long wave IR reflection by the curtains, (ii) insulating the curtains and (iii) reducing the lateral wind speed. We provide experimentally based replies to the major concerns raised in the literature about the passive nighttime warming method. We show (a) that using IR-reflective curtains during night does in fact not result in nighttime warming only as there is a small carryover.
Multi-factor climate change effects on insect herbivore performance

The impact of climate change on herbivorous insects can have far-reaching consequences for ecosystem processes. However, experiments investigating the combined effects of multiple climate change drivers on herbivorous insects are scarce. We independently manipulated three climate change drivers (CO2, warming, drought) in a Danish heathland ecosystem. The experiment was established in 2005 as a full factorial split-plot with 6 blocks × 2 levels of CO2 × 2 levels of warming × 2 levels of drought = 48 plots. In 2008, we exposed 432 larvae (n = 9 per plot) of the heather beetle (Lochmaea suturalis Thomson), an important herbivore on heather, to ambient versus elevated drought, temperature, and CO2 (plus all combinations) for 5 weeks. Larval weight and survival were highest under ambient conditions and decreased significantly with the number of climate change drivers. Weight was lowest under the drought treatment, and there was a three-way interaction between time, CO2, and drought. Survival was lowest when drought, warming, and elevated CO2 were combined. Effects of climate change drivers depended on other co-acting factors and were mediated by changes in plant secondary compounds, nitrogen, and water content. Overall, drought was the most important factor for this insect herbivore. Our study shows that weight and survival of insect herbivores may decline under future climate. The complexity of insect herbivore responses increases with the number of combined climate change drivers.

Net root growth and nutrient acquisition in response to predicted climate change in two contrasting heathland species

Accurate predictions of nutrient acquisition by plant roots and mycorrhizas are critical in modelling plant responses to climate change. We conducted a field experiment with the aim to investigate root nutrient uptake in a future climate and studied root production by ingrowth cores, mycorrhizal colonization, and fine root N and P uptake by root assay of Deschampsia flexuosa and Calluna vulgaris. Net root growth increased under elevated CO2, warming and drought, with
additive effects among the factors. Arbuscular mycorrhizal colonization increased in response to elevated CO2, while ericoid mycorrhizal colonization was unchanged. The uptake of N and P was not increased proportionally with root growth after 5 years of treatment. While aboveground biomass was unchanged, the root growth was increased under elevated CO2. The results suggest that plant production may be limited by N (but not P) when exposed to elevated CO2. The species-specific response to the treatments suggests different sensitivity to global change factors, which could result in changed plant competitive interactions and belowground nutrient pool sizes in response to future climate change.

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Contributors: Arndal, M., Merrild, M., Michelsen, A., Schmidt, I. K., Mikkelsen, T. N., Beier, C.
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Reduction of molecular gas diffusion through gaskets in leaf gas exchange cuvettes by leaf-mediated pores
There is an ongoing debate on how to correct leaf gas exchange measurements for the unavoidable diffusion leakage that occurs when measurements are done in non-ambient CO2 concentrations. In this study, we present a theory on how the CO2 diffusion gradient over the gasket is affected by leaf-mediated pores (LMP) and how LMP reduce diffusive exchange across the gaskets. Recent discussions have so far neglected the processes in the quasi-laminar boundary layer around the gasket. Counter intuitively, LMP reduce the leakage through gaskets, which can be explained by assuming that the boundary layer at the exterior of the cuvette is enriched with air from the inside of the cuvette. The effect can thus be reduced by reducing the boundary layer thickness. The theory clarifies conflicting results from earlier studies. We developed leaf adaptor frames that eliminate LMP during measurements on delicate plant material such as grass leaves with circular cross section, and the effectiveness is shown with respiration measurements on a harp of Deschampsia flexuosa leaves. We conclude that the best solution for measurements with portable photosynthesis systems is to avoid LMP rather than trying to correct for the effects.

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Response to multi-generational selection under elevated \([\text{CO}_2]\) in two temperature regimes suggests enhanced carbon assimilation and increased reproductive output in \textit{Brassica napus} L.

Functional plant traits are likely to adapt under the sustained pressure imposed by environmental changes through natural selection. Employing \textit{Brassica napus} as a model, a multi-generational study was performed to investigate the potential trajectories of selection at elevated \([\text{CO}_2]\) in two different temperature regimes. To reveal phenotypic divergence at the manipulated \([\text{CO}_2]\) and temperature conditions, a full-factorial natural selection regime was established in a phytotron environment over the range of four generations. It is demonstrated that a directional response to selection at elevated \([\text{CO}_2]\) led to higher quantities of reproductive output over the range of investigated generations independent of the applied temperature regime. The increase in seed yield caused an increase in aboveground biomass. This suggests quantitative changes in the functions of carbon sequestration of plants subjected to increased levels of \text{CO}_2 over the generational range investigated. The results of this study suggest that phenotypic divergence of plants selected under elevated atmospheric \text{CO}_2 concentration may drive the future functions of plant productivity to be different from projections that do not incorporate selection responses of plants. This study accentuates the importance of phenotypic responses across multiple generations in relation to our understanding of biogeochemical dynamics of future ecosystems. Furthermore, the positive selection response of reproductive output under increased \([\text{CO}_2]\) may ameliorate depressions in plant reproductive fitness caused by higher temperatures in situations where both factors co-occur.
Towards integration of research and monitoring at forest ecosystems in Europe

Aim of study: The main aim of the work was to summarize availability, quality and comparability of on-going European Research and Monitoring Networks (ERMN), based on the results of a COST FP0903 Action questionnaire carried out in September 2010 and May 2012. Area of study: The COST Action FP0903 involves 29 European countries and 4 non-COST institutions from USA, Morocco and Tunisia. In this study, the total of 22 replies to the questionnaire from 18 countries were included. Materials and methods: Based on the feedback from the Action FP0903 countries, the most popular European Networks were identified. Thereafter, the access to the network database, available quality assurance/quality control procedures and publication were described. Finally, the so-called “Supersites” concept, defined as a “highly instrumented research infrastructure, for both research and monitoring of soil-plant-atmosphere interactions” was discussed.

Main results: The result of the survey indicate that the vast majority of the Action FP0903 countries participate in the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forest (ICP Forest). The multi-disciplinary International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICPIM) is the second most widespread forest programme. Research highlights: To fully understand biochemical cycles in forest ecosystems, long-term monitoring is needed. Hence, a network of “Supersites”, is proposed. The application of the above infrastructure can be an effective way to attain a better integration of research and monitoring networks at forest sites in Europe.

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Contributors: Danielewska, A., Paoletti, E., Clarke, N., Olejnik, J., Urbaniak, M., Baran, M., Siedlecki, P., Hansen, K., Lundin, L., de Vries, W., Mikkelsen, T. N., Dillen, S., Fischer, R.
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UV-induced carbon monoxide emission from living vegetation

The global burden of carbon monoxide (CO) is rather uncertain. In this paper we address the potential for UV-induced CO emission by living terrestrial vegetation surfaces. Real-time measurements of CO concentrations were made with a cavity enhanced laser spectrometer connected in closed loop to either an ecosystem chamber or a plant-leaf scale chamber. Leaves of all examined plant species exhibited emission of CO in response to artificial UV-radiation as well as the UV-component of natural solar radiation. The UV-induced rate of CO emission exhibited a rather low dependence on temperature, indicating an abiotic process. The emission of CO in response to the UV-component of natural solar radiation was also evident at the ecosystem scale.

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Organisations: Department of Chemical and Biochemical Engineering, Ecosystems Programme
Contributors: Bruhn, D., Albert, K. R., Mikkelsen, T. N., Ambus, P.
Forests under climate change and air pollution: Gaps in understanding and future directions for research

Forests in Europe face significant changes in climate, which in interaction with air quality changes, may significantly affect forest productivity, stand composition and carbon sequestration in both vegetation and soils. Identified knowledge gaps and research needs include: (i) interaction between changes in air quality (trace gas concentrations), climate and other site factors on forest ecosystem response, (ii) significance of biotic processes in system response, (iii) tools for mechanistic and diagnostic understanding and upscaling, and (iv) the need for unifying modelling and empirical research for synthesis. This position paper highlights the above focuses, including the global dimension of air pollution as part of climate change and the need for knowledge transfer to enable reliable risk assessment. A new type of research site in forest ecosystems (“supersites”) will be conducive to addressing these gaps by enabling integration of experimentation and modelling within the soil-plant-atmosphere interface, as well as further model development.

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Source: orbit
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Research output: Contribution to journal › Journal article – Annual report year: 2011 › Research › peer-review
High Resilience in Heathland Plants to Changes in Temperature, Drought, and CO2 in Combination: Results from the CLIMAITE Experiment

Climate change scenarios predict simultaneously increase in temperature, altered precipitation patterns and elevated atmospheric CO2 concentration, which will affect key ecosystem processes and plant growth and species interactions. In a large-scale experiment, we investigated the effects of in situ exposure to elevated atmospheric CO2 concentration, increased temperature and prolonged drought periods on the plant biomass in a dry heathland (Brandbjerg, Denmark). Results after 3 years showed that drought reduced the growth of the two dominant species Deschampsia flexuosa and Calluna vulgaris. However, both species recovered quickly after rewetting and the drought had no significant effect on annual aboveground biomass production. We did not observe any effects of increased temperature. Elevated CO2 stimulated the biomass production for D. flexuosa in one out of three years but did not influence the standing biomass for either D. flexuosa or the ecosystem as more litter was produced. Treatment combinations showed little interactions on the measured parameters and in particular elevated CO2 did not counterbalance the drought effect on plant growth, as we had anticipated. The plant community did not show any significant responses to the imposed climate changes and we conclude that the two heathland species, on a short time scale, will be relatively resistant to the changes in climatic conditions.

Interactions between above- and belowground organisms modified in climate change experiments

Climate change has been shown to affect ecosystem process rates and community composition, with direct and indirect effects on belowground food webs. In particular, altered rates of herbivory under future climate can be expected to influence above–belowground interactions. Here, we use a multifactor, field-scale climate change experiment and independently manipulate atmospheric CO2 concentration, air and soil temperature and drought in all combinations since 2005. We show that changes in these factors modify the interaction between above- and belowground organisms. We use an insect herbivore to experimentally increase aboveground herbivory in grass phytometers exposed to all eight combinations of climate change factors for three years. Aboveground herbivory increased the abundance of belowground protozoans, microbial growth and microbial nitrogen availability. Increased CO2 modified these links through a reduction in herbivory and cascading effects through the soil food web. Interactions between CO2, drought and warming can affect belowground protozoan abundance. Our findings imply that climate change affects aboveground–belowground interactions through changes in nutrient availability.
Long-term structural canopy changes sustain net photosynthesis per ground area in high arctic Vaccinium uliginosum exposed to changes in near-ambient UV-B levels.

Full recovery of the ozone layer is not expected for several decades and consequently, the incoming level of solar ultraviolet-B (UV-B) will only slowly be reduced. Therefore to investigate the structural and photosynthetic responses to changes in solar UV-B we conducted a 5-year UV-B exclusion study in high arctic Greenland. During the growing season, the gas exchange (H₂O and CO₂) and chlorophyll-a fluorescence were measured in Vaccinium uliginosum. The leaf dry weight, carbon, nitrogen, stable carbon isotope ratio, chlorophyll and carotenoid content were determined from a late season harvest. The net photosynthesis per leaf area was on average 22% higher in 61% reduced UV-B treatment across the season, but per ground area photosynthesis was unchanged. The leaf level increase in photosynthesis was accompanied by increased leaf nitrogen, higher stomatal conductance and F(v)/F(m). There was no change in total leaf biomass, but reduction in total leaf area caused a pronounced reduction of specific leaf area and leaf area index in reduced UV-B. This demonstrates the structural changes to counterbalance the reduced plant carbon uptake seen per leaf area in ambient UV-B as the resulting plant carbon uptake per ground area was not affected. Thus, our understanding of long-term responses to UV-B reduction must take into account both leaf level processes as well as structural changes to understand the apparent robustness of plant carbon uptake per ground area. In this perspective, V. uliginosum seems able to adjust plant carbon uptake to the present amount of solar UV-B radiation in the High Arctic.
Soil respiration is stimulated by elevated CO₂ and reduced by summer drought: three years of measurements in a multifactor ecosystem manipulation experiment in a temperate heathland (CLIMAITE)

This study investigated the impact of predicted future climatic and atmospheric conditions on soil respiration (RS) in a Danish Calluna-Deschampsia-heathland. A fully factorial in situ experiment with treatments of elevated atmospheric CO2 (+130 ppm), raised soil temperature (+0.4 °C) and extended summer drought (5–8% precipitation exclusion) was established in 2005. The average RS, observed in the control over 3 years of measurements (1.7 μmol CO2 m–2 sec–1), increased 38% under elevated CO2, irrespective of combination with the drought or temperature treatments. In contrast, extended summer drought decreased RS by 14%, while elevated soil temperature did not affect RS overall. A significant interaction between elevated temperature and drought resulted in further reduction of RS when these treatments were combined. A detailed analysis of short-term RS dynamics associated with drought periods showed that RS was reduced by ~50% and was strongly correlated with soil moisture during these events. Recovery of RS to pre-drought levels occurred within 2 weeks of rewetting; however, unexpected drought effects were observed several months after summer drought treatment in 2 of the 3 years, possibly due to reduced plant growth or changes in soil water holding capacity. An empirical model that predicts RS from soil temperature, soil moisture and plant biomass was developed and accounted for 55% of the observed variability in RS. The model predicted annual sums of RS in 2006 and 2007, in the control, were 672 and 719 g C m–2 y–1, respectively. For the full treatment combination, i.e. the future climate scenario, the model predicted that soil respiratory C losses would increase by ~21% (140–150 g C m–2 y–1). Therefore, in the future climate, stimulation of C storage in plant biomass and litter must be in excess of 21% for this ecosystem to not suffer a reduction in net ecosystem exchange.

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Solar UV-B effects on PSII performance in Betula nana are influenced by PAR level and reduced by EDU: results of a 3-year experiment in the High Arctic

The long-term and diurnal responses of photosystem II (PSII) performance to near-ambient UV-B radiation were investigated in High Arctic Betula nana. We conducted an UV exclusion experiment with five replicated blocks consisting of open control (no filter), photosynthetically active radiation and UV-B transparent filter control (Teflon), UV-B-absorbing filter (Mylar) and UV-AB-absorbing filter (Lexan). Ethylenediurea (EDU), a chemical normally used to protect plants against ozone injury, was sprayed on the leaves both in the field and in an additional laboratory study to investigate if EDU mitigated the effects of UV-B. Chlorophyll-a fluorescence induction curves were used for analysis of OJIP test parameters. Near-ambient UV-B radiation reduced across season maximum quantum yield (TRo /ABS = Fv /Fm ), approximated number of active PSII reaction center (RC/ABS) and the performance index (PIABS ), despite improved leaf screening against UV-B with higher content of UV-B-absorbing compounds and a lower specific leaf area. EDU application counteracted the negative impact of UV-B on TR(o) /ABS, RC/ABS and PI(ABS) . This indicates that the mechanisms behind UV-B and ozone damage share some common features. The midday depression was present in all treatments, but TR(o) /ABS and PI(ABS) were persistently lower in near-ambient UV-B compared to UV-B reduction. The recovery phase was particularly impaired in near-ambient UV-B and interactive effects between treatment × hour raised TRo /ABS,
RC/ABS and PI_ABS higher in reduced UV-B compared to near-ambient UV-B. This demonstrates current solar UV-B to reduce the PSII performance both on a daily as well as a seasonal basis in this High Arctic species.

Temperate heath plant response to dry conditions depends on growth strategy and less on physiology
The evidence that is currently available demonstrates that future changes in precipitation patterns will affect plant carbon uptake. However, the outcome in terms of success, productivity and fecundity depends upon individual species and different responses of various growth forms. Examination of these differences in response in dry versus rewetting conditions can be used to highlight the limitations coherent in different strategies adopted by, for example, evergreen shrubs and grasses. We investigated the leaf-level photosynthetic performance, leaf C, N and d13C along with vegetation cover and biomass in the evergreen dwarf shrub Calluna vulgaris and the grass species Deschampsia flexuosa in a temperate heath during seasonal changes in soil moisture.

Higher photosynthetic capacity compensated for lower stomatal conductance and sustained higher rates of photosynthesis in the grass compared to the dwarf shrub. In combination with dieback of aboveground biomass and reduction of stomatal conductance reduction during dry conditions, the grass continued to have high carbon uptake in the remaining leaves. The dwarf shrub endured the dry conditions by preserving shoot biomass and reducing stomatal conductance. Soil rewetting increased leaf nitrogen and photosynthesis in the grass much more than for the dwarf shrub.

These different strategies may have a considerable impact on carbon uptake and on the ability of a species to compete, as future climatic changes are likely to extend the summer drought period together with the more frequent and extensive precipitation events outside the summer season.
Terrestrial plant methane production

We evaluate all experimental work published on the phenomenon of aerobic methane (CH₄) generation in terrestrial plants. We conclude that the phenomenon is true. Four stimulating factors have been observed to induce aerobic plant CH₄ production, i.e. cutting injuries, increasing temperature, ultraviolet radiation and reactive oxygen species. Further, we analyze rates of measured emission of aerobically produced CH₄ in pectin and in plant tissues from different studies and argue that pectin is very far from the sole contributing precursor. Hence, scaling up of aerobic CH₄ emission needs to take into consideration other potential sources than pectin. Due to the large uncertainties related to effects of stimulating factors, genotypic responses and type of precursors, we conclude that current attempts for upscaling aerobic CH₄ into a global budget is insufficient. Thus it is too early to draw the line under the aerobic methane emission in plants. Future work is needed for establishing the relative contribution of several proven potential CH₄ precursors in plant material.

