IV Pallas Symposium 2013

Recent trends in environmental, ecosystem, and land-use research

Abstracts

Posters

Long-term environmental monitoring

Posters

Northern ecosystems under changing environment

Ecological sustainability and sustainable planning of tourist destinations

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Increasing awareness of non-economic benefits of forests, such as biodiversity and recreation, is challenging the land-use planning of tourist destinations. Nature-based tourism has increased and diversified dramatically, with a concomitant increase in the pressure on the environment. The major local environmental effect of tourism is the trampling of vegetation, which leads to changes in microclimate, and in the physical, chemical and hydrological properties of the soil. A larger-scale effect of tourism is the change in the biodiversity, since tourism favors plant and animal species that are tolerant to disturbance. To evaluate the tolerance of habitats to different types of recreational activities, information on the type and magnitude of environmental and ecological impacts is crucial. By recognizing the most sensitive and the most tolerant habitats, it is possible to direct certain types of recreational use to ecologically most suitable habitats.

Large tourist resorts are often located close to protected areas, which poses challenges for safeguarding their nature, fulfilling visitor needs, and supporting economic growth. By combining information on the ecological values in and near tourist destinations with the information on stakeholder opinions of the same areas, new socio-ecological information is produced, which is valuable in revealing areas with conflicting needs and land-use pressures. In the presentation, we will show results on the ecological impacts of nature tourism, studied in Pallas-Ylläs and Oulanka National Parks, and discuss how the tolerance of habitats could be considered in the planning. We will also show a new approach, where GIS-based tools are developed to fulfill socio-ecologically sustainable land-use planning of tourist destinations.

Pallas supersite for atmospheric and ecosystem greenhouse gas studies

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Pallas monitoring site on the Sammaltunturi was established to monitor gaseous and aerosol air pollution levels in the unpolluted western part of Finnish Lapland. In 1996, began continuous measurements of CO_2 and after that the site became Global Atmosphere Watch (GAW) site of the World Meteorological Organization (WMO). In 2001, the site joined Co-operative flask sampling network of National Oceanic and Atmospheric Administration, U.S. which operates global air sampling network providing concentrations of main greenhouse gas on weekly basis. In 2004, we started continuous CH_4, CO, N_2O, and SF6 observations by GC. In recent years, CO_2, CH_4, CO observations are made by a laser-based analyzer. For understanding vertical concentration gradients in this arctic mountain terrain, a second CO_2 and CH_4 measurement site is maintained at a lower level forest site.

Pallas site, which is the other node of the Pallas-Sodankylä GAW site, represents Northern boreal-subarctic region between the populated continental Europe and high Arctic. As such it has been the only GAW station with continuous measurement in the Northern Eurasian continent.

For understanding variations and trends of atmospheric concentrations of greenhouse gases, it is important to understand their natural sources and sinks. For that purpose, we measure not only the atmospheric concentrations but also fluxes between characteristic ecosystems and the atmosphere. Continuous year-round fluxes are measured by micrometeorological eddy-covariance method. Measurement programme has been systematically expanded during the past years to develop Pallas to be a supersite. Presently carbon dioxide fluxes are measured at all main ecosystems: spruce forest, wetland (fen), alpine tundra and a lake. Methane fluxes are measured at the wetland site. In addition to micrometeorological flux measurements, we use automated and manual chambers for emissions by soil and ground flora. Extensive set of ancillary parameters are measured at the sites.

The data from the Pallas site is provided to the relevant international data bases including the European research infrastructure Integrated Carbon Observation Study (ICOS). We use the data for atmospheric and ecosystem studies and for developing and testing relevant modules of Earth System Models.

In this presentation we show the measurement infrastructure related to greenhouse gas studies and shortly demonstrate examples of results.

NMHC measurements at Pallas

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Non-methane hydrocarbons (NMHC) are released to the air due to petrol exhaust and evaporation, stationary combustion, gas leaks, solvent use etc. In the air the reaction with hydroxyl radical is the main sink reaction for NMHCs, but ozone reaction is also important for alkenes (Atkinson, 1994). The atmospheric lifetimes of NMHCs are rather long varying from months to days during winter, but being much shorter in summer when there is enough light to produce hydroxyl radicals. In winter NMHCs accumulate in the northern latitudes and maximum concentrations are measured during dark winter months. In spring the VOC concentrations start decreasing, concomitant with ozone increase, due to efficient photochemical reactions and the minimum concentrations are reached in summer. NMHC reactions with OH radical can result in ozone formation when enough nitrogen oxdides are present.

Light molecular weight hydrocarbons (C2-C6) have been measured at Pallas GAW station since 1996 using canister sampling twice a week and subsequent laboratory analysis. Since 2010 the measurements have been conducting using in situ gas-chromatograph with 2-hour time resolution. This study describes the NMHC trends, their short-term variability and source areas at Pallas.

A downward trend of about 1%/year can be seen for most of the alkanes, benzene and acetylene, but the trend is significant for ethyne and pentane only. Ethane is the longest living compound and its concentration has not decreased. This could indicate a growth of VOC emissions in areas more distant than Europe.

The results show that diurnal variability is quite small during winter when the amount of sunshine is limited. As spring proceeds the variability with daytime minimum is measured. Fast reacting ethene and propene have daytime maxima during summer implicating biogenic source. Source area studies show that propene has oceanic source, whereas the main source areas for alkanes are the Baltic Sea area and the Eastern Europe.

Absorbing aerosols seasonality in snow and air at Pallas spanning 2008-2013

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Investigations of absorbing aerosols, with Black Carbon (BC) being one of the most known species, are of great interest since it has been recognized as a significant contributor to climate change, especially in the Arctic (e.g. Quinn et al. 2011). BC acts as a climate forcer when residing in the atmosphere and once they have been deposited onto light reflecting surfaces, such as snow and ice. The presence of BC significantly lowers the albedo of ice and snow, and contributes to earlier melting in the spring (e.g. Flanner et al., 2007).

Here we present data on BC in the surface snow (roughly top 5 cm of the snowpack) around Sammaltunturi, Pallas-Yllästunturi National Park, Arctic Finland, and compare the concentrations to ambient air concentrations of BC measured on top of Sammaltunuri. This is done for the time period of 2008-2013. The BC in snow, measured with the OCEC filter-based method (Forsström et al., 2009), display a clear seasonality each year with an increasing trend throughout the snow season. This supports the accumulation of BC particles occurring throughout the spring in the surface of the snowpack, which has been observed elsewhere also (e.g. Aamaas et al., 2011). Over the time span of 2008-2013 no visible trend in BC concentration in the surface snow can be seen.

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Long-term Trends in Snowfall and Continuous Snow Cover Duration in Sodankylä, Northern Finland, and Their Linkage to Teleconnection Indices

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Many studies have reported increases in temperature and precipitation for high latitude areas in the Northern Hemisphere during the 20th century. This warming reduces precipitation falling form as snow, and accelerates snow cover disappearing by increasing meltout and evaporation from snowpack. However, increases in precipitation may provide sufficient snowfall for snow cover expansion. Using temperature and precipitation data in the empirical temperature-index snowmelt model, we evaluated variability of snowfall and continuous snow cover duration (CSCD) in Sodankylä, northern Finland. The model was calibrated and verified using observed precipitation, temperature and snow water equivalent data from 1949 to 2011 (missing years 1972-1981). The CSCD was defined as number of days between first and last days with snow water equivalent more than 0.00 mm in a hydrologic year (Sep-Aug). The Mann-Kendall non-parametric test was applied to determine significant trends ($p<0.05$) in snowfall and CSCD. The Spearman's correlation coefficient (rho) was used to demonstrate relationship of snowfall and CSCD with climate teleconnection indices. Analysis of climatic conditions indicated temperature warming by 0.013 (°C/year, $p<0.05$) in Sodankylä during the period 1908-2011, while no changes in precipitation. Besides, the average values of snowfall and CSCD over the full time length of study (1908-2011) were 226.35 mm and 221 days (13 Oct-20 May), respectively. Significant decreasing trends in both snowfall (1.36 mm/year) and CSCD (0.22 day/year) were found over Sodankylä during the period 1908-2011. The shortening of CSCD was associated with an increasing trend (0.07 day/year, $p<0.1$) in first day and a decreasing trend (0.18 day/year, $p<0.05$) in last day of CSCD. At 5% significance level, the East Atlantic (EA) pattern was the strongest teleconnection index influencing snowfall (rho = -0.32), CSCD (rho= -0.40), and last day of CSCD (rho = -0.48) in Sodankylä. Decreases in snowfall result in less snow pack accumulation as main component of water storage besides surface and groundwater in boreal environments like Finland. Shrinking snow cover duration leads to amplify temperature warming over high latitudes, including Finland, due to feedback from high albedo of snowpack. Hence, snowfall and CSCD can be used as indicators for detecting climate change in boreal regions.

