Atmospheric lifetime of methane in a chemistry climate model

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Methane, which has the second-largest radiative forcing of the long-lived GHGs after CO2, has increased significantly as a result of human activities related to agriculture, natural gas distribution and landfills. Both CO2 and CH4 concentrations are far higher than during at least the last 650,000 years (Spahni et al. 2005). In contrast to the low growth rates seen in the last decade, recent results show a rapid growth in the global CH4 concentrations for 2007 (NOAA 2008). This could possibly be attributed to rapidly growing industrialization in Asia and rising wetland emissions in the Arctic and tropics. The thawing of Arctic permafrost could give rise to a large increase in CH4 emissions, however it is still unclear whether this has had any significant contribution to the observed increase.

Methane concentrations display relatively large variations in space and time and the interannual variability in the global growth rate of CH4 is significant. The variability may reflect changes in source emissions or variability in the major sink (atmospheric OH), however the effect of meteorology may also be significant. A better understanding of the relative importance of sources and sinks is needed to predict future changes in atmospheric CH4 and its impact on the climate. The sources include wetlands, rice agriculture, biomass burning, ruminant animals, fossil fuel mining and distribution.

The principal tool for these studies is the ECHAM5-HAMMOZ chemistry climate model (Pozzoli et al. 2008), and the practical goal is to improve the parameterization of CH4 sources. The long-term goal is to develop a coupled biosphere-CCM including a realistic description of the response of CH4 emissions from wetlands for different hydrological conditions.

The first studies are related to the effect of meteorology on the global and local variability of CH4. Comparisons are made to data from observational sites. The model can be run at a nudged mode to follow observed meteorology using e.g. ECMWF reanalysis data. In addition, results from CH4 lifetime studies are shown, i.e. the sensitivity of CH4 abundance and trends to changes in atmospheric OH. These studies will improve the understanding of observed CH4 growth rates, and will also show how realistic the simulated CH4 life times are in the model.

References
The satellites data use for monitoring the degradation process of natural resources in semi arid zones (algeria)

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The semi-arid region of the Aurès presents an undeniable diversity of flora and fauna, however weather conditions and actual adverse anthropogenic, caused degradation of the physical environment, which have the form of a regression in the natural forest cover.

The objective of this study is to determine the contribution of satellite images in detecting changes in land use and monitoring of the degradation processes in the southern part of the Aurès region.

As far as that goes, we used images: Landsat ETM + for 2001 and TM 1987. These last cover the southern region of the Aurès which presents a landscape exposed to the phenomena of degradation including forest Beni-Mloul, Dj.Mezbel and Dj khaddou Ahmar, characterized by endemic species.

The adopted step is to treat multi-dates satellite imagery by the method of supervised classification of Maximum likelihood to see global changes of land use that have occurred in this area.

The results of treatment of satellite images show that the forest cover, rangelands and soil are being the object of advance degradation.

This study is a multi temporal diagnosis, which has allowed us to identify at a time the degradation affecting vast semi-arid areas, causing regression of plant cover, and also the pace of its development.

Keywords— Satellite Data multi-dates - Degradation of natural resources - semi-arid areas - Aurès.
Estimating river-sediment discharges in the Red River (Vietnam) using rating curves and impact of reservoirs on transport

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Data on river sediment fluxes are essential for studies on soil erosion and -loss, natural geochemical cycles and mass balances of contaminants transported in the particulate phase. Long-term time series are needed for assessing temporal variability and understanding impact of global climatic change and/or anthropogenic activities on sediment flux (Farnsworth and Milliman, 2003). Nevertheless, less than 10% of the world’s rivers have been monitored for their sediment delivery to the ocean (Syvitski et al., 2005). In the absence of (i) continuously measured suspended particulate matter (SPM) concentrations or (ii) long-term time series, sediment rating curves have been used to estimate SPM data and predict river-sediment discharges (Walling and Webb, 1981; Horowitz, 2003; Doomen et al., 2008).