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Terrestrial plant methane production and emission

In this minireview, we evaluate all experimental work published on the phenomenon of aerobic methane (CH₄) generation in terrestrial plants and plant. Clearly, despite much uncertainty and skepticism, we conclude that the phenomenon is true. Four stimulating factors have been observed to induce aerobic plant CH₄ production, i.e. cutting injuries, increasing temperature, ultraviolet radiation and reactive oxygen species. Further, we analyze rates of measured emission of aerobically produced CH₄ in pectin and in plant tissues from different studies and argue that pectin is very far from the sole contributing precursor. In consequence, scaling up of aerobic CH₄ emission needs to take into consideration other potential sources than pectin. Due to the large uncertainties related to effects of stimulating factors, genotypic responses and type of precursors, we conclude that current attempts for upscaling aerobic CH₄ into a global budget is inadequate. Thus it is too early to draw the line under the aerobic methane emission in plants. Future work is needed for establishing the relative contribution of several proven potential CH₄ precursors in plant material.

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Up-scaling of water use efficiency from leaf to canopy as based on leaf gas exchange relationships and the modeled intercanopy light distribution

The aim of this study was to evaluate the extent to which water use efficiency (WUE) at leaf scale can be used to assess WUE at canopy scale, leaf WUE being assumed to be a constant function of vapor pressure deficit and to thus not be dependent upon other environmental factors or varying leaf properties. Leaf WUE and its variability and dependencies were assessed using leaf gas-exchange measurements obtained during two growing seasons, 1999 and 2000, at the Soroe beech forest study site on Zealand in Denmark. It was found that the VPD-normalized leaf WUE, WUE_{normleaf}, although dependent on incoming PAR below 500 μmol m⁻² s⁻¹ is independent both of the canopy levels and of variations in the environmental parameters. The average WUE_{normleaf} for PAR above 500 μmol m⁻² s⁻¹ was found to be 5.5 μmol CO₂ (mmol H₂O){⁻¹} hPa and, for the full range, 2.3 μmol CO₂ (mmol H₂O){⁻¹} hPa. These results showed that WUE can be up-scaled from leaf to canopy on the basis of WUE_{normleaf} and the PAR distribution within the canopy. The up-scaling conducted was based on this WUE_{normleaf} – PAR relationship, the light distribution being assessed using the MAESTRA model, parameterized in accordance with measurements obtained for the Soroe forest. The up-scaled WUE was then compared with WUE as estimated from turbulent flux data measured above the forest with the eddy-covariance technique. The modeled daily canopy WUE obtained for daytime fluxes (6:00 AM–6:00 PM) was found to be in agreement with corresponding canopy WUE estimates based on the turbulent fluxes observed and to be dependent on VDP and light intensity alone, its thus being independent of other environmental factors. Accordingly, canopy WUE can be estimated on the basis of the up-scaled WUE relationships, provided incident PAR and VDP within the canopy are known.

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Organisations: Department of Chemical and Biochemical Engineering, Ecosystems Programme, Lund University, University of Copenhagen
Contributors: Linderson, M., Mikkelsen, T. N., Ibrom, A., Lindroth, A., Ro-Poulsen, H., Pilegaard, K.
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UV-induced carbon monoxide emission from sand and living vegetation

The global burden of carbon monoxide, CO, is rather uncertain. In this paper we address the potential of UV-induced CO emission by terrestrial surfaces. Real-time measurements of [CO] were made with a cavity enhanced laser connected in closed loop to either an ecosystem chamber or a leaf scale chamber. Sand and leaves of all examined plant species exhibited emission of CO in response to artificial UV-radiation and the UV-component of natural solar radiation. The UV-induced rate of CO emission exhibited a rather low dependence on temperature, indicating an abiotic process. The emission of CO in response to the UV-component of natural solar radiation was also evident at the ecosystem scale. When scaled to the global level, the UV-induced emission of CO by the major types of terrestrial surfaces, living leaves and soil (here represented by sand), amounts up to 28 Tg yr⁻¹. This source has till now not been accounted
for by IPCC, but is equivalent to 14–56% of the 50–200 Tg yr<sup>−1</sup> from sources currently accounted for (IPCC 2001). In addition to this are other known sources that ought to be considered. The hitherto unaccounted for terrestrial sources of CO amounts up to 207 Tg yr<sup>−1</sup>, almost two-thirds of the latest estimated global CO burden of 360 Tg yr<sup>−1</sup> (IPCC, 2001).

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**Ambient UV-B radiation reduces PSII performance and net photosynthesis in high Arctic Salix arctica**

Ambient ultraviolet-B (UV-B) radiation potentially impacts the photosynthetic performance of high Arctic plants. We conducted an UV-B exclusion experiment in a dwarf shrub heath in NE Greenland (74°N), with open control, filter control, UV-B filtering and UV-AB filtering, all in combination with leaf angle control. Two sites with natural leaf positions had ground angles of 0° (‘level site’) and 45° (‘sloping site’), while at a third site the leaves were fixed in an angle of 45° to homogenize the irradiance dose (‘fixed leaf angle site’). The photosynthetic performance of the leaves was characterized by simultaneous gas exchange and chlorophyll fluorescence measurements and the PSII performance through the growing season was investigated with fluorescence measurements. Leaf harvest towards the end of the growing season was done to determine the specific leaf area and the content of carbon, nitrogen and UV-B absorbing compounds.

Compared to a 60% reduced UV-B irradiance, the ambient solar UV-B reduced net photosynthesis in Salix arctica leaves fixed in the 45° position which exposed leaves to maximum natural irradiance. Also a reduced Calvin Cycle capacity was found, i.e. the maximum rate of electron transport (Jmax) and the maximum carboxylation rate of Rubisco (Vcmax), and the PSII performance showed a decreased quantum yield and increased energy dissipation. A parallel response pattern and reduced PSII performance at all three sites indicate that these responses take place in all leaves across position in the vegetation. These findings add to the evidence that the ambient solar UV-B currently is a significant stress factor for plants in high Arctic Greenland.

**General information**
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Ambient UV-B radiation reduces PSII performance and net photosynthesis in high Arctic Salix arctica

Ambient ultraviolet-B (UV-B) radiation potentially impacts the photosynthetic performance of high Arctic plants. We conducted an UV-B exclusion experiment in a dwarf shrub heath in NE Greenland (74°N), with open control, filter control, UV-B filtering and UV-AB filtering, all in combination with leaf angle control. Two sites with natural leaf positions had ground angles of 0° ('level site') and 45° ('sloping site'), while at a third site the leaves were fixed in an angle of 45° to homogenize the irradiance dose ('fixed leaf angle site'). The photosynthetic performance of the leaves was characterized by simultaneous gas exchange and chlorophyll fluorescence measurements and the PSII performance through the growing season was investigated with fluorescence measurements. Leaf harvest towards the end of the growing season was done to determine the specific leaf area and the content of carbon, nitrogen and UV-B absorbing compounds. Compared to a 60% reduced UV-B irradiance, the ambient solar UV-B reduced net photosynthesis in Salix arctica leaves fixed in the 45° position which exposed leaves to maximum natural irradiance. Also a reduced Calvin Cycle capacity was found, i.e. the maximum rate of electron transport (Jmax) and the maximum carboxylation rate of Rubisco (Vcmax), and the PSII performance showed a decreased quantum yield and increased energy dissipation. A parallel response pattern and reduced PSII performance at all three sites indicate that these responses take place in all leaves across position in the vegetation. These findings add to the evidence that the ambient solar UV-B currently is a significant stress factor for plants in high Arctic Greenland.
Effects of elevated CO2, warming and drought episodes on plant carbon uptake in a temperate heath ecosystem are controlled by soil water status

The impact of elevated CO2, periodic drought and warming on photosynthesis and leaf characteristics of the evergreen dwarf shrub Calluna vulgaris in a temperate heath ecosystem was investigated. Photosynthesis was reduced by drought in midsummer and increased by elevated CO2 throughout the growing season, whereas warming only stimulated photosynthesis early in the year. At the beginning and end of the growing season, a T × CO2 interaction synergistically stimulated plant carbon uptake in the combination of warming and elevated CO2. At peak drought, the D × CO2 interaction antagonistically down-regulated photosynthesis, suggesting a limited ability of elevated CO2 to counteract the negative effect of drought. The response of photosynthesis in the full factorial combination (TDCO2) could be explained by the main effect of experimental treatments (T, D, CO2) and the two-factor interactions (D × CO2, T × CO2). The interactive responses in the experimental treatments including elevated CO2 seemed to be linked to the realized range of treatment variability, for example with negative effects following experimental drought or positive effects following the relatively higher impact of night-time warming during cold periods early and late in the year. Longer-term experiments are needed to evaluate whether photosynthetic down-regulation will dampen the stimulation of photosynthesis under prolonged exposure to elevated CO2.

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Effects of Single and Multifactor Treatments with Elevated Temperature, CO2 and Ozone on Oilseed Rape and Barley

We investigated the effect of elevated [CO2], [O3] and temperature on plant productivity and if these climate factors interacted with each other in multifactor treatments. The climate effects were studied in 14 different cultivars/lines of European spring oilseed rape (Brassica napus L.) and spring barley (Hordeum vulgare L.). Seven genotypes of each species were cultivated in six single- and multifactor treatments with ambient or elevated CO2 (385 ppm and 700 ppm), O3 (20 ppb and 60 ppb) and temperature (12/19 °C and 17/24 °C). Growth and production parameters were measured. Elevated CO2 increased yield and biomass. Seed number increased by about 47 % in barley and by 26 % in oilseed rape, but in oilseed rape, the TSW was significantly decreased, possibly because of shortening of the seed filling period. Higher temperatures decreased yield and biomass significantly in both species. A significantly decreased yield and thousand grain weight was also seen in barley due to elevated O3. The multifactor combination of elevated CO2, O3 and temperature showed a decrease in growth and biomass in the two species, though not statistically significant for all parameters. This trend suggests that the expected increase in the plant production in northern Europe, indicated by Intergovernmental Panel on Climate Change (IPCC) as a consequence of increased [CO2] and temperature, may not hold, due to interactions between these abiotic factors.

General information
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Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy, University of Copenhagen
Estimating daytime ecosystem respiration from eddy-flux data

To understand what governs the patterns of net ecosystem exchange of CO2, an understanding of factors influencing the component fluxes, ecosystem respiration and gross primary production is needed. In the present paper, we introduce an alternative method for estimating daytime ecosystem respiration based on whole ecosystem fluxes from a linear regression of photosynthetic photon flux density data vs. daytime net ecosystem exchange data at forest ecosystem level. This method is based on the principles of the Kok-method applied at leaf level for estimating daytime respiration. We demonstrate the method with field data and provide a discussion of the limitations of the method.

General information

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Contributors: Bruhn, D., Mikkelsen, T. N., Herbst, M., Kutsch, W. L., Ball, M. C., Pilegaard, K.
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Research output: Contribution to journal › Journal article – Annual report year: 2010 › Research › peer-review
Increased [CO2] does not compensate for negative effects on yield caused by higher temperature and [O3] in Brassica napus L.

The projected changes of atmospheric composition and associated climatic parameters will challenge the agricultural production in ways, which existing crop populations have not previously experienced. Therefore, understanding the responsiveness to changes of multiple environmental parameters in existing genotypes is vital. In this study, the responses in yield and biomass production of four different cultivars of oilseed rape (Brassica napus L.) were tested under five different combinations of increased [CO2] (700 ppm), temperature (+5 °C) and [O3] (+40 ppb). Especially the multifactor treatments are relevant for predictions of the future production, as they mimic the multidimensional environmental changes that are expected within this century. All treatments were given the same amount of water, which mimicked future limited water availability e.g. in treatments with elevated temperature. The biomass and yield parameters were found to be significantly cultivar dependent. However, in all cultivars elevated temperature caused a significant reduction in yield parameters, while biomass was not affected significantly. Elevated [CO2] increased the vegetative biomass significantly, but seed yield was only significantly enhanced in one of the four cultivars studied. Increased [O3] did not have significant effects on any of the cultivars. In general, the negative effects of a 5 °C temperature elevation on yield could not be compensated by elevated [CO2], when simultaneously applied in multifactor treatments. The evaluation of cultivar differences in productivity under elevated [CO2] in combination with increased temperatures and [O3] is necessary to derive at a realistic prediction for the future food and biomass production and for the selection of cultivars providing an adaptation potential to environmental change. Our results suggest that future breeding of B. napus should be based on old cultivars, since more modern varieties seem to have lower potentials to respond to CO2 and thus counteract the detrimental effects of yield reducing environmental factors such as temperature and O3.

Interactive effects of drought, elevated CO2 and warming on photosynthetic capacity and photosystem performance in temperate heath plants

Increased temperature, atmospheric CO2 and change in precipitation patterns affect plant physiological and ecosystem processes. In combination, the interactions between these effects result in complex responses that challenge our current understanding. In a multi-factorial field experiment with elevated CO2 (CO2, FACE), nighttime warming (T) and periodic drought (D), we investigated photosynthetic capacity and PSII performance in the evergreen dwarf shrub Calluna vulgaris and the grass Deschampsia flexuosa in a temperate heath ecosystem. Photosynthetic capacity was evaluated using A/Ci curves, leaf nitrogen content and chlorophyll-a fluorescence OJIP induction curves. The PSII performance was negatively influenced by high air temperature, low soil water content and high irradiance dose. The experimental treatments of elevated CO2 and prolonged drought generally down-regulated Jmax, Vcmax and PItotal. Recovery from these depressions was found in the evergreen shrub after rewetting, while post-rewetting up-regulation of these parameters was observed in the grass. Warming effects acted indirectly to improve early season Jmax, Vcmax and PItotal. The responses in the multi-factorial experimental manipulations demonstrated complex interactive effects of T × CO2, D × CO2 and T × D × CO2 on photosynthetic capacity and PSII performance. The impact on the O–J, J–I and I–P phases which determine the response of PItotal are discussed. The single factor effects on PSII performance and their interactions could be explained by parallel
adjustments of Vcmax, Jmax and leaf nitrogen in combination. Despite the highly variable natural environment, the OJIP-test was very robust in detecting the impacts of T, D, CO2 and their interactions. This study demonstrates that future climate will affect fundamental plant physiological processes in a way that is not predictable from single factor treatments. The interaction effects that were observed depended upon both the growth strategy of the species considered, and their ability to adjust during drought and rewetting periods.

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**Interactive effects of elevated CO2, warming, and drought on photosynthesis of Deschampsia flexuosa in a temperate heath ecosystem**
Global change factors affect plant carbon uptake in concert. In order to investigate the response directions and potential interactive effects, and to understand the underlying mechanisms, multifactor experiments are needed. The focus of this study was on the photosynthetic response to elevated CO2 [CO2; free air CO2 enrichment (FACE)], drought (D; water-excluding curtains), and night-time warming (T; infrared-reflective curtains) in a temperate heath. A/Ci curves were measured, allowing analysis of light-saturated net photosynthesis (Pn), light- and CO2-saturated net photosynthesis (Pmax), stomatal conductance (gs), the maximal rate of Rubisco carboxylation (Vcmax), and the maximal rate of ribulose bisphosphate (RuBP) regeneration (Jmax) along with leaf δ13C, and carbon and nitrogen concentration on a monthly basis in the grass Deschampsia flexuosa. Seasonal drought reduced Pn via gs, but severe (experimental) drought decreased Pn via a reduction in photosynthetic capacity (Pmax, Jmax, and Vcmax). The effects were completely reversed by rewetting and stimulated Pn via photosynthetic capacity stimulation. Warming increased early and late season Pn via higher Pmax and Jmax. Elevated CO2 did not decrease gs, but stimulated Pn via increased Ci. The T×CO2 synergistically increased plant carbon uptake via photosynthetic capacity up-regulation in early season and by better access to water after rewetting. The effects of the combination of drought and elevated CO2 depended on soil water availability, with additive effects when the soil water content was low and T×CO2 synergistic stimulation of Pn after rewetting. The photosynthetic responses appeared to be highly influenced by growth pattern. The grass has opportunistic water consumption, and a biphasic growth pattern allowing for leaf dieback at low soil water availability followed by rapid regrowth of active leaves when rewetted and possibly a large resource allocation capability mediated by the rhizome. This growth characteristic allowed for the photosynthetic capacity up-regulations that mediated the T×CO2 and D×CO2 synergistic effects on photosynthesis. These are clearly advantageous characteristics when exposed to climate changes. In conclusion, after 1 year of experimentation, the limitations by low soil water availability and stimulation in early and late season by warming clearly structure and interact with the photosynthetic response to elevated CO2 in this grassland species.

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Is methane released from the forest canopy?