Sources and trends of atmospheric pollutants at Pallas in 1996–2009

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Introduction

Source apportionment of atmospheric pollutants was studied at the Finnish Meteorological Institute's Global Atmosphere Watch station, Pallas (67°58´N, 24°06´E).

The data set contains aerosol data for persistent organic pollutants (POP), major inorganic ions and metals from filter samples as well as ozone, nitrogen dioxide and sulphur dioxide.

Positive Matrix Factorization (PMF) was applied in source apportionment and source directions were calculated for each PMF factor using EMEP air mass trajectories.

Results and discussion

Five potential sources were identified as Kola factor (F1), insecticide factor (F2), sea spray factor (F3), soil factor (F4) and traffic and long-range transfer (LRT) factor (F5).

F1 contains trace elements (As, Ni, Cu, Pb, V, Zn) with SO2 and heavier PAHs from eastern source direction. These pollutants are characteristic to the industries in Kola peninsula.

F2 includes most of the insecticides a-HCH and g-HCH with high summer contribution, but without any specific source direction and with a decreasing trend. (Li et al., 2002).

F3 contains maritime air masses and sea salt particles from north, without clear seasonal variation. Organochlorines and lighter PAH compounds came partly in this factor. These compounds might evaporate from the waters of melting glaciers.

F4 is a soil source with aluminium, manganese, ammonium, potassium and PCBs mainly from south and west with a systematic summer maxima.

F5 includes approximately half of PAHs and NO2 with winter maxima and south source directions. NO2 and LRT nitrate and ammonium particles suggest reasonably remote traffic sources. DDT and DDE also refers to LRT from the southern areas, where DDT is still in use (ATSDR, 2002).

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The plant necromass and the ground layer vegetation are the clearest indicators of Cu and Ni deposition in a subarctic forest

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The mining and metallurgical industry on the Kola Peninsula in Russia is one of the largest sources of heavy metal emissions in the northern hemisphere. The emission impact area of the smelters in Nikel stretches for over 100 km from the smelters, extending to Finland and Norway (Poikolainen et al. 2004, Myking et al. 2009). Here we present detailed results of copper (Cu) and nickel (Ni) concentrations in Scots pine dominated ICP Forests Level II plot located at Sevettijärvi in northernmost Finland, at a distance of 54 km from the emission sources in Nikel. Our aims were to evaluate the distribution of Cu and Ni pollution in a subarctic forest and to identify those ecosystem compartments showing the highest accumulation of heavy metals.

The highest Cu and Ni concentrations were found in plant necromass (non-foliar litterfall, bryophyte and lichen necromass, litter layer) and in the living ground layer vegetation (in bryophytes > in lichens). In these compartments the Cu concentrations (14–36 mg/kg) were 5–7 times higher and the Ni concentrations (20–45 mg/kg) were 17–31 times higher than the respective concentrations averaged for three other Scots pine dominated Level II plots located elsewhere in Finland. The Cu and Ni concentrations of both living needles and branchlets were 2–3 times and 2–12 times higher, respectively, than those on the reference sites. The upper mineral soil layers showed slightly higher Cu concentrations in Sevettijärvi than on the reference plots, while soil solution and stem wood showed no signs of Cu or Ni pollution.

In conclusion, our results indicate elevated Cu and Ni concentrations in most forest compartments at Sevettijärvi plot, which is most probably caused by the emissions from mining and metallurgical industry on the Kola Peninsula and do not originate from the geology of the site.

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Soil properties along mafic Lommol/Sammaltunturi fells

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Shifts of the alpine treelines towards higher elevations have been recorded, yet the role of spatial variability of snowpack and zonal pattern soil nutrient and water regimes is poorly understood. Norway spruce (Picea abies (L.) Karst) is best suited to fertile soils developed on glacial tills derived from mafic lithologies, hence we applied soil physical-chemical and snow measurements and age chronology of Norway spruce along an elevation gradient (380–557 m a.s.l.) to address vertical soil zonality hypothesis on mafic Lommoltunturi fell in Finnish Lapland. Automatic soil monitoring data (0-100 cm) in spruce forest, treeline and tundra was provided on Sammaltunturi fell. With regard to increasing elevation, we found an increase in soil NTOT, CTOT and Al, but a decrease in soil Ca, Mg, Ca:Al ratio as well as electrical conductivity (EC). In addition, snowpack was significantly thicker in low elevation forest as compared to that in the treeline and open tundra. Exposition had no influence on soil temperature at forest sites and soil temperature did not correlate with soil water content (SWC). The mean SWC at tundra site (112–129 l/m^3) was lower than those in spruce treeline (136–150 l/m^3) and forest (187–195 l/m^3) sites through 2008–20011. In the 1840's spruce established at low elevation soils with a Ca:Al ratio of 2.2. Starting from the 1920's a significant shift of spruce occurred such that it took 60 years to expand the treeline by 55 m in elevation. The spruce treeline has advanced, and the age distribution indicated new colonization of spruce both in closed forest up to tundra, but due to shallow soil, solifluction and winter wind climate/patchy snowpack, the establishment of seedlings/saplings is difficult on the tundra. Poor soil Ca:Al ratio of 0.02 on tundra apparently is a constraint for spruce. Spruce forest is young (<170 years), hence we argue that spruce has expanded onto formerly tree-free sites of this mafic fell. This paper demonstrates that vertical soil zonality, i.e. the decrease in soil base cations and Ca:Al ratio along with increasing elevation, is a potential driver for the diffuse treeline of Picea abies on the mafic Fennoscandian fells.

Timing of spring and autumn phenophases in Northern Finland

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The Finnish National Phenological Network was established in 1995 by the Finnish Forest Research Institute in collaboration with other institutes and universities. The monitoring was done twice a week taking place in the same individual plants at 30 observation sites across Finland. The first results indicated that the onset of downy birch leaves occurred in northernmost Lapland about a month later compared with southern Finland and began to turn yellow already at the beginning of September. The first results were presented in the II Pallas Symposium in 1996. The annual monitoring has been then continued 17 years. In the Pallas Research Forest the emergence of birch leaves varied from 8 May (2006) to 11 June (1998) in the years 1997–2010.

The results of the network indicate that spring phenophases have especially in northern Finland advanced with respect to climatic conditions. No trends are observed in the timing of autumn phenophases. However, there occurs great variation of phenophases between the years and sites causing uncertainty for the use of data. The observation term of seventeen years is still too short to tell whether the advancement of spring is a constant phenomenon or a consequence of normal climatic variability. To detect long-term trends in the impacts of climate on plant phenophases, the Finnish National Phenological Network has therefore collaborated with the Finnish Museum of Natural History responsible for historical phenological data based on voluntary monitoring since 1752. This long-term data shows for example that the onset of flowering in the rowan (Sorbus aucuparia) and in the bird cherry (Prunus padus) has become earlier in Finland at the rate of three days and five days per century, respectively. The results of the National Phenological Network fit well in the historical data.