The Red River (China/Vietnam; A=155 000 km²) is strongly affected by monsoon with a rainy season from May to October cumulating 85–95% of the total annual rainfall. Daily discharge (Q) and SPM concentrations were measured during 1960 to 2007 by the Institute of Metrology, Hydrology and Environment at the SonTay gauging station (watershed outlet). Daily SPM concentrations varied from 20 to 15,000 mg/l with Q values ranging from 160 to 33,600 m³/s. Based on these data, the mean annual SPM flux of the Red River is estimated to 90 Mt/yr, corresponding to a sediment yield of 600 t/km²/yr, similar to that of the Ganges/Brahmaputra system (e.g. Ludwig and Probst, 1998). The temporal variability of annual SPM fluxes (24–200 Mt/yr) is strongly related to the interannual hydrological conditions. However, some years of high water flow dis not account for high sediment fluxes, especially after 1986 when the HoaBinh dam was built on a major tributary of the Red River. Based on Q and SPM measurements over the 1960–1985 period covering a wide range of hydrological situations, we have fitted different sediment rating curves and selected the regressions describing best the sediment load. A single sediment rating curve derived from data spanning the 1960–1985 period was used to simulate the annual variability of sediment delivery generating excellent cumulative flux estimates (error of <0.6%). In contrast, applying the same rating curve to the 1986–2007 data resulted in systematic and important (up to 94%) overestimation of cumulative SPM flux. Analysis of the pre- and post-1986 sediment rating parameters (a and b) of power functions (SPM=aQb) suggests a down shift of a-parameter values after 1986, attributed to decreased sediment supply (Wang et al., 2008). These results obtained from analysis of long-term observation data strongly suggest that the Hoa Binh dam has reduced annual SPM delivery to the delta by half.

References

A carbon budget of a low-productive boreal forested catchment

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Dissolved organic carbon (DOC) concentrations in freshwaters have increased considerably in boreal ecosystems in the past decades, possibly as a response to reduced acid deposition. Climate warming is expected to be associated with more precipitation and rain storms of higher intensity in summer and autumn, leading to more surface run-off. Both of these phenomena suggest that losses of soil C through fluvial transport may become more significant compared with C sequestration in soils and vegetation, especially in upland forests of low productivity which are typical for boreal areas.

Here, we aim to link estimates of terrestrial C uptake and losses with aquatic fluxes of DOC for a small, forested boreal lake catchment in southeastern Norway. These more detailed and process-oriented estimates are compared with estimates on aquatic C-flux from a wide range of catchments over the entire mainland of Norway, inferred from data on runoff, DOC-concentrations and Differential Vegetation Index (NDVI).

The catchment (Langtjern; 4.8 km²; 500–750 m.a.s.l.) is dominated by old unproductive pine forest on thin mineral and organic soils, in addition to wetlands. Flow-weighted DOC has increased with 20% over the last 20 years. Mean annual discharge is 600 mm, and mean annual export of DOC is 6 g C m⁻².

Estimates of terrestrial C pools (soils and vegetation) and fluxes (uptake in forest and fens, losses of CO₂ from soils, in-lake production, sedimentation and mineralization of CO₂) will be presented.

The C pool in standing tree biomass was estimated by using airborne remote sensing (Lidar), single-tree segmentation and allometric functions for pine. Tree growth was estimated based on forestry yield tables and wetland C sequestration on literature values. Litter production was estimated from biomass turnover factors.

Ground returns from the Lidar runs have also been used to generate a high-precision digital elevation model, which served as input for a spatially distributed hydrological model. Input of DOC to the lake was assessed from discharge monitoring and DOC-concentrations in the two inlets, plus hydrological estimates on diffuse runoff. Monitoring of the outflow allowed for mass balance calculations of DOC. Annual sedimentation rates were estimated using sediment traps, and separate estimates were made for mineralization losses (bacterial oxidation plus photooxidation). Also degassing of terrestrially derived CO₂ was estimated in the highly supersaturated inlets. Soil CO₂ and CH₄ effluxes were estimated using closed chambers.

Some of the flux estimates are uncertain with a coefficient of variation exceeding unity. In order to estimate the carbon budget at the whole catchment level, upscaling from point measurements as well as temporal aggregation of discontinuous measurements to the annual scale is required. The investigation aims to evaluate the relative importance of uncertainties of individual fluxes and the degree in which uncertainties are constrained by the whole-catchment perspective.
Removing the disconnect between maps and time series: can long-term monitoring data be used more effectively as a basis for model upscaling?