Laboratory experiments show that rates of CH4 emission from plant material depend exponentially on temperature and linearly on UV irradiance. The UV irradiance shall be spectrally weighted and shorter wavelengths results in higher CH4 emissions. Global upscaling models for estimating aerobic CH4, based on lab results, have be conducted with varying results, but until now field measurements based on profile and eddy covariance measurements have failed to show CH4 emissions from forest canopies. To detect CH4 production or consumption in the canopy of a beech stand we connected a CH4 analyzer to a canopy air profile system that samples air below and above the canopy from seven different heights. A profile system with many vertical sample points can detect gas concentration gradients with a high sensitivity only under conditions with no or little air movements. Under these conditions we found indications of periodic CH4 emissions in the canopy, but more data need to be analyzed before the magnitude of the canopy source of CH4 can be established.
Measurement of carbon dioxide fluxes in a free-air carbon dioxide enrichment experiment using the closed flux chamber technique

Carbon dioxide (CO2) fluxes, composing net ecosystem exchange (NEE), ecosystem respiration (ER), and soil respiration (SR) were measured in a temperate heathland exposed to elevated CO2 by the FACE (free-air carbon enrichment) technique, raising the atmospheric CO2 concentration from c. 380 μmol mol−1 to 510 μmol mol−1. All CO2 fluxes were measured by the static chamber methodology. Although the FACE technique enriches the atmosphere with CO2 to a fixed level, the above ground CO2 concentrations may nevertheless locally vary strongly (from about ambient to 1000 μmol mol−1). Deployment of static chambers to FACE experiments should therefore be performed with great care in order to ensure reproducible conditions with respect to chamber headspace CO2 concentration. We demonstrate that the fluxes measured by closed chambers relate linearly to the initial headspace CO2 concentration. When changing the initial headspace CO2 concentration from 380 to 510 μmol mol−1 the net CO2 assimilation expressed by NEE increased instantaneously 1.51 times in control plots and 1.71 times in FACE plots. By contrast, ER in control plots decreased, being 0.87 times that measured at the low CO2 concentration, and the flux also decreased in FACE plots, to 0.79 times that at low concentration. Similar SR in control plots was decreased 0.94 times in control plots and 0.88 times in FACE plots. We found that a useful method to achieve stable and reproducible chamber headspace and soil CO2 concentration prior to commencement of flux measurements was to turn off the FACE system at least 10 min in advance. Within 10 min a new equilibrium was established between the soil and atmosphere, apparently due to CO2 degassing from the top soil. The observed increase in SR in response to increased CO2 persisted for up to 18 h during which measurements should be performed. Soil CO2 concentrations were increased by up to 500 μmol mol−1 by the FACE treatment, substantially more than the 130 μmol mol−1 enrichment achieved in the atmosphere suggesting that the increased SR flux was caused by increased belowground respiration.

Reduced N cycling in response to elevated CO2, warming, and drought in a Danish heathland

Reduced N cycling in response to elevated CO2, warming, and drought in a Danish heathland

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Reduced N cycling in response to elevated CO2, warming, and drought in a Danish heathland: Synthesizing results of the CLIMAITE project after two years of treatments

Field-scale experiments simulating realistic future climate scenarios are important tools for investigating the effects of current and future climate changes on ecosystem functioning and biogeochemical cycling. We exposed a seminatural Danish heathland ecosystem to elevated atmospheric carbon dioxide (CO2), warming, and extended summer drought in all combinations. Here, we report on the short-term responses of the nitrogen (N) cycle after 2 years of treatments. Elevated CO2 significantly affected aboveground stoichiometry by increasing the carbon to nitrogen (C/N) ratios in the leaves of both co-dominant species (Calluna vulgaris and Deschampsia flexuosa), as well as the C/N ratios of Calluna flowers and by reducing the N concentration of Deschampsia litter. Belowground, elevated CO2 had only minor effects, whereas warming increased N turnover, as indicated by increased rates of microbial NH4+ consumption, gross mineralization, potential nitrification, denitrification and N2O emissions. Drought reduced belowground gross N mineralization and decreased fauna N mass and fauna N mineralization. Leaching was unaffected by treatments but was significantly higher across all treatments in the second year than in the much drier first year indicating that ecosystem N loss is highly sensitive to changes and variability in amount and timing of precipitation. Interactions between treatments were common and although some synergistic effects were observed, antagonism dominated the interactive responses in treatment combinations, i.e. responses were smaller in combinations than in single treatments. Nonetheless, increased C/N ratios of photosynthetic tissue in response to elevated CO2, as well as drought-induced decreases in litter N production and fauna N mineralization prevailed in the full treatment combination. Overall, the simulated future climate scenario therefore lead to reduced N turnover, which could act to reduce the potential growth response of plants to elevated atmospheric CO2 concentration.

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Sap flow for beech (Fagus sylvatica L.) in a natural and a managed forest-effect of spatial heterogeneity
Beech (Fagus sylvatica L.) is an important species in natural and managed forests in Europe. This drought-sensitive species dominates even-aged stands as well more natural stands composed of a mixture of tree species, age and size classes. This study evaluates the extent that heterogeneity in spacing and tree diameter affect the seasonal availability and use of water. Two stands were evaluated: (i) a heterogeneous forest remnant (NAT) with trees up to similar to 300 years old, a mean top height of 28.4 m and a total of 733 stems ha(-1) with stem diameters averaging 18 cm and (ii) an even-aged 80-year old stand (MAN), with a height of 25 m, and a total of 283 stems ha(-1) with diameters averaging 38 cm. Stem sap flow, J(s) (g m(-2) s(-1)), was continuously measured in 12 (MAN) and 13 (NAT) trees using 20-mm long heat dissipation sensors. Individual tree measures of sap flow were correlated using non-linear statistical methods with air vapour pressure deficit (D, hPa) and global radiation (R-g, J m(-2) day(-1)), along with constraints imposed by reductions
in soil water content (SWC). SWC was measured as volumetric % using time domain reflectometry. The daily integrated \( J(\text{s-sum}) \) for trees growing in the evenly spaced MAN stand and trees in canopy and closed forest positions in NAT stand decreased as the availability of soil moisture was reduced. In the heterogeneous NAT stand, SWC in a recently formed canopy gap remained high throughout the vegetation period. Based on regression models, the predicted relative decrease in \( J(\text{s-sum}) \) for dry relative to moist soil water conditions in the closed forest (at mean daily \( D = 10 \text{ hPa} \)) was 7-11% for trees near the gap and 39-42% for trees in the closed forest. In MAN, the reduction in \( J(\text{s-sum}) \) was 29% in dry relative to moist conditions. \( J(\text{s-sum}) \) in the outer 20 mm of the xylem in NAT was lower than that in MAN and the rate of decline in \( J(\text{s}) \) with xylem depth was less in NAT than in MAN. In MAN, \( J(\text{s-sum}) \) in deep and outer xylem was negatively affected at low soil moisture availability; in NAT, this was the case for only the outer xylem indicating that deep roots could be important in supplying water at times of low soil moisture in the upper soil.

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**Journal:** iForest  
**Volume:** 4  
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**Publication date:** 2011  
**Peer-reviewed:** Yes

**Towards a transnational system of supersites for forest monitoring and research in Europe - an overview on present state and future recommendations**

Science-based approaches in addressing future risks and challenges for forests require close collaboration among the communities operating different monitoring and research networks as well as experts in process and large-scale modelling. Results of the COST FP0903 conference which took place in October 2010 in Rome, reveal valuable results from different European forest monitoring and research networks. However, the need for closer integration of these activities is obvious. In this paper, representatives from major European networks recommend a new approach for forest monitoring and research in Europe, based on a reasonable number of highly instrumented “supersites” and a larger number of intensive monitoring plots linked to these. This system needs to be built on existing infrastructures but requires increased coordination, harmonisation and a joint long term platform for data exchange and modelling.

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**Contributors:** Fischer, R., Aas, W., De Vries, W., Clarke, N., Cudlin, P., Leaver, D., Lundin, L., Matteucci, G., Matyssek, R., Mikkelsen, T. N., Mirtl, M., Öztkur, Y., Papale, D., Potocic, N., Simpson, D., Tuovinen, L., Vesala, T., Wieser, G., Paolletti, E.  
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Improved UV-B screening capacity does not prevent negative effects of ambient UV irradiance on PSII performance in High Arctic plants. Results from a six year UV exclusion study

Long-term responses of ambient solar ultraviolet (UV) radiation were investigated on Salix arctica and Vaccinium uliginosum in a High Arctic heath ecosystem in Zackenberg, northeast Greenland. Over a period of six years, UV exclusion was conducted in the growing season by means of filters: 60% UV-B reduction, 90% UV-B + UV-A reduction, UV transparent filter control, and an open control without filter. Plant responses were evaluated using specific leaf area, leaf content of UV-B absorbing compounds and PSII performance parameters derived from chlorophyll-a fluorescence induction curves. Based on the JIP-test, we calculated the total performance index PItotal, which includes the integrating antennae, the PSII reaction center, intersystem electron transport and reduction of PSI end acceptors-dependent parameters. In both species, UV exclusion significantly decreased the content of UV-B-absorbing compounds. Salix increased its specific leaf area, while Vaccinium decreased it. UV exclusion increased the PItotal in both species during all six years of experimentation. This response was governed by a significantly decreased RC/ABS, a marginally non-significant increased ETo/TRo and a significantly increased TRo/ABS = FV/FM and REo/ETo. These results demonstrate the current level of ambient UV-B to decrease PSII performance significantly in these High Arctic plants. It appears that the two plant species both have improved their UV-screening capacity, but through different strategies, although this did not sufficiently prevent negative effects of the ambient UV radiation. We argue the decreased PSII performance to be part of a response decreasing plant carbon uptake. We speculate the negative effects on PSII performance mediated by ambient UV irradiance to be present in years where warming induces early snowmelt, exposing the vegetation to high spring UV-B, and to be present in the future to the degree the ozone layer is not fully recovered.

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Web of Science (2010): Impact factor 2.677
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Source-ID: 266076
Research output: Contribution to journal › Journal article – Annual report year: 2010 › Research › peer-review
Plant nutrient mobilization in temperate heathland responds to elevated CO2, temperature and drought

Temperate terrestrial ecosystems are currently exposed to increased atmospheric CO2 and progressive climatic changes with increased temperature and periodical drought. We here present results from a field experiment, where the effects of these three main climate change related factors are investigated solely and in all combinations at a temperate heathland. Significant responses were found in the top soils below the two dominant species (Calluna vulgaris and Deschampsia flexuosa). During winter incubation, microbial immobilization of N and ammonification rate decreased in response to warming in Deschampsia soil, and microbial immobilization of N and P decreased in warmed Calluna soil. Warming tended to increase microbial N and P in Calluna but not in Deschampsia soil in fall, and more microbial C was accumulated under drought in Calluna soil. The effects of warming were often counteracted or erased when combined with CO2 and drought. Below Deschampsia, the net nitrification rate decreased in response to drought and, while phosphorus availability and microbial P immobilization decreased, but nitrification increased in response to elevated CO2. Furthermore, leaf litter decomposition of both species decreased in response to drought. These complex changes in availability and release of nutrients from soil organic matter turnover and mineralization in response to elevated CO2 and climate change may influence the future plant carbon sequestration and species composition at temperate heathlands.

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Research output: Contribution to journal › Journal article – Annual report year: 2010 › Research › peer-review

The counteracting effects of elevated atmospheric CO2 concentrations and drought episodes: Studies of enchytraeid communities in a dry heathland

The potential impacts of interactions of multiple climate change factors in soil ecosystems have received little attention. Most studies have addressed effects of single factors such as increased temperature or atmospheric CO2 but little is known about how such environmental factors will interact. In the present study we investigate the effects of in situ exposure to elevated atmospheric CO2 concentration, increased temperatures and prolonged drought episodes on field communities of Enchytraeidae (Oligochaeta) in a dry heathland (Brandbjerg, Denmark). Increased CO2 had a positive effect on enchytraeid biomass, whereas drought significantly reduced it. Elevated temperature did not result in any detectable effects. No interactions between the three factors were observed. Interestingly, the positive effect of increased CO2 and the negative effect of drought were cancelled out when applied in combination. Thus, in the combined drought and CO2 treatment, and when additionally combined with increased temperature, the total biomass of enchytraeids was similar to those in the ambient plots. The positive effect of increased CO2 seemed to be influenced by season, as the response was most pronounced during summer, and less so in autumn. The impact of the drought was more consistent, with enchytraeids reduced at all sampling occasions. Moreover, the negative effect of drought seemed to depend on the inter-annual variability of precipitation. The year with a dry summer and autumn (2006) showed a stronger impact of drought on the enchytraeids, compared to the year with a wet summer and autumn (2007). Our study emphasises the importance of multi-factorial experimental design as a means to investigate effects of climatic changes.

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy, Aarhus University, University of Copenhagen
Contributors: Maraldo, K., Krogh, P. H., Linden, L., Christensen, B., Mikkelsen, T. N., Beier, C., Holmstrup, M.
Abliotic Aerobic Methane Release from Plant Material

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Contributors: Bruhn, D., Ambus, P., Mikkelsen, T. N.
Publication date: 2009
Peer-reviewed: No
Event: Poster session presented at ILEAPS/ICOS/NEU Workshop on eddy covariance flux measurements of CH4 and N2O exchanges, Hyytiälä (FI), 8-11 April.
Keywords: Bio energy, Ecosystems, climate effects, greenhouse gasses
Source: orbit
Source-ID: 252009
Research output: Contribution to conference → Poster – Annual report year: 2009 → Research

Adaption of genetic resources to a changing climate

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Contributors: Bagger Jørgensen, R., Frenck, G., Linden, L., Mikkelsen, T. N.
Number of pages: 21
Pages: 8-9
Publication date: 2009

Host publication information
Title of host publication: Abstracts
Place of publication: Lyngby (DK)
Publisher: Technical University of Denmark (DTU)
Keywords: Bio energy, Ecosystems, climate effects, greenhouse gasses
Electronic versions:
abstracts_workshop_12_13_may.pdf
Source: orbit
Source-ID: 252005
Research output: Chapter in Book/Report/Conference proceeding → Conference abstract in proceedings – Annual report year: 2009 → Research

Atmospheric composition change: Ecosystems–Atmosphere interactions
Ecosystems and the atmosphere: This review describes the state of understanding the processes involved in the exchange of trace gases and aerosols between the earth's surface and the atmosphere. The gases covered include NO, NO2, HONO, HNO3, NH3, SO2, DMS, Biogenic VOC, O3, CH4, N2O and particles in the size range 1 nm–10 μm including organic and inorganic chemical species. The main focus of the review is on the exchange between terrestrial
ecosystems, both managed and natural and the atmosphere, although some new developments in ocean–atmosphere exchange are included. The material presented is biased towards the last decade, but includes earlier work, where more recent developments are limited or absent. New methodologies and instrumentation have enabled, if not driven technical advances in measurement. These developments have advanced the process understanding and upscaling of fluxes, especially for particles, VOC and NH3. Examples of these applications include mass spectrometric methods, such as Aerosol Mass Spectrometry (AMS) adapted for field measurement of atmosphere–surface fluxes using micrometeorological methods for chemically resolved aerosols. Also briefly described are some advances in theory and techniques in micrometeorology. For some of the compounds there have been paradigm shifts in approach and application of both techniques and assessment. These include flux measurements over marine surfaces and urban areas using micrometeorological methods and the up-scaling of flux measurements using aircraft and satellite remote sensing. The application of a flux-based approach in assessment of O3 effects on vegetation at regional scales is an important policy linked development through improved quantification of fluxes. The coupling of monitoring, modelling and intensive flux measurement at a continental scale within the NitroEurope network represents a quantum development in the application of research teams to address the underpinning science of reactive nitrogen in the cycling between ecosystems and the atmosphere in Europe. Some important developments of the science have been applied to assist in addressing policy questions, which have been the main driver of the research agenda, while other developments in understanding have not been applied to their wider field especially in chemistry-transport models through deficiencies in obtaining appropriate data to enable application or inertia within the modelling community. The paper identifies applications, gaps and research questions that have remained intractable at least since 2000 within the specialized sections of the paper, and where possible these have been focussed on research questions for the coming decade.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Biosystems Division, Biosystems Division. Management, Ecosystems, Centre for Ecology and Hydrology, University of Oslo, Université Blaise Pascal, Clermont-Ferrand II, Università degli Studi di Urbino Carlo Bo, Research Institute for Nature and Forest, Institut National de la Recherche Agronomique, Wageningen IMARES, National Institute for Agronomic Research, Finnish Meteorological Institute, Catholic University of the Sacred Heart, Justus Liebig University Giessen, Agroscope, European Commission Joint Research Centre Institute, Istituto per la Protezione delle Piante, Energy Research Centre of the Netherlands, Netherlands Organisation for Applied Scientific Research, Chalmers University of Technology, Norwegian Meteorological Institute, Istituto di Scienze dell'Atmosfera e del Clima, University of Copenhagen, Pierre and Marie Curie University - University of Paris VI, University of Leicester, University of Bonn, Bundesforschungsanstalt für Landwirtschaft, Forschungs Zentrum Karlsruhe GmbH, Hungarian Meteorological Service, Istituto di Biologia Agroambientale e Forestale, Estonian University of Life Sciences, University of Edinburgh, Stockholm University, Indiana University-Purdue, University of Manchester, Austrian Federal Office and Research Centre for Forests, Max Planck Institute, National University of Ireland, University of Helsinki
Pages: 5193-5267
Publication date: 2009
Peer-reviewed: Yes

Publication information
Journal: Atmospheric Environment
Volume: 43
Issue number: 33
ISSN (Print): 1352-2310
Ratings:
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.979 SNIP 1.467
Web of Science (2009): Indexed yes
Original language: English
Keywords: Bio energy, Ecosystems, climate effects, greenhouse gasses
DOIs:
10.1016/j.atmosenv.2009.07.068
Source: orbit
Source-ID: 252824
Research output: Contribution to journal › Journal article – Annual report year: 2009 › Research › peer-review
Barley and oilseed rape production will decrease in the future climate

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Pages: 372024
Publication date: 2009

Host publication information
Title of host publication: Climate change: Global risks, challenges and decisions
Publisher: IOP Publishing
(IOP Conference Series: Earth and Environmental Science; No. 6).
Keywords: Bio energy, Ecosystems, climate effects, greenhouse gases
DOIs:
10.1088/1755-1307/6/37/372024
Source: orbit
Source-ID: 256573
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 2009 › Research

Denitrification and N2O losses in a heathland under changing climate conditions

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Biosystems Division, Ecosystems
Publication date: 2009
Peer-reviewed: No
Event: Paper presented at Seminar at University of Hohenheim, Stuttgart (DE), 2 June, .
Keywords: Bio energy, Ecosystems, climate effects, greenhouse gases
Source: orbit
Source-ID: 244635
Research output: Contribution to conference › Paper – Annual report year: 2009 › Research

Ecosystem carbon balance under future climate conditions: the CLIMAITE project carbon synthesis

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy, Biosystems Division. Management, Danish Centre for Environment and Energy, University of Copenhagen
Pages: 042021
Publication date: 2009

Host publication information
Title of host publication: Climate change: Global risks, challenges and decisions
Publisher: IOP Publishing
(IOP Conference Series: Earth and Environmental Science; No. 6).
Keywords: Bio energy, Ecosystems, climate effects, greenhouse gases
DOIs:
10.1088/1755-1307/6/4/042021
Source: orbit
Source-ID: 256574
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 2009 › Research

Ecosystem recovery after drought events in our future climate

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy, University of Copenhagen
Effects of temperature, ultraviolet radiation and pectin methyl esterase on aerobic methane release from plant material

This study examines the effects of different irradiance types on aerobic methane (CH4) efflux rates from terrestrial plant material. Furthermore, the role of the enzyme pectin methyl esterase (PME) on CH4 efflux potential was also examined. Different types of plant tissue and purified pectin were incubated in glass vials with different combinations of irradiation and/or temperature. Purified dry pectin was incubated in solution, and with or without PME. Before and after incubation, the concentration of CH4 was measured with a gas chromatograph. Rates of CH4 emission were found to depend exponentially on temperature and linearly on UV-B irradiance. UV-B had a greater stimulating effect than UV-A, while visible light had no effect on emission rates. PME was found to substantially reduce the potential for aerobic CH4 emissions upon demethylation of pectin.