Phenological monitoring by using field observations is nowadays more important than ever especially in arctic and boreal regions, where spring temperatures are elevated. Compilation and documentation of observations on plant phenophases play a key role in working out the rate of global climate change. The timing of phenophases and the animations showing on the green wave will be discussed and presented in the symposium.

The changes of forest timberline in Northern Finland during 1983–2009

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Changes of forest timberline have been monitored in Northern Finland from the early 1980's. Seedling (≤ 2 m) density and tree (> 2 m) density of Scots pine (Pinus sylvestris) and Norway spruce (Picea abies) were monitored five (5) times in the timberline areas during the period 1983–2009. Monitoring was carried out in nine (9) circular plots in 13 localities in four (4) regions: pine-dominated northern and southern regions and spruce-dominated western and eastern regions. The measurements were made in three (3) altitudinal zones: in the forest, at the coniferous timberline (where forest canopy closure ends), and at the tree line (where coniferous trees > 2 m end). Changes in timberline advancement were assessed on the basis of the repeated measurements of the chosen variables.

The density of spruce seedlings and the density of spruce trees have clearly increased in all the spruce-dominated regions and zones during the monitoring period. The density of pine seedlings and pine trees is slowly increasing in all the regions and zones, as well. The preliminary results indicate a clear potential for the spruce timberline and spruce tree line to advance upwards. In addition, the results also indicate a subtle potential for the timberline and tree line of pine to advance.

We think that the observed increase in conifer timberlines in Finnish Lapland reflects mainly the increased temperatures after the Little Ice Age with a time delay. The role of climatic variations during the last hundred years for the conifer tree line dynamics is less clear.

Wetland methane fluxes and isotopic signature – measurements at Sodankylä and Pallas

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Methane measurements across northern Scandinavia are being studied in the NERC funded MAMM project and in the EU INGOS project.

Isotopic measurements of methane can provide a constraint on global and regional methane emission models, but source signatures of wetland emissions vary across different types of wetland and with temperature and need to be studied in more detail to refine the signatures used. The isotopic signature of methane emissions from Northern Finland have been characterised using measurements at different scales, from chamber to aircraft.

Air samples from Pallas Sammaltunturi and a 50 m mast at Sodankylä are collected weekly throughout the year and identify seasonal variations in the isotopic composition of regional methane emissions. Methane δ13C in these ambient air measurements decreases in summer when wetlands emit methane - wetland methane is isotopically depleted in 13C.

Air samples have also been collected from low height (0.3 and 3m) over wetlands at Sodankylä, Lompolojänkkä and Kaamanen during 24-hour periods, to collect daily emissions maxima, inversion maxima, and ambient minima when mixing occurs. Keeling plots, of methane δ13C against the reciprocal of methane mixing ratio have been plotted to identify the signature of emissions. Measurements of the isotopic signature of methane that has built up in chambers at Sodankylä has also been measured, to investigate the causes of heterogeneity in the signature of emissions across the site.

Fluxes of methane from wetland and forest at Sodankylä were measured in chambers in summer and autumn 2012. 60 chambers were located in the footprint of the eddy flux towers at the site. Flux variations have been correlated with vegetation, temperature and water levels recorded for each chamber.

In July 2012 and August and September 2013 aircraft campaigns above northern Scandinavia as part of MAMM have measured methane concentration variation across wetland regions and samples have been collected for isotopic analysis. Samples were also collected in road transects. These campaigns coincided with the ground based monitoring of wetland methane fluxes and isotopic signature.

Results from Summer 2012 and preliminary results from August 2013 will be presented.

Prediction of CO_2 and CH_4 fluxes at a northern boreal fen and model uncertainty analysis using COUP model

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COUP is a very detailed and flexible process based model environment which has already performed well in simulating water table and heat dynamics, plant growth, nutrient demand of crops as well as gas emissions (CO_2, CH_4, N_2O, NO) on agricultural and forest sites. It is therefore a promising tool to gain process understanding and to predict fluxes under different scenarios (e.g. land use or climate change) as well as interpolation (e.g. at sites where only manual chamber fluxes are available) or space (upscaling)

To extend the applicability of COUP model to open peatlands, it is calibrated on the data rich Lompolojänkkä site, located in Pallas area in northern Finland. Climate, water table and soil characteristics are used as input data. The model is calibrated using GLUE Monte Carlo based multi-criteria calibration to fit to measured CO_2 and CH_4 fluxes, soil temperature, snow depth and leaf area index. Sensitivity and intercorrelation of the calibration parameters as well as sensitivity to input data like higher temperatures are analyzed.

To ensure a reasonable behavior of the model under different conditions, the same calibration is tested at four other grassland sites on organic soil with a wide gradient in land use intensity, soil fertility and mean annual temperature.

First results show that COUP can achieve a good fit to measured CO_2 fluxes as well as abiotic parameters at all sites. However, high uncertainty exists for modeled winter respiration. Spring respiration at Lompolojänkkä is underestimated, which might be caused by the release of gases trapped under snow and ice - a process which is not realized in the used model version.

Dynamics of CH_4 fluxes can only be captured to some extend at Lompolojänkkä.

Simulation with increased temperatures at Lompolojänkkä lead to higher respiration rates but the effect is overcompensated by higher and longer lasting uptake by the vegetation. In the presentation we will discuss these simulation results in more detail.

Short-term effect of temperature rise and water table level drawdown on the greenhouse gas dynamics of boreal segde fens

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Boreal ecosystems are sensitive to global temperature rise, since the present low temperatures restrict markedly all biological activity. Also possible changes in hydrology due to the temperature rise affect boreal mire ecology because of the prevailing humid climate type and high water table levels. Because of their large carbon storage, carbon release from boreal mires may cause a large positive feedback for global warming. This study was carried out on three boreal wet oligotrophic sedge fens during 2008–2010. Two of the fens (Lakkasuo, Orivesi and Närhinneva, Virrat) were situated in the middle boreal coniferous forest zone (61°47'N, 24°18'E and 62°13'N, 23°23'E, respectively) and one fen (Lompolojänkkä, Kittilä) in the northern boreal coniferous forest zone (67°59'N, 24°12'E). We used an open top chamber (OTC) to simulate moderate global warming effect, i.e. the seasonal temperature rise of 0.5–1.5ºC, combined with short-term and long-term water table level (WTL) drawdown treatments. On average during study years, all pristine control treatments at all the study sites were acting as rather large sinks for CO_2, rather large sources for CH_4 and small sources of N_2O. The OTC-warming solely decreased carbon sequestration at the middle boreal sites, but on the contrary, increased it at the northern boreal site. The short-term WTL drawdown solely had no significant effect on carbon sequestration or on N_2O fluxes, but a significant decreasing effect on CH_4 fluxes. The short-term WTL drawdown+OTC-warming combined and the long-term WTL drawdown solely and combined with OTC-warming decreased the carbon sequestration at middle boreal sites, but increased it at the northern boreal site. The long-term WTL drawdown had the superior decreasing effect on CH_4 fluxes at all the sites. The short-term effects of moderate temperature rise and WTL drawdown on the carbon sequestration seem to vary between boreal mires depending on the prevailing climate type. According to our study, mires in the southern and middle parts of boreal zone will probably act as a positive feedback for global warming, but the mires of the northern part of boreal zone may act as opposite way, at least during the first years or decades.

Lompolojänkkä fen carbon accumulation and climate forcing during the Holocene, effect of climate change on peatland carbon balance

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High latitude peatlands act as a huge reservoir of carbon, containing ca. 547 Pg of organic carbon. Pristine mires are generally regarded as long-term sinks for atmospheric carbon, because of the slow decomposition rate of organic matter under water-logged conditions. However, both peat ecosystem production as decomposition are highly dependent on environmental conditions. Climate factors as temperature and hydrology influence peat accumulation rates and peat carbon dynamics. Peat accumulation results in uptake of atmospheric carbon dioxide (CO_2), but due to anaerobic decomposition processes, methane (CH_4) is released to the atmosphere. In order to better understand the role of northern mires in future global carbon budget, it is important to understand the past relationship between climate and peatlands: how different types of mires responded to climate changes before. In terms of modeling the climate-biosphere interactions, peatlands have proved to be a complicated environment where autogenic and allogenic forcing factors operate in tandem. Palaeoecological approach provides means to understand past, present and future peatland dynamics and subsequent changes in carbon accumulation and emission patterns. Analysis of carbon accumulation, in combination with palaeovegetation analysis, performed on a peat core from Lompolojänkkä, showed that ca. 8000 years BP peat accumulation rates decreased rapidly, to increase again ca. 2000 years BP. This time period coincides with the warmer and drier Holocene Thermal Maximum. This result suggests that a change in climate can severely alter peatland carbon balance. As a result of this the climate forcing of the peatland changes and it is possible that peatlands under future climate with act as a climate warming agent.

Nitrogen fixation activity by cyanobacteria living on forest mosses increaces towards the north in Finland

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In nitrogen limited boreal ecosystems, biological nitrogen (N_2) fixation of bryophyte-associated microbes is an important source of new N. We studied N_2 fixation of cyanobacteria-moss associations on 12 intensively monitored forest ecosystem plots (ICP Forests Level II) along a latitudinal gradient in Finland during 2009–2010. Acetylene reduction assay (ARA) was calibrated against stable isotope ($15N_2$) method for measuring N_2 fixation in two forest bryophytes, Hylocomium splendens and Pleurozium schreberi; this gave a conversion factor of 3.3 (Leppänen et al. 2013). N_2 fixation rate associated to mosses increased towards the north and was at highest 0.6–1 kgN/ha/year (based on the bryophyte biomass in the field). In southern Finland, only few signals of N_2 fixation were found and it is possible that elevated anthropogenic N deposition reduces the rate of N_2 fixation. The upper parts of the moss shoots showed 2–3 times higher N_2-fixing activity than the lower parts, but there were not big differences between H. splendens and P. schreberi. The moisture level of mosses and light/temperature conditions of the growing site regulated strongly the rate of N_2-fixing activity. The results show that the bryophyte layer has a significant effect on the N input in northern forests. We emphasize that rich bryophyte communities control the N and C balances of boreal ecosystems and play an important role in producing ecosystem services

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Partitioning of CO_2 fluxes at two northern ICOS sites

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Eddy covariance (EC) measurements at two northern ICOS sites, Kenttärova spruce forest (N67°59.237', E24°14.579'; 2003–2012) and Sodankylä pine forest (N67°21.708', E26°38.29'; 1999–2012), have shown these sites to be either sources of CO_2 to the atmosphere or close to balance in most years, despite of concurrent net accumulation of C to the growing tree stands. With the aim of distinguishing the contributions of soil organic matter (SOM) and tree stand growth to the CO_2 fluxes, we set up an experiment for partitioning the components of soil respiration (SR), and measured the increment of the tree stand biomass on both sites.

The experimental lay-out for partitioning the different components of SR included the following treatments:

I = SRTOT (Total SR, which includes both heterotrophic respiration from organic matter decomposition, and respiration of live ground vegetation and roots)

II = SRTOT - LAG (decomposition of newly shed aboveground tree litter)

III = RSOM (decomposition of soil organic matter below the O-horizon) + RORG (respiration from the humus layer, including live mosses).

IV = RSOM

For assessing RSOM (treatments III and IV), we trenched plots of approximately 1 m^2 in area in June 2011 to the depth where no more roots could be detected (40–60 cm), and excluded further root ingrowth by inserting a root isolation fabric around the plots. We measured soil CO_2 respiration (SR) weekly to biweekly from early June to the end of September in 2012. The decomposition flux from the newly cut roots, based on measured biomass of fine and small roots and mass loss rates obtained from litter bag experiments and literature, was deducted from RSOM, as well as estimated carbon inputs to SOM as DOC fluxes from the humus layer and litter from recently died roots. Tree stand biomass increment was estimated at 150 g and 400 g CO_2 m-2 yr-1 in Kenttärova and Sodankylä, respectively.

Emission rates from the different components of soil respiration and the accumulation rate of CO_2 to the growing tree stands in relation to the EC-measured net ecosystem exchange will be discussed in the presentation.

Aerosol optical properties in northern Finland

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This work is based on data measured Pallas-Sodankylä Global Atmospheric Watch station in Northern Finland, on the gateway to Arctic areas. It has been estimated that one aerosol component, black carbon, is responsible for some 50 percent of the total temperature increases in the Arctic from 1890 to 2007. Aerosols affect climate directly by scattering solar radiation back to space and altering cloud optical and life time properties. In Arctic areas deposition of absorbing aerosols to snow and ice surfaces have also been estimated to have significant effect to climate. The way that aerosol affects to Arctic climate depends not only on their properties, but also the time of the year they reach Arctic areas. This work concentrates on studying aerosol optical properties. These parameters are scattering and absorption coefficients, single scattering albedo and aerosol optical depth (AOD). In situ aerosol scattering and absorbing properties are measured in at Pallas (67°58'N, 24°07'E, 565 m asl) and AOD in Sodankylä (67.37°N, 26.63°E, 179 m asl). The distance between the stations is about 120 km.

Over the studied measurement period from 2001 to 2011 scattering and absorption coefficient have slight declining trend. Years 2008 and 2009 have clearly lower values than the overall average value of 13 1/Mm. Similar trend is also seen in absorption coefficient, but the time series is much shorter.

Seasonal variation shows that aerosol scattering coefficient has maximum in August, which might be related to natural aerosol loading by boreal forest. Aerosol absorption coefficient has maximum on February and March, which is mainly due to domination of prevailing air masses from continental regions. AOD has maximum values on March-May, this might be related to high AOD occasions with aerosol layers or thin clouds at higher troposphere. Scattering, absorption and AOD have their minimum on fall when aerosols are effectively washed out by more frequent rain than other seasons. Aerosol single scattering albedo is clearly lower during winter than during summer which is most probably due to lower anthropogenic emissions of absorbing aerosols during summer time.

Pallas Cloud Experiment (PaCE) 2012: Intensive campaign on aerosol and cloud properties

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Vulnerable Arctic region is slowly heading towards a new climatic state with substantially decreased permanent ice cover. However, due to poorly understood feedback mechanisms, the rate of Arctic climate response to changes is very hard to predict with current global models. Arctic clouds are supposed to play a central role in these feedback processes.

Pallas is an ideal place to study Arctic aerosol particles, which are the seeds for cloud droplets, as well as the aerosol-cloud-climate interactions, due to the high elevation of the station. Therefore, intensive campaigns to measure aerosol and cloud droplet physical and chemical properties have been regularly carried out there. The latest campaign, in autumn 2012, was organized for six weeks between September 17th and October 30th. In autumn, the probability of station to be inside a cloud is high and during the last campaign it was 50 % of time. The in-cloud periods allow for determining cloud droplet properties using in-situ instrumentation.

The measurements at Pallas station include instrumentation for aerosol total number and size distribution, particle absorption and mixing state, and for particle scattering. In addition, the aerosol CCN and hygroscopic properties during campaign were measured with the HTDMA (Hygroscopicity Tandem Differential Mobilitity Analyzer) and the Cloud Condensation Nuclei Counter (CCNC, DMT model CCN-100). In-situ cloud droplet properties were measured with a Forward Scattering Spectrometer Probe (FSSP, 3-47μm, model SPP-100, DMT) and the Cloud, Aerosol and Precipitation Spectrometer (CAPS, DMT). Mass and chemical composition of non-refractory submicron particulate matter was characterized with Aerosol Chemical Speciation Monitor (ACSM, Aerodyne) and the chemical composition of gas and aerosol phase was measured with an online ion chromatograph for Measuring AeRosols and GAses (MARGA 2S ADI 2080, Metrohm Applikon Analytical BV).