Greenhouse gas fluxes in a temperate shrub-land under future climatic and environmental conditions

This study examines the effects of different irradiance types on aerobic methane (CH4) efflux rates from terrestrial plant material. Furthermore, the role of the enzyme pectin methyl esterase (PME) on CH4 efflux potential was also examined. Different types of plant tissue and purified pectin were incubated in glass vials with different combinations of irradiation and/or temperature. Purified dry pectin was incubated in solution, and with or without PME. Before and after incubation, the concentration of CH4 was measured with a gas chromatograph. Rates of CH4 emission were found to depend exponentially on temperature and linearly on UV-B irradiance. UV-B had a greater stimulating effect than UV-A, while visible light had no effect on emission rates. PME was found to substantially reduce the potential for aerobic CH4 emissions upon demethylation of pectin.
**N2O and CH4 fluxes in a temperate heathland under future climatic conditions**

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Publication date: 2009

Host publication information
Title of host publication: Abstracts
Keywords: Bio energy, Ecosystems, climate effects, greenhouse gasses
Source: orbit
Source-ID: 252258
Research output: Chapter in Book/Report/Conference proceeding – Annual report year: 2009 › Research

**Responses of carbon and water fluxes following drought events in combinations with warming and elevated CO2**

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Publication date: 2009

Host publication information
Title of host publication: Oral and Poster Presentations of the BIOGEOMON 2009 Conference (online)
Publisher: Finnish Environment Institute
Keywords: Bio energy, Ecosystems, climate effects, greenhouse gasses
Electronic versions: Biogeomon_presentation.pdf
Source: orbit
Source-ID: 252151
Research output: Chapter in Book/Report/Conference proceeding – Annual report year: 2009 › Research

**The newly discovered aerobic methane release from terrestrial vegetation: Causes and consequences**

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Contributors: Bruhn, D., Ambus, P., Mikkelsen, T. N.
Publication date: 2009
Peer-reviewed: No
Event: Poster session presented at International Scientific Congress on Climate Change, Copenhagen, Denmark.
Keywords: Bio energy, Ecosystems, climate effects, greenhouse gasses
Source: orbit
Source-ID: 244644
Research output: Contribution to conference – Poster – Annual report year: 2009 › Research

**The newly discovered aerobic methane release from terrestrial vegetation: Causes and consequences**

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Contributors: Bruhn, D., Mikkelsen, T. N., Øbro, J., Willats, W., Ambus, P.
Publication date: 2009
Peer-reviewed: No
Keywords: Bio energy, Ecosystems, climate effects, greenhouse gasses
Source: orbit
UV-irradiation induces aerobic methane release from plant material

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy, University of Copenhagen
Contributors: Bruhn, D., Øbro, J., Willats, W. G., Mikkelsen, T. N., Ambus, P.
Publication date: 2009
Peer-reviewed: No
Keywords: Bio energy, Ecosystems, climate effects, greenhouse gasses
Source: orbit

Water use efficiency as a means to assess forest carbon uptake for different management strategies

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy, Biosystems Division. Management, Lund University
Contributors: Linderson, M., Mikkelsen, T. N., Ibrom, A., Lindroth, A., Pilegaard, K.
Publication date: 2009

Host publication information
Title of host publication: Proceedings (cd-rom)
Publisher: Max-Planck-Institute for Biogeochemistry
Keywords: Bio energy, Ecosystems, climate effects, greenhouse gasses
Electronic versions:
Maj-Lena_abstract.pdf
Source: orbit
Source-ID: 251452

Water use efficiency as a measure to assess forest carbon uptake for different management strategies

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy, Biosystems Division. Management
Contributors: Linderson, M., Mikkelsen, T. N., Ibrom, A., Lindroth, A., Pilegaard, K.
Publication date: 2009
Peer-reviewed: No
Keywords: Bio energy, Ecosystems, climate effects, greenhouse gasses
Electronic versions:
Maj-Lena_poster.pdf
Source: orbit
Source-ID: 251450

Ambient UV-B radiation decreases photosynthesis in high arctic Vaccinium uliginosum

An UV-B-exclusion experiment was established in high arctic Zackenberg, Northeast Greenland, to investigate the possible effects of ambient UV-B on plant performance. During almost a whole growing season, canopy gas exchange and Chl fluorescence were measured on Vaccinium uliginosum (bog blueberry). Leaf area, biomass, carbon, nitrogen and UV-B-absorbing compounds were determined from a late season harvest. Compared with the reduced UV-B treatment, the plants in ambient UV-B were found to have a higher content of UV-B-absorbing compounds, and canopy net photosynthesis was as an average 23% lower during the season. By means of the JIP-test, it was found that the potential of processing light energy through the photosynthetic machinery was slightly reduced in ambient UV-B. This indicates that
not only the UV-B effects on PSII may be responsible for some of the observed reduction of photosynthesis but also the
effects on other parts of the photosynthetic machinery, e.g. the Calvin cycle, might be important. The 60% reduction of the
UV-B irradiance used in this study implies a higher relative change in the UV-B load than many of the supplemental
experiments do, but the substantial effect on photosynthesis clearly indicates that V. uliginosum is negatively affected by
the current level of UV-B.

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Rise National Laboratory for Sustainable Energy
Contributors: Albert, K. R., Mikkelsen, T. N., Ro-Poulsen, H.
Pages: 199-210
Publication date: 2008
Peer-reviewed: Yes

Publication information
Journal: Physiologia Plantarum : An International Journal for Plant Biology
Volume: 133
Issue number: 2
ISSN (Print): 0031-9317
Ratings:
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.232 SNIP 1.016
Web of Science (2008): Indexed yes
Original language: English
DOIs:
10.1111/j.1399-3054.2008.01065.x
Source: orbit
Source-ID: 223006
Research output: Contribution to journal › Journal article – Annual report year: 2008 › Research › peer-review

Biological responses to current fluxes of ultraviolet radiation in High Arctic After the Melt

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Rise National Laboratory for Sustainable Energy
Contributors: Albert, K. R., Rinnan, R., Mikkelsen, T. N., Ro-Poulsen, H., Michelsen, A., Arndal, M., Schmidt, N.
Publication date: 2008
Peer-reviewed: No
Event: Abstract from International Conference on Ecological Responses to Arctic Climate Change, Århus (DK), 5-7 May, .
Source: orbit
Source-ID: 252142
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2008 › Research

Biological responses to current UV-B radiation in Arctic regions

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Rise National Laboratory for Sustainable Energy
Contributors: Albert, K. R., Mikkelsen, T. N., Ro-Poulsen, H.
Pages: EGU2008-A-11698
Publication date: 2008

Host publication information
Title of host publication: Geophysical Research Abstracts
Volume: 10
Publisher: European Geophysical Union
Source: orbit
Source-ID: 252145
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report
year: 2008 › Research

Biological responses to current UV-B radiation in Arctic regions
Challenges in understanding the risks to natural and semi-natural vegetation from ozone exposure

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Contributors: Cape, J., Bassin, S., Fuhrer, J., Gerosa, G., Alonso, R., Gimeno, B., Grünhage, L., Mikkelsen, T. N., Mills, G.
Pages: 53-59
Publication date: 2008
Peer-reviewed: Yes

Publication information
Journal: Italian Journal of Agronomy
Volume: 3
ISSN (Print): 1125-4718
Original language: English
Source-ID: 222885
Research output: Contribution to journal › Journal article – Annual report year: 2008 › Research › peer-review

CLIMAITE - a three factor climate change ecosystem manipulation experiment

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy, Biosystems Division.
Pages: EGU2008-A-07931
Publication date: 2008

Host publication information
Title of host publication: Geophysical Research Abstracts
Volume: 10
Publisher: European Geophysical Union
Source-ID: 252146
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 2008 › Research

Experimental design of multifactor climate change experiments with elevated CO2, warming and drought: the CLIMAITE project

Recent findings indicate that the interactions among CO2, temperature and water can be substantial, and that the combined effects on the biological systems of several factors may not be predicted from experiments with one or a few factors. Therefore realistic multifactorial experiments involving a larger set of main factors are needed. We describe a new Danish climate change-related field scale experiment, CLIMAITE, in a heath/grassland ecosystem. CLIMAITE is a full factorial combination of elevated CO2, elevated temperature and prolonged summer drought. The manipulations are intended to mimic anticipated major environmental changes at the site by year 2075 as closely as possible. The impacts on ecosystem processes and functioning (at ecophysiological levels, through responses by individuals and communities to ecosystem-level responses) are investigated simultaneously. The increase of [CO2] closely corresponds with the scenarios for year 2075, while the warming treatment is at the lower end of the predictions and seems to be the most
difficult treatment to increase without unwanted side effects on the other variables. The drought treatment follows predictions of increased frequency of drought periods in summer. The combination of the treatments does not create new unwanted side effects on the treatments relative to the treatments alone.

**General information**
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy, Biosystems Division.

**Management**
Pages: 185-195
Publication date: 2008
Peer-reviewed: Yes

**Publication information**
Journal: Functional Ecology
Volume: 22
Issue number: 1
ISSN (Print): 0269-8463
Ratings:
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 2.451 SNIP 1.519
Web of Science (2008): Indexed yes
Original language: English
DOIs: 10.1111/j.1365-2435.2007.01362.x
Source: orbit
Source-ID: 223196
Research output: Contribution to journal › Journal article – Annual report year: 2008 › Research › peer-review

**Future photosynthetic performance of heath plants - results from the multi-factorial ecosystem experiment CLIMAITE**

**General information**
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Contributors: Albert, K. R., Mikkelsen, T. N., Ro-Poulsen, H.
Publication date: 2008
Peer-reviewed: No
Source: orbit
Source-ID: 252149
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2008 › Research

**Linking xylem diameter variations with sap flow measurements**

**General information**
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Pages: 77-90
Publication date: 2008
Peer-reviewed: Yes

**Publication information**
Journal: Plant and Soil
Volume: 305
Issue number: 1-2
ISSN (Print): 0032-079X
Ratings:
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.128 SNIP 1.164
Plant-ecophysiological response patterns to summer drought, elevated CO2 and warming in a natural temperate heath ecosystem

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Contributors: Albert, K. R., Mikkelsen, T. N., Ro-Poulsen, H., Michelsen, A.
Publication date: 2008
Peer-reviewed: No
Event: Abstract from Ecological Society of America 93rd ESA Annual Meeting, Milwaukee, USA.
Source: orbit
Source-ID: 223093
Research output: Contribution to journal › Journal article – Annual report year: 2008 › Research › peer-review

Solar ultraviolet-B radiation at Zackenberg: The impact on higher plants and soil microbial communities

General information
Publication status: Published
Organisations: Biosystems Division
Contributors: Albert, K. R., Rinnan, R., Ro-Poulsen, H., Mikkelsen, T. N., Håkansson, K. B., Arndal, M., Michelsen, A.
Pages: 421-440
Publication date: 2008
Peer-reviewed: Yes
Publication information
Journal: Advances in Ecological Research
Volume: 40
ISSN (Print): 0065-2504
Ratings:
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.341 SNIP 1.072
Web of Science (2008): Indexed yes
Original language: English
DOIs:
10.1016/S0065-2504(07)00018-9
Source: orbit
Source-ID: 222873
Research output: Contribution to journal › Journal article – Annual report year: 2008 › Research › peer-review

Studies of plant responses to UV-B radiation 2007

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Contributors: Albert, K. R., Boesgaard, K., Ro-Poulsen, H., Mikkelsen, T. N., Michelsen, A., Schmidt, N. M.
Pages: 80-81
Publication date: 2008
Host publication information
Title of host publication: Zackenberg Ecological Research Operations 13th Annual Report, 2007
Place of publication: Copenhagen
Publisher: Danish Polar Center
ISBN (Print): 87-90369-25-5
Source: orbit
Source-ID: 252131
Research output: Contribution to journal › Journal article – Annual report year: 2008 › Research › peer-review
Water Use Efficiency as a Means of Up Scaling Carbon Flux from Leaf to Stand

General information
Publication status: Published
Organisations: Biosystems Division, Risø National Laboratory for Sustainable Energy, Lund University
Contributors: Linderson, M., Mikkelsen, T. N., Ibrom, A., Lindroth, A., Pilegaard, K.
Pages: EGU2008-A-09322
Publication date: 2008
Peer-reviewed: No

Publication information
Journal: Geophysical Research Abstracts
Volume: 10
ISSN (Print): 1607-7962
Original language: English
Electronic versions:
EGU2008_A_09322.pdf

Water Use Efficiency as a Means of Up Scaling Carbon Flux from Leaf to Stand

General information
Publication status: Published
Organisations: Biosystems Division, Risø National Laboratory for Sustainable Energy, Lund University
Contributors: Linderson, M., Mikkelsen, T. N., Ibrom, A., Lindroth, A., Pilegaard, K.
Publication date: 2008
Peer-reviewed: No
Event: Poster session presented at European Geosciences Union General Assembly 2008, Vienna, Austria.
Electronic versions:
Poster.pdf
Source: orbit
Source-ID: 252057

Abiotic aerobic methane release from plant material

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Contributors: Bruhn, D., Ambus, P., Mikkelsen, T. N.
Publication date: 2007
Peer-reviewed: No
Event: Poster session presented at Joint Assembly of the American Geophysical Union (AGU), San Francisco, CA, United States.
URLs:
Source: orbit
Source-ID: 215588

Ambient UV-B decreases PSII performance and net photosynthesis under natural irradiance of the high arctic dwarf shrub Salix arctica

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Contributors: Albert, K. R., Mikkelsen, T. N., Ro-Poulsen, H., Arndal, M., Michelsen, A.
Publication date: 2007
Peer-reviewed: No
Event: Abstract from Nordic Photosynthetic Congress, Copenhagen, Denmark.
CLIMAITE - a three factor climate change ecosystem manipulation experiment

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Beier, C., Albert, K. R., Ro-Poulsen, H.
Publication date: 2007

Host publication information
Title of host publication: EOS Transactions AGU
Volume: 88
Publisher: American Geophysical Union
Source: orbit
Source-ID: 220706
Research output: Chapter in Book/Report/Conference proceeding – Annual report year: 2007 › Research

CLIMAITE - manipulation med klimaet

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Contributors: Beier, C., Mikkelsen, T. N., Michelsen, A., Holmstrup, M., Schmidt, I.
Pages: 71-74
Publication date: 2007
Peer-reviewed: Unknown

Publication information
Journal: Vand & Jord
Volume: 14
Issue number: 2
ISSN (Print): 0908-7761
Original language: Danish
Source: orbit
Source-ID: 215643
Research output: Contribution to journal › Journal article – Annual report year: 2007 › Communication

Combined effects of drought, temperature and CO2 on GHG emissions from temperate shrub-land

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy, Biosystems Division.
Management
Publication date: 2007
Peer-reviewed: No
Event: Paper presented at COST 639 plenary meeting, Vienna, Austria.
Source: orbit
Source-ID: 215582
Research output: Contribution to conference › Paper – Annual report year: 2007 › Research

Denitrification and N2O losses in a heath-land under changing climate conditions

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy, Biosystems Division.
Management
Effects of current UV-B fluxes on high arctic vegetation (UV-exclusion experiments)

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Contributors: Albert, K. R., Arndal, M., Ro-Poulsen, H., Michelsen, A., Mikkelsen, T. N.
Pages: 78-80
Publication date: 2007

Host publication information
Title of host publication: Zackenberg Ecological Research Operations 12th Annual Report, 2006
Place of publication: Copenhagen
Publisher: Danish Polar Center
Editors: Kiltgaard, A., Rasch, M., Caning, K.
ISBN (Print): 87-90369-14-9
Source: orbit
Source-ID: 252130

Klimaændringer og processer og funktion i terrestriske økosystemer

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Pages: 117-128
Publication date: 2007
Peer-reviewed: Yes

Publication information
Journal: Flora og Fauna
Volume: 113
ISSN (Print): 0015-3818
Original language: Danish
Electronic versions:
apper_Kappel2008_ff.pdf
Source: orbit
Source-ID: 253704

Klima-tidsmaskinen - hvordan bliver det danske klima anno 2075?

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N.
Publication date: 2007
Peer-reviewed: Unknown
Source: orbit
Source-ID: 216623
Research output: Contribution to conference – Paper – Annual report year: 2007 – Communication
Plant eco-physiological response patterns to summer drought, elevated CO2 and warming in a semi-natural temperate heath ecosystem

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Contributors: Ro-Poulsen, H., Albert, K. R., Mikkelsen, T. N., Michelsen, A.
Publication date: 2007
Peer-reviewed: No
Event: Abstract from Nordic Photosynthetic Congress, Copenhagen, Denmark.
Source: orbit
Source-ID: 252134
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2007 › Research

Scaling of carbon fluxes in canopies: Simulation of gross canopy photosynthesis in a beech forest canopy

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy, Meteorology, Wind Energy Division, Biosystems Division. Management
Contributors: Ibrom, A., Mikkelsen, T., Dellwik, E., Pilegaard, K.
Publication date: 2007
Peer-reviewed: No
Source: orbit
Source-ID: 215485
Research output: Contribution to conference › Paper – Annual report year: 2007 › Research

Scaling of photosynthesis in a Danish beech forest canopy

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy, Biosystems Division. Management
Contributors: Ibrom, A., Mikkelsen, T. N., Jarvis, P., Pilegaard, K.
Number of pages: 88
Publication date: 2007

Host publication information
Title of host publication: [Programme and Abstracts]
Place of publication: Poznan
Publisher: Organizing Committee
Source: orbit
Source-ID: 215985
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 2007 › Research

Climaite - a three factor climate change ecosystem manipulation study: Set up and approaches for data analysis

General information
Publication status: Published
Organisations: Biosystems Division, Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Beier, C., Kappel Schhmidt, I., Michelsen, A., Albert, K., Ambus, P., Andersen, K.
Publication date: 2006
Peer-reviewed: No
Source: orbit
Source-ID: 309524
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2006 › Research
Continuous flux measurements as a tool to observe stresses in and strains on forests

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Biosystems Division
Contributors: Ibrom, A., Mikkelsen, T. N.
Publication date: 2006
Peer-reviewed: No
Source: orbit
Source-ID: 309031
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2006 › Research

Den biologiske tidsmaskine og planternes fysiologiske respons

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Biosystems Division
Contributors: Albert, K., Ro-Poulsen, H., Mikkelsen, T. N.
Publication date: 2006
Peer-reviewed: No
Event: Abstract from BIO-dagen, Risø (DK), Jan, .
Source: orbit
Source-ID: 310012
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2006 › Research

Effekter af klima- og UV-B manipulationer på processer og organismer i højarktiske teræstriske økosystemer. Opsummerende rapport til Miljøstyrelsen

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Number of pages: 16
Publication date: 2006

Publication information
Original language: Danish
Source: orbit
Source-ID: 310002
Research output: Book/Report › Report – Annual report year: 2006 › Research

How does prolonged drought affect plant physiological processes? - Focus on the interactions with increased temperature and elevated [CO₂] within the CLIMAITE project?

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Biosystems Division
Contributors: Albert, K., Ro-Poulsen, H., Mikkelsen, T. N.
Publication date: 2006
Peer-reviewed: No
Event: Abstract from EPRECOT Precipitation Workshop, Elsinore, Denmark.
Source: orbit
Source-ID: 309512
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2006 › Research

Klimatidsmaskinen - hvordan vil Danmark påvirkes af den foresegde CO₂ koncentration og drivhuseffekt?

General information
Publication status: Published
Organisations: Biosystems Division, Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N.
Ozone deposition to forest is dynamic and correlates positive with temperature (poster)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Hovmand, M.
Publication date: 2006
Peer-reviewed: No
Source: orbit
Source-ID: 309525
Research output: Contribution to conference › Poster – Annual report year: 2006 › Research

RERAF - a new resource for BIO. Which new experimental possibilities arise?

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N.
Publication date: 2006
Peer-reviewed: No
Event: Abstract from BIO seminar, Risø, Denmark.
Source: orbit
Source-ID: 309693
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2006 › Research

Solar ultraviolet-B radiation (UV-B) in Zackenberg: Inter-annual variability and the impact on higher plants and microbial communities

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Albert, K., Eriksen, P., Rinnan, R., Mikkelsen, T. N., Håkansson, K.
Publication date: 2006
Peer-reviewed: No
Event: Abstract from Zackenberg Symposium, Menstrup, Denmark.
Source: orbit
Source-ID: 309032
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2006 › Research

Studying effects of current UV-fluxes on high arctic vegetation (UV-B exclusion experiments)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Albert, K., Arndal, M., Michelsen, A., Tamstorf, M., Ro-Poulsen, H., Mikkelsen, T. N.
Pages: 90-91
Publication date: 2006

Host publication information
Title of host publication: Zackenberg Ecological Research Operations. 11th Annual report, 2005
Place of publication: Copenhagen
Publisher: Danish Polar Center
Editors: Klitgaard, A., Rasch, M., Caning, K.
Source: orbit
Study trip to Borneo - Research in the tropical rain forest

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Ibrom, A.
Publication date: 2006
Peer-reviewed: No
Event: Abstract from BIO seminar, Risø, Denmark.
Source: orbit

The Biological Time Machine - Biological responses to multiple environmental and climatic changes, environment and stress

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Publication date: 2006
Peer-reviewed: No
Event: Abstract from PhD Symposium at KVL, Copenhagen (DK), Oct.,
Source: orbit

Transpiration and canopy conductance in a natural and a managed mature stand of European beech

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Risø National Laboratory for Sustainable Energy
Contributors: Dalsgaard, L., Mikkelsen, T. N., Bastrup-Birk, A.
Pages: 21-27
Publication date: 2006

Host publication information
Title of host publication: Patterns and processes in forest landscapes. Consequences of human management.
Proceedings
Place of publication: Bari
Publisher: IUFRO
Editors: Laforteza, R., Sanesi, G.
Source: orbit
Source-ID: 309585
Research output: Chapter in Book/Report/Conference proceeding – Annual report year: 2006

Ambient ultraviolet radiation in the Arctic reduces root biomass and alters microbial community composition but has no effects on microbial biomass

General information
Publication status: Published
Organisations: Ecosystems, Biosystems Division, Rise National Laboratory for Sustainable Energy
Contributors: Rinnan, R., Keinänen, M., Kasurinen, A., Asikainen, J., Kekki, T., Holopainen, T., Ro-Poulsen, H., Mikkelsen, T. N., Michelsen, A.
Pages: 564-574
Publication date: 2005
Peer-reviewed: Yes
Ambient UV-radiation decreases photosynthetic performance on high arctic plants

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Albert, K., Ro-Poulsen, H., Mikkelsen, T. N.
Publication date: 2005
Peer-reviewed: No
Event: Abstract from 11. Biennial meeting of Arctic Biology, University of Copenhagen, Copenhagen (DK), March, .
Source: orbit
Source-ID: 310015
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2005 › Research

Diurnal pattern in water tension of tree stems begins before bud break and does not cease with leaf fall

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Publication date: 2005
Peer-reviewed: No
Event: Abstract from ESA 2005 annual meeting, Montreal (CA), 7-12 Aug, .
Source: orbit
Source-ID: 308304
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2005 › Research

Effects of ambient versus reduced UV-B radiation on high arctic Salix arctica assessed by measurements and calculations of chlorophyll a fluorescence parameters from fluorescence transients

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Albert, K., Mikkelsen, T. N., Ro-Poulsen, H.
Pages: 208-226
Publication date: 2005
Peer-reviewed: Yes

Publication information
Journal: Physiol. Plant.
Volume: 124
Original language: English
DOIs:
10.1111/j.1399-3054.2005.00502.x
Source: orbit
Source-ID: 308096
Research output: Contribution to journal › Journal article – Annual report year: 2005 › Research › peer-review
Effects of reduced ambient UV-B radiation in the high Arctic on Salix arctica and Vaccinium uliginosum

Effects of reducing the ambient UV-B radiation on gas exchange and chlorophyll fluorescence of two dwarf shrub species, Salix arctica and Vaccinium uliginosum, was studied in a high arctic heath in North East Greenland during two growing seasons. Films (Mylar, transmitting λ > 320 nm, and Lexan, transmitting λ > 400 nm) were used to reduce UV-B radiation and UV-B+A respectively. A UV transparent film (Teflon, transmitting λ > 280 nm) and no film were used as controls. Field measurements showed that the plants under Teflon, Mylar and Lexan received app. 91%, 39% and 17% of the ambient UV-B irradiance, respectively. UV radiation decreased the maximal photochemical efficiency (Fv/Fm) and other fast fluorescence transient derived parameters in both species, despite an increased level of leaf flavonoid content. The responses varied in significance according to species and site. The relation of these effects to a significantly decreased stomatal conductance (gs) and intercellular CO2 concentration (Ci) pointed to respiration as an important factor in the interpretation of the observed unaffected net CO2 assimilation (Pn) in UV-reduced treatments. It is concluded that the studied species have not fully acclimatized to the level of ambient UV-B radiation, and that ambient UV-B level is an important stress factor for the investigated plants in High Arctic.

Monitoring effects of ambient UV-B radiation on high arctic vegetation

General information
Nighttime ozone deposition is dynamic and correlates positive with temperature (poster)

Transgene expression and fitness of hybrids between GM oilseed rape and Brassica rapa

CLIMAITE - CLIMATE change effects on biological processes in Terrestrial Ecosystems. A new Danish global change experiment (poster)
Effects of UV-B radiation on vegetation in Zackenberg

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ro-Poulsen, H., Mikkelsen, T. N., Bredahl, L., Albert, K., Håkansson, K.
Pages: 69-70
Publication date: 2004

Host publication information
Title of host publication: Zackenberg Ecological Research Operations. 9th Annual report, 2003
Place of publication: Copenhagen
Publisher: Danish Polar Center
Editors: Rasch, M., Caning, K.
Source: orbit
Source-ID: 307650
Research output: Chapter in Book/Report/Conference proceeding – Annual report year: 2004 – Research

Exploitation of future increased CO₂ in varieties of oat, Avena sativa

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Johannessen, M., Mikkelsen, T. N., Bagger Jørgensen, R.
Publication date: 2004
Peer-reviewed: No
Event: Abstract from PRD-seminar March 2003, Risø, Denmark.
Source: orbit
Source-ID: 306686
Research output: Contribution to conference – Annual report year: 2004 – Research

Five-year measurements of ozone fluxes to a Danish Norway spruce canopy

Ozone concentrations and fluxes have been measured continuously during 5 years (1996-2000) by the gradient method in a Norway spruce dominated forest stand in West Jutland, Denmark, planted in 1965. The method has been validated against other methodologies and a relatively good relationship was found. The data are analysed to quantify diurnal, seasonal and yearly fluxes, and non-stomatal and stomatal removal are estimated. Monthly means of climatic data are shown, and day and night values of the aerodynamic resistance, r(a), viscous sub-layer resistance, r(b), and the surface or canopy resistance, r(c), are presented. The yearly ozone deposition is approximately 126 kg ha(-1). The canopy ozone uptake is highest during the day and during the summer. This is interpreted as increased stomatal uptake and physical and chemical reactions. The daily means of ozone concentration and fluxes averaged over 5 years correlate, but the correlation is primarily based on two different uncoupled processes outside and inside the stomates: (1) The ozone destruction in the canopy occurring outside the stomates is much influenced by temperature, light and humidity, e.g. surface reactions, NO- and VOC-emissions. (2) The same factors have a strong influence on the stomatal opening, e.g. midday and night closure. Thus, looking at diurnal variations, the diurnal ozone concentration and ozone flux do not correlate at all during the growing season. The maximum diurnal difference for the ozone concentration is a factor 1.3 and the maximum diurnal difference for the ozone flux is a factor 3. From dawn to ca. 8:00 the ozone deposition increases and the ozone concentration decreases.

The yearly stomatal uptake of ozone is estimated to minimum 21% of the total deposition, being highest in May-August (30-33%) and lowest in November-February (4-9%). The physiological ozone uptake per leaf area is estimated to 0.33 g ozone m(-2) Y(-1). (C) 2004 Elsevier Ltd. All rights reserved.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Ro-Poulsen, H., Hovmand, M., Jensen, N., Pilegaard, K., Egeløv, A.
Pages: 2361-2371
Publication date: 2004
Peer-reviewed: Yes

Publication information
Implementation of the optimal stomatal control formulation into a single layer model

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Dellwik, E., Mikkelsen, T. N.
Publication date: 2004
Peer-reviewed: No
Event: Abstract from International conference on modeling forest production, Vienna (AT), 19-22 Apr.
Source: orbit
Source-ID: 307100
Research output: Contribution to conference » Conference abstract for conference – Annual report year: 2004 » Research


General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ro-Poulsen, H., Albert, K. R., Mikkelsen, T. N.
Number of pages: 12
Publication date: 2004

Publication information
Original language: English
Source: orbit
Source-ID: 307739
Research output: Book/Report » Report – Annual report year: 2004 » Research

Ozone deposition to a Danish forest - comparison of flux, stomatal uptake, non-stomatal uptake and multiple indexes

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Pilegaard, K., Jensen, N., Ro-Poulsen, H., Hovmand, M.
Publication date: 2004
Peer-reviewed: No
Event: Abstract from Copenhagen global change initiative - atmospheric chemistry seminar series, Department of Chemistry, Physical Chemistry, University of Copenhagen, Copenhagen (DK), 4 Nov.
Source: orbit
Source-ID: 307320
Research output: Contribution to conference » Conference abstract for conference – Annual report year: 2004 » Research

Ozone deposition to a Danish forest - comparison of flux, stomatal uptake, non-stomatal uptake and multiple indexes (lecture and poster)

General information
Photorespiration contributes to stomatal regulation and carbon isotope fractionation: A study with barley, potato and Arabidopsis plants deficient in glycine decarboxylase

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Igamberdiev, A., Mikkelsen, T. N., Ambus, P., Bauwe, H., Lea, P., Gardeström, P.
Pages: 139-152
Publication date: 2004
Peer-reviewed: Yes

Publication information
Journal: Photosynthesis Research
Volume: 81
ISSN (Print): 0166-8595
Ratings:
Scopus rating (2004): SJR 0.895 SNIP 0.744
Web of Science (2004): Indexed yes
Original language: English
DOIs:
10.1023/B:PRES.0000035026.05237.ec
Source: orbit
Source-ID: 307056
Research output: Contribution to journal › Journal article – Annual report year: 2004 › Research › peer-review

Photosynthesis and UV-B in the high Arctic - does ambient UV-B matter? (poster)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Albert, K., Mikkelsen, T. N., Ro-Poulsen, H., Bredahl, L., Haakanson, K.
Publication date: 2004
Peer-reviewed: No
Event: Poster session presented at 26th Annual Air Pollution Workshop, Rhinelander, WI, United States.
Source: orbit
Source-ID: 306755
Research output: Contribution to conference › Poster – Annual report year: 2004 › Research

Reduction of the ambient UV-B radiation in the high Arctic increases Fv/Fm in Salix arctica and Vaccinium uliginosum and reduces stomatal conductance and internal CO2 concentration in Salix arctic

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Bredahl, L., Ro-Poulsen, H., Mikkelsen, T. N.
Pages: 364-368
Publication date: 2004
Peer-reviewed: Yes

Publication information
Journal: Arctic, Antarctic, and Alpine Research
Volume: 36
ISSN (Print): 1523-0430
Ratings:
Scopus rating (2004): SJR 0.776 SNIP 0.807
Web of Science (2004): Indexed yes
Original language: English
Source: orbit
Source-ID: 307723
Research output: Contribution to journal › Journal article – Annual report year: 2004 › Research › peer-review

**Tree stem diameter variations before bud break and after leaf fall in *Fagus sylvatica***

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Sevanto, S., Mikkelsen, T. N., Nikinmaa, E., Vesala, T.
Pages: 277-280
Publication date: 2004

**Host publication information**
Title of host publication: Research unit on physics, chemistry and biology of atmospheric composition and climate change: 2. Progress report and proceedings of seminar, Helsinki 14-16.4.2004
Place of publication: Helsinki
Publisher: Finnish Association for Aerosol Research
Editors: Kulmala, M., Salonen, M., Ruuskanen, T.
(Finnish Association for Aerosol Research. Report Series in Aerosol Science; No. 68).
Source: orbit
Source-ID: 307738
Research output: Chapter in Book/Report/Conference proceeding › Book chapter – Annual report year: 2004 › Research › peer-review

**Atmosfærisk deposition til skove**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Andersen, H., Hovmand, M., Ro-Poulsen, H., Hansen, K., Pilegaard, K., Mikkelsen, T. N., Hummelshøj, P., Jensen, N., Stenholt, C.
Pages: 33-67
Publication date: 2003