This extensive dataset is used to understand aerosol impacts on low-level cloud formation and on properties of clouds forming around the Arctic.

The EQUIANOS (EQUator-Inter-Atlantic-NOrth-South) Network: A new global collaboration of greenhouse gas monitoring sites.

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The EQUIANOS Network is a recently formed collaboration of Carbon Dioxide and Methane monitoring stations with the primary goal of creating a network of greenhouse gas monitoring stations which would otherwise not be part of a global network, allowing a more coordinated approach to global monitoring of greenhouse gas emissions especially in the South Atlantic and Arctic systems.

The aim of EQUIANOS is to join together research groups under a broader name, which can then be used to share data and expertise, put in collaborative grant applications and combine knowledge to help us further understand the regional and global processes involved in greenhouse gas emissions without the need for each institute to invest heavily in regions where measurements are already being made by partner members.

The network is operated by the Royal Holloway Greenhouse Gas Research Group and has already attracted several partners making continuous greenhouse gas measurements including the University of East Anglia, NILU, The British Antarctic Survey and The Jersey Meteorological Office. Here we demonstrate the reach of EQUIANOS, with a special focus on the Arctic and Atlantic coverage of the network and explain the potential in terms of collaboration and the expected future development of the network.

Currently there are 7 permanent stations measuring minute by minute methane and carbon dioxide atmospheric concentrations (and another 2 due to start this year), with regular sampling from a further 9 sites (including Sodankyla and Pallas with assistance from the Finnish Meteorological Institute) through tedlar bag and flask sampling which are then analysed by the greenhouse gas research group at Royal Holloway. It is hoped that more institutions can be encouraged to join and further the reach of the EQUIANOS network.

UV measurements at Sodankylä

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Long-term monitoring of solar ultraviolet (UV) started at Sodankylä in 1990. The spectral UV time series of the Finnish Meteorological Institute - Arctic Research Centre is one of the longest Arctic UV time series. In addition to spectral measurements, broad band UV measurements were started in 1993 and multifilter radiometer measurements in 2002. Data time series include UV-B and UV-A radiation, and dose rates can be calculated using a chosen action spectrum, like response of human skin, plant damage and biological effectiveness. In this work, the spectral changes of the time series are studied. The maximum UV index of the time period 1990-2012 was measured in summer 2011. The main factors affecting UV radiation variability at Sodankylä are solar zenith angle, total ozone, cloudiness and albedo. Periods of high UV irradiances are strongly linked to low total ozone amounts during clear sky days. Even if significant UV increase were observed during one single day, no statistically significant changes were observed when studying the whole time period 1990-2012.

Winter climate in northern Fennoscandia at present and estimates for the future

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Winters at high latitudes in northern Fennoscandia are long and snowy: winter conditions with sub-zero temperatures and snow cover typically prevail from October or early November to late April or May. The longest winter occur at the northern end of the Scandinavian Mountains, where the thermal winter lasts on average over seven months, while conditions on the coast of the Bay of Bothnia are notably milder. The harsh winter climate in the region presents a challenge to road maintenance, for instance. On the other hand, testing the performance of cars and snow tyres in winter conditions is a growing economic activity in the region and the continually-growing tourism industry in Lapland is also highly dependent on the winter climate.

The spatial variation of selected climatological parameters describing winter temperature and snow conditions in northern Fennoscandia is examined by using the gridded European wide high-resolution E-OBS data set for temperature and the global GlobSnow data set for snow water equivalent. The longest and snowiest winters are on average found to occur in the mountainous areas of north-western Sweden. In contrast, the lowest temperatures seldom occur in the highest areas. In the future, the length of thermal winter and snow season are estimated to shorten due to climate change. Depending on the location, a rise of 4 °C in midwinter temperatures would lead to a shortening of approximately 20–40 days in the length of the thermal winter. Thus, the thermal winter would on average then last only in the highest mountainous areas as long as it does in central Lapland at present. The present conditions prevailing on the coast of the Gulf of Bothnia would correspondingly be shifted approximately 200 kilometres northwards.

Meteorological and geophysical monitoring in and around Pallas area

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The Finnish Meteorological Institute (FMI) operates several measurement stations for long-term meteorological and geophysical monitoring in and around Pallas area.

Air chemistry measurements at Pallas started in 1991 and on-site weather observations were considered essential in analyzing and interpreting the gathered air chemistry data. Currently there are four operational automatic weather stations in the area, at Sammaltunturi, Laukukero, Matorova, and Kenttärova. In addition, there are two research stations gathering also weather data, namely at Lompolojänkkä and Pallaslompolonniemi. Geophysical monitoring, especially magnetometric measurements and aurora borealis imaging, has been made at Yli-Muonio, west of Pallas, since 1982. The FMI has two stations north of the Pallas-Ylläs National Park. At Enontekiö airport aviation weather observations are made. Precipitation observations have been made at Hetta since 1981. The FMI also operated for many years a weather station at Pallasjärvi and a precipitation monitoring station at Särkijärvi.

The gathered data is used in general and special weather forecasts, climatological service, and atmospheric, environmental, and space research. An important user of the data is the local business life working especially with tourism and other outdoor activities, not to mention the local authorities working with public safety, transport etc.

Assessing one-way coupling between a limited area climate model and a land surface scheme

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We evaluate from the energy balance point of view the functionality of a modeling framework set up to estimate the current land ecosystem CO_2 balance in a region covering Fennoscandia and Baltic countries. The modeling framework consists of a Regional Climate Model (RCM), REMO, and a land surface scheme (LSS) JSBACH. The models are one-way coupled so that REMO provides the meteorology for the surface processes of LSS.

REMO is derived from the operational weather forecast model of the Deutscher Wetter Diendst, therefore it has been extensively evaluated for its capability to predict the synoptic scale meteorological phenomena. The climatic boundary data is from ERA-Interim.

JSBACH that is used to produce the CO_2 balance terms, is the LSS of general circulation model (GCM) ECHAM6 of MPI-Hamburg. The role of LSS in a GCM is to calculate the surface atmosphere interaction by providing 1) the vertical diffusion scheme; 2) radiation scheme and 3) hydrological cycle such that the surface energy balance and water balance are physical. Stomatal functioning, the most crucial control of water vapor exchange between the vegetation and the atmosphere, constrains the photosynthetic CO_2 exchange as well. Thus LSS JSBACH, that treats the surface water cycle by considering the physiological response of vegetation to the climatic variables, is readily able to predict the photosynthetic CO_2 exchange rate.

In order to evaluate the functionality of the coupling, we compare the common energy balance terms produced by REMO and JSBACH. Based on these comparisons we will recognize regions and seasons when the coupling is justified from the energy balance point of view.

Modeling of carbon dioxide fluxes of coniferous forests in Pallas-Sodankylä region

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The carbon balance of forest is determined by two different flux components, the uptake of carbon by the plants via photosynthesis and release of carbon through plant respiration and decomposition of the soil organic matter. Understanding the dynamics of the carbon cycle is important in making predictions of the carbon balances in future climate.

The exchanges of carbon dioxide, water and energy fluxes can be measured directly by the micrometeorological eddy covariance measurements. Long-term flux measurement sites include the Sodankylä Scots pine and the Kenttärova Norway spruce forests that have been run by the Finnish Meteorological Institute in Finnish Lapland.