**Host publication information**
Title of host publication: Næringsstofkredsløb i skove - Ionbalanceprojektet
Place of publication: Hørsholm
Publisher: Danish Forest and Landscape Research Institute
Editor: Hansen, K.
ISBN (Print): 87-7903-156-0
(Forest and Landscape Research, no. 33, 2003).
Source: orbit
Source-ID: 305724
Research output: Chapter in Book/Report/Conference proceeding › Book chapter – Annual report year: 2003 › Research

**Biomasse og produktion**

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Bastrup-Birk, A., Hansen, K., Ro-Poulsen, H., Jørgensen, B., Mikkelsen, T. N., Pilegaard, K., Bille-Hansen, J.
Pages: 69-96
Publication date: 2003

**Host publication information**
Title of host publication: Næringsstofkredsløb i skove - Ionbalanceprojektet
Place of publication: Hørsholm
Publisher: Danish Forest and Landscape Research Institute
Comparison of tree stem diameter variations in beech (Fagus sylvatica L.) in Sorø Denmark and in Scots pine (Pinus sylvestris L.) in Hyytiälä, Finland

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Sevanto, S., Mikkelsen, T. N., Pilgaard, K., Vesala, T.
Pages: 457-464
Publication date: 2003
Peer-reviewed: Yes

Publication information
Journal: Boreal Environment Research
Volume: 8
ISSN (Print): 1239-6095
Ratings:
Scopus rating (2003): SJR 0.439 SNIP 0.479
Web of Science (2003): Indexed yes
Original language: English
Source: orbit
Source-ID: 306161
Research output: Contribution to journal › Journal article – Annual report year: 2003 › Research › peer-review

Eddy kovarians og gradient målinger af fluxe af O3 og NO2

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Pilgaard, K., Mikkelsen, T. N., Jensen, N.
Publication date: 2003
Peer-reviewed: No
Event: Abstract from Seminar om atmosfæriske tørdeposition af gasser og partikler, Roskilde (DK), 16 Dec, .
Source: orbit
Source-ID: 306189
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2003 › Research

Effects of UV-B radiation on arctic perennial plants

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Ro-Poulsen, H., Bredahl, L.
Pages: 56-58
Publication date: 2003

Host publication information
Title of host publication: Zackenberg Ecological Research Operations. 7th Annual report, 2001
Place of publication: Copenhagen
Publisher: Danish Polar Center
Editors: Caning, K., Rasch, M.
ISBN (Print): 87-90369-63-7
URLs:
Source: orbit
Source-ID: 305740
Research output: Chapter in Book/Report/Conference proceeding › Book chapter – Annual report year: 2003 › Research
Physiology of the tree studies via the trunk. Introduction to three techniques used to study sap flow, diameter variation and respiration, all related to CO₂ or/and water fluxes

Test and implementation of a dry deposition module for use in transport-chemistry models for Northern Europe

Climate change in a plant ecophysiological perspective

Comparison of carbon uptake by a coniferous and a deciduous forest in Denmark
CO₂ exploitation and genetic diversity in winter varieties of oilseed rape (Brassica napus); varieties of tomorrow

General information
Publication status: Published
Organisations: Rise National Laboratory for Sustainable Energy
Contributors: Johannessen, M., Mikkelsen, T. N., Bagger Jørgensen, R.
Pages: 75-86
Publication date: 2002
Peer-reviewed: Yes

Day and night respiration in a beech forest ecosystem

General information
Publication status: Published
Organisations: Rise National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Bruhn, D.
Publication date: 2002
Peer-reviewed: No
Event: Abstract from EU-meeting arranged by Atmospheric Science Research Group, Environmental Change Institute, Department of Experimental Physics, National University of Ireland, Carna (IE), 26-28 Aug, .
Source: orbit
Source-ID: 304464
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2002 › Research

Does the direct effect of atmospheric CO₂ concentration on leaf respiration vary with temperature? Responses in two species of Plantago that differ in relative growth rate

General information
Publication status: Published
Organisations: Rise National Laboratory for Sustainable Energy
Contributors: Bruhn, D., Mikkelsen, T. N., Atkin, O.
Pages: 57-64
Publication date: 2002
Peer-reviewed: Yes
Five year measurements of ozone fluxes to a Danish Norway spruce canopy (poster)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Ro-Poulsen, H., Hovmand, M., Jensen, N., Pilegaard, K.
Publication date: 2002
Peer-reviewed: No
Event: Poster session presented at Workshop establishing ozone critical levels II, Göteborg (SE), 19-22 Nov,.
Source: orbit
Source-ID: 304797
Research output: Contribution to conference › Poster – Annual report year: 2002 › Research

Hvad betyder den atmosfæriske ozonkoncentration for ozonoptagelsen i planter? - belyst ved mikrometeorologiske målinger over en nåleskov (poster)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Ro-Poulsen, H., Jensen, N., Hovmand, M., Pilegaard, K.
Pages: 211-212
Publication date: 2002

Host publication information
Title of host publication: Resumé af foredrag og posters
Place of publication: Roskilde
Publisher: Danmarks Miljøundersøgelser
ISBN (Print): 87-7772-681-2
URLs:
Source: orbit
Source-ID: 304322
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 2002 › Research

In situ autumn ozone fumigation of mature Norway spruce - Effects on net photosynthesis

Twelve cuvettes were installed on current year's twigs in the top of the canopy of a 35 years old Norway spruce stand in Denmark. From 10 to 16 hours, six of the cuvettes received 5-60 nl l(-1) ozone in addition to ambient air and six cuvettes received ambient air with a 40% reduced ozone concentration. The experiment was conducted during 70 days during the autumn. Our system could not detect any ozone effects on dark respiration, but eventually effects on dark respiration could be masked in signal noise. An inhibition of daily net photosynthesis in ozone treated shoots was apparent, and it is was found that a mean increase in ozone concentration of 10 nl l(-1) reduced net photosynthesis with 7.4 %. This effect should be related to a pre-exposure during the season of AOT40 12.5 mul l(-1) h.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Ro-Poulsen, H.
Pages: 97-104
Publication date: 2002
Peer-reviewed: Yes

Publication information
Journal: Phyton. Annales Rei Botanicae
Volume: 42
Issue number: 3
ISSN (Print): 0079-2047
Ratings:
Kulstofbinding i skov- og landbrugsøkosystemer

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Pilegaard, K., Jensen, N., Mikkelsen, T. N., Ro-Poulsen, H.
Pages: 183-184
Publication date: 2002

Photorespiration contributes to stomatal regulation and carbon isotope fractionation. A study with barley, potato and Arabidopsis plants deficient in the glycine decarboxylase

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Igamberdiev, A., Mikkelsen, T. N., Ambus, P., Gardeström, P.
Publication date: 2002
Peer-reviewed: No
Source: orbit
Source-ID: 304261
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2002 › Research

Plantefysiologiske effekter af ambient UV-B stråling på to arter i Nordøstgrønland (poster)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Bredahl, L., Mikkelsen, T. N., Ro-Poulsen, H.
Pages: 207-209
Publication date: 2002

Host publication information
Title of host publication: Resumé af foredrag og posters
Place of publication: Roskilde
Publisher: Danmarks Miljøundersøgelser
ISBN (Print): 87-7772-681-2
URLs:
http://www.risoe.dtu.dk/rispubl/prd/prdpdf/uv_b_greenland.pdf
Source: orbit
Source-ID: 304321
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 2002 › Research
UV-B strålingens betydning for den højarktiske vegetation i Nordøstgrønland

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Ro-Poulsen, H., Bredahl, L.
Pages: 195-196
Publication date: 2002

Host publication information
Title of host publication: Resumé af foredrag og posters
Place of publication: Roskilde
Publisher: Danmarks Miljøundersøgelser
ISBN (Print): 87-7772-681-2
URLs:
Source: orbit
Source-ID: 304361
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 2002 › Research

Climate change in a plant ecophysiological perspective

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, Biosystems Division
Contributors: Bruhn, D., Mikkelsen, T. N., Pilegaard, K., Gavito, M., Saxe, H.
Pages: 167-190
Publication date: 2001

Host publication information
Title of host publication: Climate change research. Danish contributions
Place of publication: Copenhagen
Publisher: Danish Meteorological Institute/Gads Forlag
Editors: Jørgensen, A., Fenger, J., Halsnæs, K.
ISBN (Print): 87-12-03775-3
Source: orbit
Source-ID: 302456
Research output: Chapter in Book/Report/Conference proceeding › Book chapter – Annual report year: 2001 › Research › peer-review

Comparisons of measured and modelled ozone deposition to forests in Northern Europe

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Pages: 263-274
Publication date: 2001
Peer-reviewed: Yes

Publication information
Journal: Water Air Soil Pollut. Focus
Volume: 1
Issue number: 5/6
Original language: English
Source: orbit
Source-ID: 303503
Research output: Contribution to journal › Journal article – Annual report year: 2001 › Research › peer-review
CO₂ balance measurements and modelling for Danish terrestrial areas (poster)

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Jensen, N., Pilegaard, K., Hasager, C., Mikkelsen, T. N.
Publication date: 2001
Peer-reviewed: No
Event: Poster session presented at Global Terrestrial Observing System GTOS, in situ terrestrial carbon observation meeting, Frascati (IT), 5-8 Jun, .
URLs:
Source: orbit
Source-ID: 302602
Research output: Contribution to conference › Poster – Annual report year: 2001 › Research

Den øgede drivhuseffekt påvirker respiration og fotosyntese

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Bruhn, D., Mikkelsen, T. N.
Pages: 14
Publication date: 2001
Peer-reviewed: Unknown

**Publication information**
Journal: Risønyt
Issue number: 4 (temanummer om bioproduktion)
Original language: Danish
URLs:
Source: orbit
Source-ID: 303400
Research output: Contribution to journal › Journal article – Annual report year: 2001 › Communication

Interactive effects of soil temperature, atmospheric carbon dioxide and soil N on root development, biomass and nutrient uptake of winter wheat during vegetative growth

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Gavito, M., Curtis, P., Mikkelsen, T. N., Jakobsen, I.
Pages: 1913-1923
Publication date: 2001
Peer-reviewed: Yes

**Publication information**
Volume: 52
Original language: English
Source: orbit
Source-ID: 302907
Research output: Contribution to journal › Journal article – Annual report year: 2001 › Research › peer-review

Klimaforandringer effekt på det globale kulstofkredsløb

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Beier, C., Ambus, P., Bruhn, D., Pilegaard, K.
Pages: 8-13
Publication date: 2001
Peer-reviewed: Unknown
Atmospheric CO$_2$ and mycorrhiza effects on biomass allocation and nutrient uptake of nodulated pea (Pisum sativum L.) plants

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Gavito, M., Curtis, P., Mikkelsen, T. N., Jakobsen, I.
Pages: 1931-1938
Publication date: 2000
Peer-reviewed: Yes

Kulstof- og vanddamp-fluxe i en bøgeskov ved Sorø

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Pilegaard, K., Mikkelsen, T. N.
Publication date: 2000
Peereviewed: No
Event: Abstract from Seminar på Københavns Universitet, Botanisk Institut, København (DK), 18 Dec, .
Source: orbit

Ozon deposition og effekter

**General information**
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N.
Publication date: 2000
Peer-reviewed: No
Event: Abstract from Møde i DMU, Roskilde (DK), 29 Feb, .
Source: orbit

Ozone uptake by an evergreen forest canopy - temporal variation and possible mechanisms

Patterns of ozone concentration ([O(3)]), O(3) deposition velocity (nu(d)) and O(3) flux (F(c)) over an evergreen forest canopy are shown in relation to measuring method, physiological activity of the trees, and time of year. The gradient and eddy correlation methods were compared and showed similar diel nu(d) patterns. Daytime F(c) was correlated with CO(2) and water vapour fluxes, while no correlation between [O(3)] in the range 10-70 ppb (nl l(-1)) and F(c) was seen in this study. F(c) was primarily driven by stomatal conductance, reactions with surfaces, particles and gases, and not by [O(3)].

On a monthly basis, [O(3)] was always highest in the afternoon while nu(d) was typically higher in the morning, resulting in an equal F(c) over the day. Night-time F(c) was more than half of the daytime O(3) flux. The data reveal the importance of emissions of nitric oxide and terpenes as O(3) removal factors in evergreen forest dominated by Norway spruce. (C) 2000
CO₂-balance målinger og modellering for danske landområder

Evapotranspiration from a mixed temperate forest in relation to climate and soil moisture
Carbon and water balance for a mixed forest stand in relation to ozone uptake

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Ro-Poulsen, H., Hovmand, M., Hummelsøj, P., Jensen, N.
Pages: 269-274
Publication date: 1998

Host publication information
Title of host publication: Critical levels for ozone in Europe: Testing and finalizing the concepts. UN-ECE workshop report
Place of publication: Kuopio
Publisher: University of Kuopio
Editors: Kärenlampi, L., Skärby, L.
ISBN (Print): 951-780-653-1
Source: orbit
Source-ID: 298928

Carbon dioxide fluxes above a coniferous/hardwoods stand in relation to climate - consecutive measurements from 17 months

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Ro-Poulsen, H., Hummelsøj, P., Jensen, N.
Pages: 331-336
Publication date: 1998

Host publication information
Title of host publication: Impacts of global change on tree physiology and forest ecosystems. Proceedings
Place of publication: Dordrecht
Publisher: Kluwer Academic Publishers
Editors: Möhren, G., Kramer, K., Sabaté, S.
ISSN (Print): 0-7923-4921-0
Source: orbit
Source-ID: 298927

Deposition of ozone to plant canopies - mechanisms and effects

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ro-Poulsen, H., Mikkelsen, T. N., Hummelsøj, P., Hovmand, M.
Pages: 129
Publication date: 1998
Peer-reviewed: Yes

Publication information
Journal: Environmental Science and Pollution Research
Volume: 5
ISSN (Print): 0944-1344
Original language: English
Source: orbit
Source-ID: 298408
Research output: Contribution to journal › Journal article – Annual report year: 1998 › Research › peer-review
Genetic variation and CO₂ exploitation in winter varieties of oilseed rape (Brassica napus R)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Johannessen, M., Mikkelsen, T. N., Bagger Jørgensen, R.
Publication date: 1998
Peer-reviewed: No
Event: Abstract from 11. Crucifer genetics workshop, Montréal (CA), 3-7 Oct, .
Source: orbit
Source-ID: 298201
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1998 › Research

Ozone deposition in relation to canopy physiology in a mixed conifer forest in Denmark
In this study CO(2) and H(2)O flux measurements made above a spruce forest was compared with the ozone flux to the canopy during growing season 1995. The fluxes were determined by micro meteorological gradient methods using a 36-m tall meteorological mast. The trees were about 12 m high and air sampling was done from 36 and 18 m. The preliminary results suggest that there is only little correlation between ozone concentration in 36 m and the ozone flux to the forest, but the diurnal pattern of ozone uptake seems to be significantly influenced by stomatal conductance. The cumulative total ozone uptake seems to follow very well the evapotranspiration. (C) 1998 Elsevier Science Ltd.

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Ro-Poulsen, H., Mikkelsen, T. N., Hovmand, M., Hummelshøj, P., Jensen, N.
Pages: 669-674
Publication date: 1998
Peer-reviewed: No
Publication information
Journal: Chemosphere
Volume: 36
Issue number: 4-5
ISSN (Print): 0045-6535
Original language: English
DOIs: 10.1016/S0045-6535(97)10105-9
Source: orbit
Source-ID: 299025
Research output: Contribution to journal › Journal article – Annual report year: 1999 › Research

Carbon dioxide fluxes above a mixed forest stand in relation to climate - consecutive measurements from 17 months

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Ro-Poulsen, H., Hummelshøj, P., Jensen, N.
Publication date: 1997
Peer-reviewed: No
Event: Abstract from International Conference on Impacts of Global Change on Tree Physiology and Forest Ecosystems, Wageningen, Netherlands.
Source: orbit
Source-ID: 295909
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 1997 › Research

Effects of increased UV-B radiation and elevated levels of tropospheric ozone physiological processes in European Beech (Fagus Sylvatica)

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Zeuthen, J., Mikkelsen, T. N., Paludan-Müller, G., Ro-Poulsen, H.
Pages: 281-290
Publication date: 1997
Acceleration of leaf senescence in Fagus sylvatica L. by low levels of tropospheric ozone demonstrated by leaf colour, chlorophyll fluorescence and chloroplast ultrastructure

From April 1988 to October 1991 3-year-old seed propagated beech (Fagus sylvatica L.) trees were exposed in open-top chambers to four different levels of air pollution: (1) charcoal filtered air, (2) ambient air, (3) ambient air plus 30 nl l⁻¹ ozone during the summer, and (4) ambient air plus 30 nl l⁻¹ ozone during the summer and 20 nl l⁻¹ SO₂ and NO₂ during the winter. Leaf colour was studied in the autumns of 1989 and 1991 and a close relationship between ozone dose and premature senescence was found. A correlation also exists between the colour groups and chlorophyll fluorescence (F(v)/F(m)). Ozone fumigation increases the size and speeds up the development of the plastoglobules. This is described using an index based on the volume of plastoglobules as a percentage of chloroplast volume. The index was significantly higher for ozone fumigated plants than for control plants during August to November 1989. According to all three methods it is concluded that low levels of ozone accelerate leaf senescence processes in F. sylvatica. There are indications that leaves of the first and the second flush react differently to the ozone treatment. Irrespective of the ozone treatment a special cell wall structure, probably a local suberization, is confined to the subsidiary cells in leaves of the first flush.

Carbon and water balance for a mixed forest stand in relation to ozone uptake

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Ro-Poulsen, H., Hovmand, M., Hummelshøj, P., Jensen, N.
Pages: 162-167
Publication date: 1996

Host publication information
Title of host publication: Workshop on critical levels for ozone in Europe: Testing and finalising the concepts. Background papers, contributing papers and poster presentation
Place of publication: Kuopio
Publisher: University of Kuopio. Department of Ecology and Environmental Science
Source: orbit
Source-ID: 294443
Research output: Chapter in Book/Report/Conference proceeding – Article in proceedings – Annual report year: 1996 – Research
Carbon and water balance for a mixed forest stand in relation to ozone uptake

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Ro-Poulsen, H., Hovmand, M., Hummelshøj, P., Jensen, N.
Pages: 80-85
Publication date: 1996

Host publication information
Title of host publication: Critical levels for ozone. Experiments with crops, wild plants and forest tree species in the Nordic countries
Place of publication: Copenhagen
Publisher: Nordic Council of Ministers
Editors: Skårby, L., Pleijel, H.
(TemaNord; No. 582).
Source: orbit
Source-ID: 294461

In situ measurements of ozone effects in the forest

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N.
Number of pages: 45
Publication date: 1996

Host publication information
Title of host publication: Mineral cycling and air pollution fluxes in reforested heathland
Place of publication: Roskilde
Publisher: National Environmental Research Institute. Department of Atmospheric Environment
Source: orbit
Source-ID: 294455
Research output: Chapter in Book/Report/Conference proceeding – Article in proceedings – Annual report year: 1996 – Research

Spontaneous hybridization between oilseed rape (Brassica napus) and weedy relatives

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Bagger Jørgensen, R., Andersen, B., Mikkelsen, T. N.
Pages: 193-200
Publication date: 1996
Peer-reviewed: No

Publication information
Journal: Acta Hortic.
Issue number: 407
Original language: English
Source: orbit
Source-ID: 294348
Research output: Contribution to journal – Journal article – Annual report year: 1996 – Research

Changes in pigment concentration and composition in Norway spruce induced by long-term exposure to low levels of ozone

Rametes of Norway spruce were fumigated with 30 ppb (nl litre−1) ozone above ambient level for 4 years in open-top chambers. They were grown under different light conditions, because some of the chambers received approximately 10% less light than the others. Samples from three age classes were analyzed for nitrogen and pigments using HPLC. It could be demonstrated that the ozone treatment reduced the concentration of chlorophyll (a) and (b), α- and β-carotene, but increased the concentration of antheraxanthin. A significant decrease was found for the violaxanthin/antheraxanthin ratio
following the ozone treatment. The concentration of all the pigments and of nitrogen were significantly related to the age classes, and a similar relationship was found for the light levels, except for antheraxanthin and total carotenoids. The ratio of chlorophyll a:b was only significantly related to the age classes.

General information
Publication status: Published
Organisations: University of Copenhagen, EPOKA A/S
Contributors: Mikkelsen, T. N., Dodell, B., Lütz, C.
Number of pages: 9
Pages: 197-205
Publication date: 1995
Peer-reviewed: Yes

Publication information
Journal: Environmental Pollution
Volume: 87
Issue number: 2
ISSN (Print): 0269-7491
Original language: English
DOIs: 10.1016/0269-7491(94)P2607-B
Source: FindIt
Source-ID: 2190913624
Research output: Contribution to journal › Journal article – Annual report year: 1995 › Research › peer-review

Long term in situ measurements of gas exchange in a Norway spruce canopy at ambient and elevated ozone levels using a light weight chamber system - System designs and first results
The gas exchange system is computer controlled and is designed to measure and control 14 temperature regulated chambers enclosing spruce twigs for several months with minimum ozone absorption. The system is mounted on sun exposed single year classes of a Norway spruce stand in western Jutland, Denmark. Since July 1994 the temperature control system has been in function. Results show that 95% of the temperature measurements inside the cuvettes are within the range -2 to +3 degrees C of the ambient temperature. Gas exchange measurements show that the current year shoots have a higher net photosynthesis than the older shoots. The net photosynthesis in current year needles on sunny days is significantly reduced by the 6 h daily 30-40 ppb ozone addition.

General information
Publication status: Published
Organisations: University of Copenhagen
Contributors: Mikkelsen, T. N., Ro-Poulsen, H.
Number of pages: 6
Pages: 1413-1418
Publication date: 1995
Peer-reviewed: Yes

Publication information
Journal: Water, Air and Soil Pollution
Volume: 85
Issue number: 3
ISSN (Print): 0049-6979
Original language: English
Keywords: Age classes, Branch cuvette, Chamber design, CO2, Gas exchange, Ozone, Picea abies, Photosynthesis, Transpiration, Twigs
DOIs: 10.1007/BF00477179
Source: FindIt
Source-ID: 9130410
Research output: Contribution to journal › Journal article – Annual report year: 1995 › Research › peer-review

Ozone, CO2 and water vapour fluxes above a forest
General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Jensen, N., Hummelshøj, P., Hovmand, M., Mikkelsen, T. N., Ro-Poulsen, H.
Number of pages: 104
Physiological responses of *Fagus sylvatica* L. exposed to low levels of ozone in open-top chambers

Four-year-old beech seedlings were fumigated with three levels of ozone for 2 consecutive years in open-top chambers. During the second growth season different physiological measurements were conducted before and during daily fumigation. A 25-40% decrease in net photosynthesis was seen during fumigation, whereas no differences were detected before fumigation in July. In August lasting effects in net photosynthesis were seen. The apparent quantum yield was decreased after fumigation. Stomatal conductance was generally decreased during fumigation, but transpiration was reduced relatively less than net photosynthesis indicating a lower water use efficiency of the trees exposed to ozone. Chlorophyll fluorescence (F_v/F_m) showed additive reductions in relation to ozone and light.

**General information**
- Publication status: Published
- Organisations: University of Copenhagen
- Contributors: Mikkelsen, T. N.
- Number of pages: 7
- Pages: 355-361
- Publication date: 1995
- Peer-reviewed: Yes

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Exposure of Norway spruce to ozone increases the sensitivity of current year needles to photoinhibition and desiccation

Physiological effects of ozone exposure over three consecutive growing seasons on current year needles of Norway spruce were studied in open-top chambers, during daily fumigation cycles in the summer, and after the termination of ozone fumigation in autumn 1990. The trees were exposed to two levels of ozone: charcoal filtered air and non-filtered air to which 30 nl l−1 of ozone was added in three consecutive years from 1988 to 1990, daily from May to September (8 hours a day). Photosynthesis, stomatal conductance, transpiration and chlorophyll fluorescence were studied on selected days. Significant decreases in net photosynthesis and chlorophyll fluorescence (F_v/F_m) were found during periods with co-occurrence of high ozone concentrations. High light intensities, indicating interactions between effects of ozone and photoinhibition. After termination of fumigation enhanced rates of photosynthesis were seen in the trees which had been exposed to ozone. A significant decrease in F_v/F_m was found for twigs from ozone treated trees when exposed to severe desiccation.

**General information**
- Publication status: Published
- Organisations: Department of Environmental Engineering, Atmospheric Environment, University of Copenhagen
- Contributors: Mikkelsen, T. N., Ro-Poulsen, H.
- Number of pages: 11
- Pages: 153-163
- Publication date: 1994
- Peer-reviewed: Yes
Ecophysiological studies of beech (Fagus sylvatica L.) and Norway spruce (Picea abies (L.) Karst) exposed to low levels of ozone

General information
Publication status: Published
Organisations: University of Copenhagen
Contributors: Mikkelsen, T. N.
Publication date: 1993

Publication information
Publisher: University of Copenhagen
Original language: English

Genspiejset raps - en risiko for naturen?

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Mikkelsen, T. N., Landbo, L., Bagger Jørgensen, R.
Pages: 8-9
Publication date: 1993
Peer-reviewed: Unknown

Publication information
Journal: Risønyt
Issue number: 2
Original language: Danish
Source: orbit
Source-ID: 291252
Research output: Contribution to journal › Journal article – Annual report year: 1993 › Communication

Microbial and ecophysiological response to manipulation of the atmospheric input to a spruce forest in Denmark

General information
Publication status: Published
Organisations: Risø National Laboratory for Sustainable Energy, University of Copenhagen
Contributors: Beier, C., Mikkelsen, T. N., Ro-Poulsen, H.
Number of pages: 2
Pages: 728-729
Publication date: 1992

Host publication information
Title of host publication: Responses of Forest Ecosystems to Environmental Changes
Publisher: Springer
Editors: Teller, A., Mathy, P., Jeffers, J. N. R.
ISBN (Print): 978-1-85166-878-6
DOIs:
10.1007/978-94-011-2866-7_135
Source: FindIt
Source-ID: 147646503
Research output: Chapter in Book/Report/Conference proceeding › Book chapter – Annual report year: 1992 › Research › peer-review
Physiological effects of ozone on beech (Fagus sylvatica L.) under semi-field conditions

General information
Publication status: Published
Organisations: University of Copenhagen
Contributors: Mikkelsen, T. N.
Number of pages: 6
Pages: 45-50
Publication date: 1990
Peer-reviewed: Yes

Publication information
Journal: Aquilo Ser Botanica
Volume: 29
ISSN (Print): 0570-5169
Original language: English
Source: FindIt
Source-ID: 64267508
Research output: Contribution to journal – Journal article – Annual report year: 1990 – Research – peer-review

Responses to ozone of insects feeding on a crop and a weed species
The influence of ozone on insect herbivore growth and population development was investigated. Fumigation of both pea (Pisum sativum L.) and dock (Rumex obtusifolius L.) at a range of O₃ concentrations between 21–206 nl litre⁻¹ produced changes in mean relative growth rates of the aphids Acyrthosiphon pisum Harris and Aphis rumicis L. of between 24 and −6% relative to controls. However, there was no evidence of a dose-related response to O₃ fumigation and no clear differences in aphid response when fumigated with the plant on prefumigated or previously unfumigated plant material. It is suggested that this may, in part, be due to the presence of NO contamination during O₃ fumigation. However, the MRGR of dock aphids was found to be greater on new compared to old leaves as well as the increase on the new growth and decrease on the old growth of fumigated plants relative to unfumigated controls. The size of egg batches of the chrysomelid beetle Gastrophysa viridula Degeer were found to be larger, survival and productivity of larvae was higher, and the food consumption lower on R. obtusifolius fumigated with 70 nl litre⁻¹ O₃ compared with unfumigated controls. This meant that these beetle larvae consumed less leaf area per mg of production on fumigated leaves probably because of their better nutritional quality and/or reduced leaf defences. However, the rate of development of larvae was similar on fumigated and control plants.

General information
Publication status: Published
Organisations: Lancaster University, Danish Centre for Environment and Energy
Contributors: Whittaker, J., Kristiansen, L. W., Mikkelsen, T. N., Moore, R.
Number of pages: 13
Pages: 89-101
Publication date: 1989
Peer-reviewed: Yes

Publication information
Journal: Environmental Pollution
Volume: 62
Issue number: 2-3
ISSN (Print): 0269-7491
Original language: English
DOIs: 10.1016/0269-7491(89)90180-2
Source: FindIt
Source-ID: 78007722

Projects:

Traffic controlled by Air Quality - Organic City
Increased urbanisation puts pressure on city infrastructures. In traffic this infers increased congestion detriment to health and to the more general liveability of the city. As a City, Copenhagen has a strong will to find news ways to management the increased urbanisation in order to provide citizens with a high quality of life. Smart city solutions hold potentials to restructure the management of the city with digital solutions rather than cumbersome and expensive physical investments.
However, many of these solutions have no or little track record, and needs testing – by the civil services operating the new solutions and by the citizens living in them. Our motivation to apply to this call is a genuine interest in building new solutions to our citizens that provide them higher quality of life. The ability to try and test solutions with agility and citizens’ feedback holds a promise to shortcut and to accelerate the transition of the city to the future. The aim of this project is therefore twofold: 1) to build capacity to swiftly conduct experiments in the settings where solutions have to be implemented, 2) to generate new knowledge about the relation of traffic management to air quality. Combined the project aims to establish proofs of value of smart city solutions in traffic to health and related public expenses and to the ability to implement new city workflows of prototyping and testing. Previous Organicity participants have already focused on the topics of air quality and traffic: AirPublic through high-resolution, real-time and low cost spatial maps of air pollution in London through small sensors in an effort to produce data that can enable informed decision making related to the problem. While the use of real-time data in both instances is intriguing we are of the opinion that such data is only needed for a limited time and not forever. We believe that the gathering of real-time data through a reasonable time period can provide enough information to still make changes possible if that information is integrated into the planning and management aspect of a city. Thus, we propose a project for improving the air pollution of a city through changes in traffic management through a limited time period of real-time data gathering. The project design monitor two stretches of roads of similar design and with consistent traffic flows. Sensors placed at intersections will monitor air quality (NOx, CO, CO2, PM10 and PM2.5). Traffic lights would then be optimized for better health possibilities by altering the traffic flow and registering differences.

Mikkelsen, T. N., Project Participant, Department of Environmental Engineering, Air, Land & Water Resources
Pereira, F. C., Project Participant, Department of Management Engineering, Transport DTU, Transport Modelling
01/10/2017 → 31/03/2018
Collaborators: Copenhagen Solutions Lab
Project: Research

ÉCLAIRE: Effects of Climate Change on Air Pollution and Response Strategies for European Ecosystems
The ÉCLAIRE project investigates the ways in which climate change alters the threat of air pollution on European land ecosystems including soils. Based on field observations, experimental data and models, the project will establish new flux, concentration and dose-response relationships, as a basis to inform future European policies.

Starting with biosphere-atmosphere exchange measurements, ÉCLAIRE will quantify how global warming and altered precipitation will affect emissions of key European primary pollutants (NOx, NH3, VOCs), including interactions with increasing aerosol and hemispheric O3 background concentrations, modifying atmospheric transport and deposition. An ensemble of chemistry transport models will be applied to assess uncertainty in response to harmonized scenarios for climate, emissions and land-use, while high resolution studies will investigate how climate change alters local patterns of pollutant exposure and threshold exceedance.

A network of European experiments for contrasting ecosystems and climates, combined with meta-analysis of unpublished datasets, will quantify how climate change alters ecosystem vulnerability to tropospheric O3 and N deposition, including interaction with increased CO2. Combined with special topics on interactions with N form (wet/dry, NHx/NOy), aerosol-exacerbated drought stress and BVOC self-protection of O3 effects, novel threshold and dose-response approaches will be developed. These will be combined with regional atmospheric and biogeochemical models to estimate interactions and feedbacks on plant/soil carbon stocks, greenhouse gas balance and plant species change.

The new risk assessment chain to be developed will be applied at the European scale, quantifying how projected climate change will alter damage estimates. Combined with economic valuation of ecosystem services, improved integrated assessment modelling will allow a cost-benefit analysis to inform future mitigation and adaptation strategies on air pollution and climate change.

Mikkelsen, T. N., Project Participant, Department of Environmental Engineering, Air, Land & Water Resources
Beier, C., Project Participant, Department of Chemical and Biochemical Engineering, Risø National Laboratory for Sustainable Energy
Albert, K. R., Project Participant, Department of Chemical and Biochemical Engineering, Ecosystems Programme
01/10/2011 → 30/09/2015
Project: Research

Climate-CAFE: Climate Change Adaptability of cropping and Farming systems for Europe
The Climate-CAFE project focuses on increasing the “adaptive capacity” of arable and forage crops to climate change (CC). We will use an interdisciplinary approach to evaluate traditional and more novel regional adaptation and mitigation strategies along a North-South climate gradient in the EU and propose new farming system designs for adaptation to CC. The evaluation includes synergies and trade-offs between strategies using different scales and indicators for IPCC scenarios in 2050 and 2100. Synthesis of existing data from experimentation and expert knowledge (advisors and farmers) will be used to propose adaptation measures for a selection of Adaptation Pilots based on representative regional cropping and farming systems located in consortium countries.

These pilots will be defined and used to design and evaluate adaptation strategies based on multicriteria economic and environmental analyses. The proposed adaptation strategies will focus on improved soil and water management via ecological intensification, including new cultivars, novel rotations, alternative tillage options, and the inclusion of legumes and intercrops, to enhance the buffering capacity of the soil-crop system and capitalize on emerging value chains in the bio-economy. The STICS and DAYCENT models will be used to simulate scenarios at the cropping system level (plot scale and rotation duration). Existing long-term experiments, including FACE
and Ecotron specific experiments will be used for analyzing the quality of predictions and where necessary models will be improved to accommodate new processes (e.g. introduction of O3 effects in STICS). Over the short/medium-term, the STICS soil-crop model will be run on the RECORD modelling and software platform to make multiple simulations for testing the potential efficiency of proposed CC adaptation measures for maintaining crop production without degrading environmental impacts. In addition, the DAYCENT soil model will be used to evaluate the long-term impact of adaptation measures on soil carbon sequestration and greenhouse gas emissions (CO2, N2O, and CH4). The Modam and Farm-design models will be used to assess the impact of CC adaptation measures on the farms’ economic and environmental performances. In addition, the Farm-design model will be applied to evaluate these outcomes at the supra-farm level, considering the regional constraints of agri-food chain organization and pedoclimatic conditions. The expected results of the Climate-CAFE project are: i) an overview of potential CC adaptation measures in accordance with farm constraints, ii) simulation of the impact of IPCC scenarios 2050 and 2100 in interaction with adaptation measures on European agriculture production, considering a wide range of EU countries representing a North-South climate gradient in Europe.