We apply a generic biosphere model JSBACH that can be used at global, regional and site level studies. We have used observations at the two Lappish flux sites to assess the model performance and to see if some modifications for the larger-scale run can be induced from these evaluations. We have done large-scale runs for the Finland and the surrounding region with the JSBACH model, where we used climate data generated from the regional climate model REMO. These climatic data were evaluated at the site level and the effect of the different forcing data on the fluxes was assessed.

Also, different initialization procedures for the carbon cycle simulations were studied, e.g. with a historical atmospheric CO_2 concentration record and with the realistic set-up of the initial forest biomass.

The carbon cycle of JSBACH model in autumn is more controlled by light than by temperature at the forest sites, which is not seen in the measurements. The evaporation of simulated during spring starts too early compared to the measurements. This is likely due to the soil water model of the JSBACH. The comparison to site level data offers valuable knowledge about the model performance at larger scale.

Long-term CO_2 exchange in a Scots pine forest in Sodankylä

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Long-term CO_2 exchange measurements have been conducted in a Scots pine forest in Sodankylä (67°21'N, 26°38'E) since January 2000 as a part of various EU projects (LAPP, Carboeuroflux, Carboeurope-IP). Presently the Sodankylä station acts as a supersite within the ICOS programme.

Due to the cool and short summer, the annual net ecosystem exchange of CO_2 is typically relatively small in most ecosystems at these latitudes. At the Sodankylä forest, the annual CO_2 balance varies from a small sink to a moderate source. On the average, the ecosystem has acted as a net source of carbon during the recent decade. A tree inventory conducted in the forest, however, suggests that the trees are growing and thus accumulating carbon. In order to understand this discrepancy we have initiated a set of new studies in the area. The growth of the reindeer population and resulting disappearance of the thick lichen (Cladonia spp.) cover from the ground has been suggested as possible cause for the imbalance. We evaluated the influence of this lichen carpet on the soil respiration by installing automatic and manual soil chambers on grazed and ungrazed forest floor in an area which has been partly fenced since 1950s. The manual soil respiration monitoring design includes four different treatments for partitioning the total soil respiration. We also analyzed soil samples from both sides of this fence in order to compare the soil carbon content with and without the insulating lichen cover. We have conducted a similar soil C survey at the actual flux measurement site twice, in 2004 and 2011, in order to assess the long-term carbon loss from the soil. These results will be compared to the heterotrophic respiration of the mineral soil layer, which is obtained from the manual chambers.

One possible error source of the flux measurements is the limited fetch in certain wind directions. To the east of the measurement mast, the forest is bounded by a peatland, which may have an effect on the fluxes in the night-time. We installed a second measurement system closer to the wetland area to compare the fluxes originating from different areas of the forest. We have also started flux measurements on an adjacent wetland, enabling the estimation of the CO_2 exchange on a watershed scale. These measurements also include the CH_4, flux which is an essential part of the greenhouse gas balance of a wetland.

Decomposition of coarse root systems in different soils

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Coarse root systems (CRS) of trees build up a significant pool of biomass and thereby have the potential of comprising fairly long-term storages of atmospheric carbon in forest soils. Very little, however, is known on the decomposition rates of dead CRS in different soil types and climate conditions.

We investigated the decomposition dynamics of CRS by measuring their mass loss and carbon contents in different stages of decomposition in a forestry-drained peatland and in northern upland forests. Our aim was to quantify the role of CRS as a carbon pool and compare the decomposition rates between different soil types. We hypothesized that in nutrient-poor peatlands, i) the decomposition of CRS is very slow even in drained sites and, ii) CRS forms an important part of the biomass carbon pool and acts as a long-term C sink after harvesting the aboveground tree biomass.

The peatland site, Kalevansuo, is a dwarfshrub-pine bog in southern Finland. The upland sites were selected to represent the north boreal zone with most unfavourable decomposition conditions. The pine site in Sodankylä is a MCClT pine forest and the Kenttärova site in Kittilä is a HMT spruce-birch forest. We excavated tree stumps and CRS of both live trees and those of trees that had been cut earlier. We tested different biomass models against the measured dry mass of living stumps and roots and modeled the CRS biomass using tree inventory data. The time of death for the old stumps was either known from records or determined with dendrochronological methods. Mass loss rates for the old CRS were then calculated as the difference of measured necromass and modelled biomass of a similar live tree. Preliminary results show that decomposition of the belowground parts of CRS in poorly aerated soils, in Kalevansuo Sphagnum peat and Kittilä silty morain, is markedly slow whereas in the well-aerated sandy soil in Sodankylä, the coarse roots had decomposed even faster than the aboveground parts of the stumps.

Connecting terrestrial and aquatic ecosystem across scales in a heterogeneous boreal landscape - An example from the Krycklan Catchment

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The Krycklan Catchment Study (KCS) provides a unique field infrastructure for hillslope to landscape-scale process-based research. The purpose is to allow assessments of short to long-term ecosystem dynamics and how external drivers, including forest management, climate change, and long-range transport of pollutants affects forests, mires, soils, streams, lakes and groundwater in the boreal landscape. Here one example is shown of how to elucidate the mechanistic understanding of water pathways during snow melt using a combination of detailed soil transect investigations together with the 15 intensively monitored catchments ranging over three orders of magnitude in scale. By combining isotope hydrograph separation methods with basic biogeochemistry I will show that the majority of snow melt (~80%) reaches the stream via subsurface flow pathways in forested catchments. In contrast, flow pathways through the wetland dominated catchment has a larger component of snowmelt (<50%) caused by overland flow over frozen wetland surface. As a result, the contrasting flow pathways during the spring flood causes large variations in the dynamics of dissolved organic carbon (DOC). No effect of catchment scale could be found for hydrological flow pathways but the DOC concentration during both base flow and peak flow decreased as the catchments became larger suggesting an increased deep groundwater contribution. These results from this work suggest that the amount and timing of snow melt and the extent of soil frost can have a large influence on the DOC concentration in small streams and rivers in the region. Most climate scenarios indicate that warming will be greatest in northern latitudes and especially strong during the winter months. A shift in the extent and timing of snow cover and soil frost could thus affect the flux and concentrations of DOC from these northern landscapes.

Measurements of plant and soil characteristics for producing satellite image based vegetation type and land cover classification

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We conducted a vegetation and soil survey in East Siberia, Tiksi (N71°35.791', E128°53.327') in July 2012 to explain the spatial variation in the observed CH_4 and CO_2 fluxes. The study area is located close to the Tiksi Hydrometeorological Observatory in the middle arctic tundra zone with continuous permafrost. Finnish Meteorological Institute started the flux and concentration measurements of CH_4, CO_2, and H2O in the area in 2010 as a co-operation with the National Oceanic and Atmospheric Administration (NOAA) and the Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet). The aim of this survey was to create a vegetation type and a land cover map to be used to predict the measured fluxes with vegetation and soil properties. We established 56 plots, each with three sub-plots, and estimated the vegetation community type and the coverage and height of different plant species on each plot. On 28 of these plots, we also analyzed soil properties, such as depth of unfrozen soil, soil organic matter (SOM) content, soil moisture and litter layer depth. For these plots, we also calculated the leaf area index (LAI). As a result of the vegetation survey, we divided the vegetation plots to five groups: stony non-vegetated areas with some vegetation patches, lichen and shrub-moss tundra heath, tussock tundra, willow and grassy meadows, peatland areas from bogs to wet fens. In the data processing, two satellite images of extremely high resolution have also been used: Quickbird (4 channels, pansharpened to 0.6 m pixel size, acquired on 15th of July 2005 and thus representing the early part of the growing season) and WorldView2 (8 channels in 2 m, one channel in 0.5 m, acquired on 11th of August 2012 and thus representing the late part of the growing season). As a preliminary result, the satellite image based NDVI (Normalized Difference Vegetation Index) seems to explain the spatial variation in LAI and total plant cover and moss cover. Furthermore, it appears that SOM can be estimated using the variation in plant cover, and thus satellite imagery can also be used to predict the soil organic matter content.