Mikkelsen, T. N., Project Participant, Department of Environmental Engineering, Air, Land & Water Resources

Hauggaard-Nielsen, H., Project Participant, Department of Chemical and Biochemical Engineering

01/01/2015 → 01/09/2018

Collaborators: Roskilde University

Project: Research

CLIMAITE: Climate change in Terrestrial Ecosystems (CLIMAITE)

CLIMAITE is a Danish research center investigating how biological processes and ecosystems will be affected by climate change.

Mikkelsen, T. N., Project Participant, Department of Environmental Engineering, Air, Land & Water Resources

Beier, C., Project Participant, Ecosystems Programme, Department of Chemical and Biochemical Engineering

Ambus, P., Project Participant, Department of Chemical and Biochemical Engineering, Ecosystems Programme

Pilegaard, K., Project Participant, Department of Environmental Engineering, Air, Land & Water Resources

01/01/2004 → 30/04/2016

Project: Research

INCREASE: INCREASE - climate change effects on shrublands.

INCREASE is an EU-funded infrastructure of six large-scale climate change experiments and one phytotron designed to study climate change effects on shrublands.

Mikkelsen, T. N., Project Participant, Department of Environmental Engineering, Air, Land & Water Resources

01/04/2009 → 31/03/2013

Collaborators: Aarhus University, University of Copenhagen

Project: Research

UVWARM: UV-stimulated nitrous oxide emissions, the ignored part in atmospheric warming (UVWARM)

Recent research reveals that the harmful greenhouse gas nitrous oxide (N2O) is produced photo-chemically by ultra-violet (UV) radiation in terrestrial environments. This process has hitherto remained unnoticed. We propose work to answer two compelling questions in relation to this finding:

(1) What is the intensity of UV-induced N2O emissions from terrestrial settings in relation to natural UV irradiance, landscape features and N deposition
(2) What are the fundamental mechanisms and controls for UV-induced formation of N2O in relation to surface characteristics, UV spectra and environment

Mikkelsen, T. N., Project Participant, Department of Environmental Engineering, Air, Land & Water Resources

01/07/2018 → 30/06/2021

Collaborators: University of Copenhagen, Aalborg University

Project: Research

AnaEE, Denmark: AnaEE, Denmark Analysis and Experimentation on Ecosystems

AnaEE Denmark is “experiments”. Through a range of experimental approaches the aim is to increase our understanding of how different ecosystems respond to future conditions of elevated CO2, higher temperatures, more extreme climate events and changes in global cycling of core elements like nitrogen and phosphorus. And to help develop new and innovative management strategies to maintain or improve the ecosystem services that are fundamental to our society, i.e. food and fiber production, clean water, biodiversity preservation, climate mitigation through managing ecosystem greenhouse gas balance etc

Mikkelsen, T. N., Project Participant, Department of Environmental Engineering, Air, Land & Water Resources

01/01/2018 → 31/12/2022

Collaborators: Aarhus University, University of Copenhagen, Roskilde University
AnaEE: AnaEE (international, EU) Analysis and Experimentation on Ecosystems

AnaEE will be a research infrastructure for experimental manipulations of managed and unmanaged terrestrial and aquatic ecosystems. It will strongly support scientists in their analysis, assessment and forecasting of the impact of climate and other global changes on the services that ecosystems provide to society.

AnaEE will support European scientists and policymakers to develop solutions to the challenges of food security and environmental sustainability, with the aim of contributing to a vibrant bioeconomy. AnaEE will accomplish this mission by building substantial links among researchers, science managers, policy makers, public and private sector innovators, and citizens.

Mikkelsen, T. N., Project Participant, Department of Environmental Engineering, Air, Land & Water Resources
Ibrom, A., Project Participant, Department of Environmental Engineering, Air, Land & Water Resources, Department of Chemical and Biochemical Engineering
Larsen, K. S., Project Participant, Department of Chemical and Biochemical Engineering

01/01/2012 → 31/07/2016

Project: Research

Plant Uptake of Environmental Chemicals

Jensen, C. K., PhD Student, Department of Environmental Engineering
Trapp, S., Main Supervisor
Mikkelsen, T. N., Supervisor
Rein, A., Supervisor

Technical University of Denmark
01/11/2016 → 10/12/2020

Award relations: Plant Uptake of Environmental Chemicals

Project: PhD

Climate Change Effects to Plant Ecosystems

Ingvorsen, C. H., PhD Student, Department of Chemical and Biochemical Engineering
Bagger Jørgensen, R., Main Supervisor
Mikkelsen, T. N., Supervisor
Pilegaard, K., Examiner
Flavell, A. J., Examiner
Ainsworth, L., Examiner

Institut, samfinansiering
01/01/2011 → 24/09/2014

Award relations: Climate Change Effects to Plant Ecosystems

Project: PhD

Activities:

EU COST (External organisation)

Period: 24 Oct 2018 → 23 Oct 2022

Teis Nørgaard Mikkelsen (Member)

Department of Environmental Engineering
Air, Land & Water Resources

Description

Optical synergies for spatiotemporal sensing of scalable ecophysiological traits

Degree of recognition: International

Related external organisation

EU COST

Avenue Louise 149, 1050, Brussels, Belgium

Activity: Membership › Membership of research networks or expert groups

International Conference on Ozone and Plant Ecosystems

Period: 21 May 2018 → 25 May 2018
Teis Nørgaard Mikkelsen (Participant)
Department of Environmental Engineering
Air, Land & Water Resources
Degree of recognition: International

Related event

International Conference on Ozone and Plant Ecosystems
21/05/2018 → 25/05/2018
Florence, Italy
Activity: Attending an event › Participating in or organising a conference

Forests and Climate symposium - Oak Spring Garden Foundation, Virginia, USA
Period: 25 Apr 2018 → 28 Apr 2018
Teis Nørgaard Mikkelsen (Participant)
Department of Environmental Engineering
Air, Land & Water Resources

Description
Forests and Climate symposium - Oak Spring Garden Foundation, Virginia, USA
Degree of recognition: International

Related event

Forests and Climate symposium - Oak Spring Garden Foundation, Virginia, USA
25/04/2018 → 28/04/2018
Virginia, United States
Keywords: Methane emission
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

Characteristics of BVOC emissions from a Swedish boreal forest. Using chambers to capture biogenic volatile organic compounds (BVOCs) from trees and forest floor
Period: 9 Feb 2018
Teis Nørgaard Mikkelsen (External examiner)
Department of Environmental Engineering
Air, Land & Water Resources

Description
PhD committee
Degree of recognition: International
Activity: Examinations and supervision › External examination

Ozone effects on wheat grain quality - A summary AND CO2-Induced Changes in Wheat Grain Composition: Meta-Analysis and Response Functions
Period: 11 Jan 2018
Teis Nørgaard Mikkelsen (External examiner)
Department of Environmental Engineering
Air, Land & Water Resources

Description
MMid-term PhD evaluation
Degree of recognition: International
Activity: Examinations and supervision › External examination

EU Climate Cafe meeting in Roskilde: Climate-CAFÉ final meeting Cordoba
Period: 12 Nov 2017 → 15 Nov 2017
Teis Nørgaard Mikkelsen (Organizer)
Department of Environmental Engineering
Air, Land & Water Resources
Degree of recognition: International

Related event

EU Climate Cafe meeting in Roskilde: Climate-CAFÉ final meeting Cordoba
12/11/2017 → 15/11/2017
Cordoba, Spain
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

External examiner at the Research Council of Norway
Period: 8 Oct 2017 → 9 Nov 2017
Teis Nørgaard Mikkelsen (External examiner)
Department of Environmental Engineering
Air, Land & Water Resources
Degree of recognition: International
Activity: Examinations and supervision › Internal examination

First Nordic Icos Symposium
Period: 29 Aug 2017 → 31 Aug 2017
Teis Nørgaard Mikkelsen (Participant)
Department of Environmental Engineering
Air, Land & Water Resources
Degree of recognition: International

Related event

First Nordic Icos Symposium: The Nordic ICOS Symposium is on the Nordic ICOS stations and the use of results from these stations. All researchers working with the Nordic stations and data from them are invited to give presentations
29/08/2017 → 31/08/2017
Kgs. Lyngby, Denmark
Activity: Attending an event › Participating in or organising a conference

EGU General Assembly 2017
Period: 27 Apr 2017
Teis Nørgaard Mikkelsen (Speaker)
Department of Environmental Engineering

Description
N2O emission from plant surfaces – light stimulated and a global phenomenon PICO Presentation. Teis N. Mikkelsen, Dan Bruhn, Kim Pilegaard & Per Ambus
Degree of recognition: International
Documents:
PICO presentation EGU 2017

Related event

EGU General Assembly 2017: European GEosciences Union 2017
24/04/2017 → 28/04/2017
Vienna, Austria
Activity: Talks and presentations › Conference presentations

Period: 4 Apr 2017 → 6 Apr 2017
Teis Nørgaard Mikkelsen (Participant)
Department of Environmental Engineering
Air, Land & Water Resources
Degree of recognition: International

Related event

Green infrastructure . Nature based solutions for sustainable and resilient cities. COST 1204
04/04/2017 → 06/04/2017
Orvieto, Italy
Activity: Attending an event › Participating in or organising a conference

American Geophysical Union Fall meeting
Period: 12 Dec 2016 → 16 Dec 2016
Teis Nørgaard Mikkelsen (Participant)

Department of Environmental Engineering
Atmospheric Environment

Description
Abstract ID and Title: 177175: Solar UV irradiation-induced production of N2O from plant surfaces - low emissions rates but all over the world. Final Paper Number: B11E-0509 Presentation Type: Poster Session Date and Time: Monday, 12 December 2016; 08:00 - 12:20 Session Number and Title: B11E: Global Nitrous Oxide Budget: Magnitude, Sources, and Drivers I Posters Location: Moscone South; Poster Hall

American Geophysical Union Fall meeting

Related event

American Geophysical Union Fall meeting
12/12/2016 → 16/12/2016
San Francisco, United States
Activity: Attending an event › Participating in or organising a conference

Supersites for Superior Forest Science: Launching Supersites for Superior Forest Science - Novelty, Needs and Networking
Period: 24 Oct 2016 → Oct 2017
Teis Nørgaard Mikkelsen (Other)

Department of Environmental Engineering
Atmospheric Environment

Description
Presentation by Rainer Matyssek at the IUFRO Task Force on Climate Change and Forest Health, Beijing, China. IUFRO regional Asia Oceania congres.
Documents:
IUFRO_China_Matyssek_Oct_2016

Related event

IUFRO regional Asia Oceania congress
24/10/2016 → 27/10/2016
Beijing, China
Activity: Talks and presentations › Conference presentations

Research Council of Norway - assessing grant applications.
Period: 2 Oct 2016 → 3 Nov 2016
Teis Nørgaard Mikkelsen (External examiner)

Department of Environmental Engineering
Air, Land & Water Resources
Degree of recognition: International
Activity: Examinations and supervision › Internal examination
Advances in FACE and manipulation technique
Period: 26 Sep 2016 → 29 Sep 2016
Teis Nørregaard Mikkelsen (Speaker)
Department of Environmental Engineering
Atmospheric Environment

Related event
FACEing the future : food production and ecosystems under a changing climate
26/09/2016 → 29/09/2016
Giessen, Germany
Activity: Talks and presentations › Conference presentations

FACEing the future
Period: 26 Sep 2016 → 29 Sep 2016
Teis Nørregaard Mikkelsen (Chairman)
Department of Environmental Engineering
Atmospheric Environment

Description
Yields, food quality and phenotypes

Related event
FACEing the future : food production and ecosystems under a changing climate
26/09/2016 → 29/09/2016
Giessen, Germany
Activity: Attending an event › Participating in or organising a conference

EU Climate Cafe meeting in Roskilde
Period: 11 May 2016 → 13 May 2016
Teis Nørregaard Mikkelsen (Organizer)
Department of Environmental Engineering
Atmospheric Environment

Description
Climate-CAFE is the acronym for “Climate Change Adaptability of cropping and Farming systems for Europe”. The project Climate-CAFE aims at assessing the « adaptive capacity » to climate change of Europeans arable cropping and farming systems, through the modelling and simulation of innovative strategies co-designed with actors. Started the 4th of February 2015, this project brings together under the coordination of Eric Justes (INRA Toulouse, UMR AGIR), 12 European research teams who met in Toulouse for the kick-off then. The second meeting is organized by Roskilde University, Denmark. The meeting is an opportunity to share and coordinate work in progress and to enforce work relations across the country teams during two and a half days of face to face contact and interaction.

EU Climate Cafe meeting in Roskilde

Related event
EU Climate Cafe meeting in Roskilde: Climate-CAFÉ 2nd meeting Roskilde
11/05/2016 → 13/05/2016
Roskilde, Denmark
Activity: Attending an event › Participating in or organising a conference

Climate-CAFE programme meeting
Period: 4 Feb 2015 → 6 Feb 2015
Teis Nørgaard Mikkelsen (Participant)
Ecosystems Programme
Department of Chemical and Biochemical Engineering

Description
Facilities for Ecosystem manipulating: Methods under the Climate-CAFE programme - Toulouse France
The DTU Risø based facilities for ecosystem manipulating was presented for the international participant group

Related event
Climate-CAFE programme meeting
04/02/2015 → 06/02/2015
Toulouse, France
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

The Research Council of Norway (External organisation)
Teis Nørgaard Mikkelsen (Participant)
Department of Environmental Engineering
Atmospheric Environment

Description
Panel member Research Council of Norway (Projects on ecosystem effects )
Degree of recognition: International

Related external organisation
The Research Council of Norway
Drammensveien 288 Lysaker, Norway, N-1327, Oslo, Norway
Activity: Membership › Membership of commitees, commissions, boards, councils, associations, organisations, or similar

Climate change and ozone toxicity in plants
Teis Nørgaard Mikkelsen (Lecturer)
Department of Chemical and Biochemical Engineering
Ecosystems Programme

Description
ECLAIRE Open Science Conference

Related external organisation
Unknown Organization
Activity: Talks and presentations › Conference presentations

4th ECLAIRE General Assembly and Annual Meeting
Period: 28 Sep 2014 → 30 Sep 2014
Teis Nørgaard Mikkelsen (Participant)
Department of Chemical and Biochemical Engineering
Ecosystems Programme

Related event
4th ECLAIRE General Assembly and Annual Meeting
28/09/2014 → 30/09/2014
Budapest, Hungary
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.
A free air in situ ozone fumigation system designed for partial plant exposure
Period: 18 May 2014 → 22 May 2014
Teis Nørgaard Mikkelsen (Lecturer)
Department of Chemical and Biochemical Engineering
Ecosystems Programme

Description
Foredrag afholdt ved "International conference on ozone and plants".

Related event
International conference on ozone and plants
18/05/2014 → 21/05/2014
Beijing, China
Activity: Talks and presentations › Conference presentations

Long term acclimation to elevated CO2 and drought increases the ozone toxicity in plants
Period: 18 May 2014 → 22 May 2014
Teis Nørgaard Mikkelsen (Lecturer)
Department of Chemical and Biochemical Engineering
Ecosystems Programme

Description
Participation in "International conference on ozone and plants".

Related event
International conference on ozone and plants
18/05/2014 → 21/05/2014
Beijing, China
Activity: Talks and presentations › Conference presentations

46th American Air pollution workshop
Period: 7 Apr 2014 → 10 Apr 2014
Teis Nørgaard Mikkelsen (Speaker)
Department of Chemical and Biochemical Engineering
Ecosystems Programme

Description
Long term acclimation to elevated CO2 and drought increases the ozone toxicity in plants.

46th American Air pollution workshop, Guadalajara, Mexico.

Related event
46th American Air pollution workshop
07/04/2014 → 10/04/2014
Guadalajara, Mexico
Activity: Talks and presentations › Conference presentations

BreedFACE
Period: 19 Mar 2014
Teis Nørgaard Mikkelsen (Invited speaker)
Department of Chemical and Biochemical Engineering
Ecosystems Programme
**Description**
Past, present, future FACE activities in Jülich, Germany.

FACE systems for breeding and diversity of genetic and molecular responses to elevated CO2.

**Related event**
**BreedFACE**
19/03/2013 → 20/03/2014
Jülich, Germany
Activity: Talks and presentations › Conference presentations

**Increase**
Period: 24 May 2013
Teis Nørgaard Mikkelsen (Speaker)
Department of Chemical and Biochemical Engineering
Ecosystems Programme

**Description**
Improving the performance of infrared reflective night curtains for warming field plots.

INCREASE Project meeting in Copenhagen.

**Related event**
**Increase : Improving the performance of infrared reflective night curtains for warming field plots**
23/05/2013 → 24/05/2013
København, Denmark
Activity: Other

**EU COST (External organisation)**
Period: 14 Feb 2013 → 30 Apr 2017
Teis Nørgaard Mikkelsen (Member)
Department of Environmental Engineering
Air, Land & Water Resources

**Description**
FPS COST Action FP1204
Degree of recognition: International

**Related external organisation**
**EU COST**
Avenue Louise 149, 1050, Brussels, Belgium
Activity: Membership › Membership of research networks or expert groups

**EU COST (External organisation)**
Period: 1 Oct 2009 → 30 Sep 2013
Teis Nørgaard Mikkelsen (Member)
Risø National Laboratory for Sustainable Energy
Atmospheric Environment

**Description**
COST Action FP0903 -Climate Change and Forest Mitigation and Adaptation in a Polluted Environment.
Degree of recognition: International

**Related external organisation**
**EU COST**
Avenue Louise 149, 1050, Brussels, Belgium
Activity: Membership › Membership of research networks or expert groups