Methane emissions from arctic wetlands – Isotopic characterisation

Rebecca Fisher et al.

Royal Holloway University

Arctic wetland methane production is a significant source in the global budget of this important greenhouse gas and emissions need to be quantified. Emissions are sensitive to year to year meteorological variations and climatic change. Isotopic measurements of methane (δ13C) can provide a constraint on the sources in global and regional methane emission models, but isotopic signatures of wetland methane vary across different types of wetland and with temperature and need to be studied in more detail to refine the signatures used in models. The isotopic signatures of methane emissions from the European Arctic are being characterised using measurements at different scales, from aircraft to chamber.

In July 2012 and August and September 2013 FAAM aircraft campaigns above northern Scandinavia as part of the NERC funded MAMM project are measuring methane concentration and isotopic variation across wetland regions. Samples are also collected in road transects. These campaigns coincide with ground based monitoring of wetland methane fluxes and isotopic signature at sites including Sodankylä (Finland) and Abisko (Sweden).

Air samples from a hilltop site in Pallas (Finland) and a 50 m mast at Sodankylä are collected weekly throughout the year and identify seasonal variations in the isotopic composition of regional methane emissions. Methane δ13C in these ambient air measurements decreases in summer when wetlands emit methane as wetland methane is depleted in 13C.

Air has also been collected from low height (0.3 and 3m) over wetlands during 24-hour periods, to collect daily emissions maxima, inversion maxima, and ambient minima when mixing occurs. Keeling plots, of methane δ13C against the reciprocal of methane concentration have been plotted to identify the signature of emissions. Measurements of the isotopic signature of methane that has built up in chambers has also been measured, to investigate the causes of heterogeneity in the signature of emissions across the site.

Results from Summer 2012 and preliminary results from August 2013 will be presented.

Episodic CH_4 emission from wet upland forest soil controls the catchment-scale balance in a wet year

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Methane (CH_4) is an important greenhouse gas which is formed in many anthropogenic activities, such as landfills, biomass burning or in natural gas production. In boreal and arctic zone, one of the main natural sources of CH_4 is pristine mires, whereas the upland forests typically show uptake of methane from the atmosphere through soil microbial oxidation. Although the rate of oxidation is much lower as compared to the production in wetlands, the high areal coverage of upland soils may have regional significance in the CH_4 balance. In this presentation we will demonstrate this through direct measurements in several locations at Pallas area. In a year with normal precipitation, the forest soil at Kenttärova station (67°59'N, 24°15'E) shows relatively high uptake rate of atmospheric CH_4, whereas in the following year with extraordinary high autumn-time precipitation, the soil turns into a source, the absolute emission value being 1-2 magnitudes as high as the typical sink. However, the methane fluxes at the nearby Lompolojänkkä fen (68°00'N, 24°15'E) were not affected by the wet autumn. In addition, we show how this sudden change of the upland forest soils at the area from a sink to a source can be seen in the atmospheric signature in the GAW-station at the top of the Sammaltunturi fjell (67°58'N, 24°07'E). We will also discuss how the longer-term (2004-2012) atmospheric CH_4 concentration measured in September is positively correlated with the general water level height at the soils of the area, indicated by the lake water level, whereas in other times of year a similar relationship cannot be found.

Using digital repeat photography to monitor phenology and to investigate its control on carbon dioxide exchange processes in the Lompolojänkkä fen

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Phenology is an important driver of the net ecosystem exchange (NEE) of carbon dioxide (CO_2) since seasonal plant development is tightly coupled to the processes of photosynthesis and respiration. Digital repeat photography has been previously used in other terrestrial ecosystems (i.e., forest, cropland and grassland) to continuously monitor and quantitatively describe changes in ecosystem phenology. Here, we present results from applying this technique in a nutrient-rich sedge fen located in north-western Finland. We use the chromatic greenness index (Gcc) derived from digital images analysis to investigate the control of phenology on the ecosystem CO_2 exchanges measured by the eddy covariance technique over eight growing seasons (2005 – 2012). We demonstrate that digital repeat photography may serve as a simple, cheap and automated method to continuously track seasonal changes in phenology and to evaluate its effects on the CO_2 exchange in peatland ecosystems. Moreover, Gcc derived from digital image analysis could help improving gap-filling of flux data and modeling of the seasonal development of the peatland CO_2 exchange.

Impacts of experimental warming and water level drawdown on leaf area and CO_2 exchange in a north boreal fen

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Peatlands are carbon (C) rich ecosystems, which hold potential as climate regulators. Climate change impacts, through changes in temperature and hydrological conditions, may induce drastic changes in the sink/source functions of these ecosystems.

An experimental site was established in 2008 in Pallasjärvi, Lompolojänkkä fen to test the impacts of warming, water-level drawdown, and their interactions on CO_2 fluxes. Experimental design includes pristine plots (control), warming using small open-top chambers (OTC), slight drainage, and combined drainage and warming. Weekly or biweekly measurements of net ecosystem exchange (NEE) on various levels of PAR, total ecosystem respiration (RECO) and monitoring of leaf area index (LAI), ground water level (WL), and air and soil temperatures were carried out from early summer till late fall during years 2011 and 2012. These data were used for parameterizing the LAI, Gross Photosynthesis (PG) and RECO models, and for estimating the seasonal (May-September) development of LAI, gas fluxes of NEE, PG, and RECO, separately for the different water-level and temperature treatments.

On the drained plots, WL was approximately 4 cm deeper compared to that on the control. Warming raised air temperature by approximately 1.5o C, and the effect was observed in the soil to the depth of 5 cm. Drainage decreased maximum LAI (1.1 m^2/m^2), compared to that of the control (1.42 m^2/m^2), through lower LAI of sedges and herbs, whereas maximum LAI of shrubs increased. Warming had no effect on maximum LAI or on species composition. Warming delayed the timing of maximum LAI by 2.3 days.

The fen acted as a carbon sink from the atmosphere during modeled May-September periods under all treatments. The strength of the sink function was slightly stronger on the pristine plots (557 g CO_2 m-2 season-1) compared to that of the drained plots (508 g CO_2 m-2 season-1). This was mainly due to the higher RECO on the drained plots, not fully compensated for by the slightly increased PG. Also warming increased RECO and PG but these changes were not statistically significant.

Changes in temperature and WL had only small impacts on the observed CO_2 sink, possibly due to fairly small treatment effects, especially on temperature, as compared to year-to-year variation in weather conditions. However, the minor changes in the CO_2 sink could also be interpreted as an indication of the ecosystem being rather resilient and that the CO_2 sink function may remain despite of moderate changes in environmental conditions.

Effects of experimental warming and water-level drawdown on microbial communities in Lompolojänkkä and Lakkasuo fens

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Peatlands with high water levels are net sinks of atmospheric carbon dioxide. In the long term, temperature increase due to climatic warming has been predicted to cause a moderate water-level drawdown (WLD) in boreal peatlands which may alter the carbon balance. Microbial decomposition of organic matter and microbial translocation of carbon in the aerobic surface peat are key factors affecting the output of carbon from peatlands. We tested the impacts of temperature increase and WLD on the activity and structure of microbial communities.

The field experiment was carried out in southern and northern boreal fens (Lakkasuo and Lompolojänkkä) in Finland. Experimental temperature increase was created with open-top chambers to mimic climatic warming impacts. The sites include a natural plot, and a moderately ditched plot simulating the WLD. We conducted analyses from peat cores divided into 10 cm sub-samples. Field and laboratory (basal respiration) CO_2 fluxes were measured by gas chromatography analyses. We used phospholipid fatty acid (PLFA) analyses to determine microbial communities. We conducted quantitative PCR for bacteria (16S) and fungi (ITS), and thymidine incorporation and 14C-acetate incorporation into ergosterol analyses for bacterial and fungal growth rates. To test the effects of environmental variables on microbial communities we used multivariate analysis.

Highest basal respiration rates were detected from the surface layer of the northern fen. Basal respiration rates in the surface layer of the southern fen increased following WLD. The warming together with WLD explained only a small part (4%) of the variation in the PLFA data. Site location alone explained 14%, and together with the warming and WLD 21%, of the respective variation. Sampling depth explained 25% of the variation. Notably high fungal biomasses measured as PLFA 18:2ω6, ergosterol amounts and ITS copy numbers were measured in the surface layers of the natural plot in the northern fen.

The results showed that microbial communities differed most between sampling depths and between fens. The results also indicated that the microbial response to experimental warming and WLD were different in two fens. All fungal indicators showed the same trend: there is a high fungal abundance in Lompolojänkkä fen with high water level conditions.

Tracing baseline in atmospheric carbon dioxide concentrations measured at Pallas and Sodankylä stations

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Global baseline CO_2 concentration is increasing year by year. This increase is monitored by numerous stations around the globe. The ground-based stations are situated in various locations ranging from marine to mountainous environments. The aim is to measure air samples that are representative to a large volume of atmosphere, and far from large point emission sources. Thus measurements are being selected for well-mixed air using e.g. wind speed and hourly standard deviation. Even if the station is remotely located, atmospheric circulation can occasionally bring in air masses that are affected by large emissions and thus are elevated in CO_2. These episodes need to be tracked. Air mass back-trajectories and footprints are useful in finding explanations for the observed CO_2 level. If air masses have been transported in low altitude over continental populated regions before arrival to measurement station, we can expect higher CO_2 levels than after transport above marine region. There are different methods to trace the history of air masses. Traditionally a Lagrangian trajectory model has been used, which gives only one back-trajectory path related to one observation time and place. However, in a dispersion model an ensemble of particles can be released relating to one observation time and place, and these particle paths can be used to construct a footprint map depicting the probable source regions. In this work, trajectory model FLEXTRA and dispersion model SILAM are compared from a perspective of selecting Pallas CO_2 observations according to different source regions. A re-assessment of the baseline conditions is given together with an overview of Pallas and Sodankylä observations and their specific features.

Monitoring snow and ice evolution in lake Orajärvi, Sodankylä using unmanned prototype ice mass balance buoy

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The evolution of snow and ice in lake Orajärvi has been monitored by a prototype ice mass balance buoy developed by the SAMS (Scottish Association for Marine Science). The SAMS Ice Mass Balance Buoy (SIMB) has been deployed in lake Orajärvi in winter 2009/2010, 2011/2012 and 2012/2013. SIMB consists of a high-resolution ice thermistor chain (2 cm sensor interval with totally 240 sensors); data logger compartment; the GPS and iridium data transmission board; SD flush memory data card and high-capacity alkaline batteries. The snow and ice temperature profiles have been investigated and snow and ice thicknesses are derived from high spatial resolution temperature profile and compared with borehole snow and ice thickness measurements.

Snow presented on lake ice for every winter season. SIMB measurements indicated that in addition to bottom ice growth, ice can grew thicker also at snow/ice interface to form so called white ice. The white ice counts from 20% up to 60% of the total ice thickness depending on weather conditions in early winter season.

A snow/ice model is applied to simulate snow and ice thicknesses and temperatures. The model results are compared with various in situ measurements.

Based on our long terms testing of SIMB, we conclude that SIMB is capable to monitor seasonal snow and ice evolution in lake. The real time snow and ice data acquisition can be used together with Numerical Weather Prediction (NWP) ensemble forecasts as driving force to product long term (up to 1 month) snow and ice forecasts.

Long-term variations and trends in distribution of ground temperature regime: A model study in Hyrylä, southern Finland

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Distribution of ground temperature at different depths plays a key role in physical, biological and microbiological processes through the soil. It can also be used as energy source/heat sink for house heating/cooling objectives and road de-icing, design parameter for foundation constructing based on maximum depth of soil frost, and an indicator of climate change especially in cold regions. This study aims at evaluating long-term variations and trends in distribution of ground temperature at different depths in Hyrylä (southern Finland), based on simulated results by SVHeat software which is commonly used to calculate geothermal gradients in soil. Daily air temperature and precipitation time series as well as soil properties are the main input datasets to the SVHeat. For model calibration and validation, measured soil temperatures by Lemmelä and Sucksdorf (1981) at 6 various depths (from 0.00 to 7.00 m) in Hyrylä during the period 1969-1973 are used. The verified model simulates the distribution of soil temperature regime for the period from 01.01.1969 to 31.12.2011. Long-term variations are shown by anomalies of ground temperature gradients on different timescales from daily to annual. To detect possible trends, the Mann-Kendall non-parametric test is used. The Spearman's correlation coefficient will determine relationships between ground temperature regime with climate teleconnection indices (e.g. North Atlantic Oscillation, NAO). Motivation for this work is the need to know about diurnal, monthly, seasonal and annual temperature variations in soil layers between depths 0.00-7.00 m in order to: 1) Indicate climate change impacts on ground temperature regime; 2) show the role of snow cover as thermal insulator; 3) determine changes in maximum depth of soil frost; and 4) assess shallow geothermal energy resource for depth less than 7 m. Main findings by this study may be one of key steps toward utilization of geothermal energy in cold environments (e.g. by energy pile foundations), and will be presented during the symposium.

CarbonTracker Europe inverse modelling for methane surface flux estimations: comparison of primary result to observations in Finland

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Biosphere is the largest contributor of methane emissions in Northern Europe, but large uncertainty in the estimation of the emissions remains. In oder to derive optimized estimates of global methane surface fluxes, CarbonTracker Data Assimilation Shell (CTDAS) has been further developed. EDGAR v4.2, LPJ-WhyMe, GFED and NOAA GMD Carbon Cycle GHG MBL References are used as the prior emissions for anthropogenic, biosphere, natural fire and ocean respectively. Further, prior for termites has been added. The priors are transported by TM5 chemistrytransport model to match time and location where the observations are available, and constrained by the observations, anthropogenic and biosphere priors are optimized through the Ensemble Kalman filter data assimilation system. The latest version of TM5 with a two-way nested European domain and 1ºx1º grid over high Northern latitudes (up to 70ºN), is used to focus the estimates over Central and Northern Europe. Atmospheric methane sink with OH is included with contributions from tropospheric and stratospheric OH, Cl and O(1D). The atmospheric observations are collected from WCGGG. The forward model result for year 2007 is compared to the atmospheric observations in Finland in order to prepare and validate the modelling system for inverse approach.

Using digital repeat photography to monitor phenology and to investigate its control on carbon dioxide exchange processes in the Lompolojänkkä fen

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Phenology is an important driver of the net ecosystem exchange (NEE) of carbon dioxide (CO_2) since seasonal plant development is tightly coupled to the processes of photosynthesis and respiration. Digital repeat photography has been previously used in other terrestrial ecosystems (i.e., forest, cropland and grassland) to continuously monitor and quantitatively describe changes in ecosystem phenology. Here, we present results from applying this technique in a nutrient-rich sedge fen located in north-western Finland. We use the chromatic greenness index (Gcc) derived from digital images analysis to investigate the control of phenology on the ecosystem CO_2 exchanges measured by the eddy covariance technique over eight growing seasons (2005 – 2012). We demonstrate that digital repeat photography may serve as a simple, cheap and automated method to continuously track seasonal changes in phenology and to evaluate its effects on the CO_2 exchange in peatland ecosystems. Moreover, Gcc derived from digital image analysis could help improving gap-filling of flux data and modeling of the seasonal development of the peatland CO_2 exchange.