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Long-term monitoring sites provide key process understanding, and are frequently the basis for detailed biogeochemical model applications. Implicitly or explicitly, the information provided by both monitoring and modelling must be upscaled in order to have wider scientific and policy application. However, upscaling models inevitably requires trade-offs between scale of application and data quality. Across Europe, work under the UNECE Convention on Long-Range Transboundary Air Pollution has aimed to simulate the effects of atmospheric S and N deposition on semi-natural ecosystems at large spatial scales. In general, the approach taken has been to parameterise models to large numbers of individual locations (surface waters) or grid squares (soils). Such modelling involves high uncertainty, is difficult to test, and makes no direct use of long-term monitoring data.

Significant changes have occurred since large-scale modelling was first undertaken in the 1990s. Firstly, biogeochemical models have developed to include more accurate process descriptions, including better representation of the influence of climatic as well as deposition drivers, and more sophisticated methods for parameter estimation, notably those including uncertainty estimation such as Markov chain Monte Carlo analysis. These changes provide the capability to more accurately reproduce observed temporal variations in long-term data. Secondly, monitoring datasets have increased in duration. Although spatial variations are often large, reflecting gradients in deposition, climate, soil and land-use, many key chemical variables show remarkable temporal coherence among sites (e.g. Fig. 1), linked primarily to consistent large-scale changes in deposition and climate. We propose that this temporal coherence provides the potential for more effective utilisation of long-term monitoring data in model upscaling. More sophisticated models can be accurately parameterised from individual monitoring sites to reproduce observed temporal changes. Changes at unmodelled sites can then be predicted through identification of suitable modelled analogues, and application of statistical models incorporating space and time components. The utility of this method will be critically evaluated by testing 1) the ability of the statistical model to predict long-term changes at one site based on measured data from other sites, and 2) the performance of ‘low data quality’ model applications direct to survey sites, relative to ‘high data quality’ model applications extrapolated from long-term monitoring sites.

Figure 1. Coherent temporal variations in standardised annual mean concentrations of a) dissolved organic carbon and b) acid neutralising capacity for the lakes and streams in the UK Acid Waters Monitoring Network. Lines show 10th, 50th and 90th percentile values for the 22 sites.
Linking litter to lakes: A modelling study of the effects of climate change on carbon cycling and lake thermal properties in a boreal catchment

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The combined effects of reductions in acid deposition and a changing climate are leading to increases in surface water dissolved organic carbon (DOC) concentrations in the boreal ecozone. Climate change is also affecting the timing of ice cover, water temperature, and stratification period for boreal lakes. The concentration of DOC in a lake exerts a major influence on its thermal behaviour, affecting degree and timing of stratification as well as heat storage. Recently two models have been developed to simulate the effects of changing climate on catchment-scale cycling of DOC and lake thermodynamics. A catchment-scale model of carbon cycling (Futter et al. 2009) was able to produce long-term (1961–2100) simulations of DOC concentration in surface waters but would have benefited from improved estimates of litter fall to drive the model. A model of lake thermodynamics (Saloranta et al. 2009) was calibrated to current conditions and used to provide estimates of lake thermal behaviour under baseline (1961–1990) and future (2071–2100) climate scenarios and constant DOC concentration. Here we present a modelling study in which empirical models of litter fall are used to drive a catchment-scale, process based model of DOC cycling which in turn is used to drive a physically-based model of lake thermodynamics. Our study links the effects of climate change on biological processes occurring in the catchment to lake thermal behaviour and discusses the uncertainties in model projections.

References
Inorganic nitrogen leaching from two Finnish research catchments under future climate conditions

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The semi-distributed dynamic INCA-N (Integrated Nutrients from Catchments – Nitrogen) model (Whitehead et al., 1998; Wade et al., 2002) was applied to two research catchments in Finland, within the EU Euro-limpacs project. The aim was to simulate nitrogen (N) loads under different climate change scenarios. The Mustajoki catchment (78 km²) is a forested upstream catchment located in highlands in southern Finland where the soil types are mostly coarse (till 68%, sand and silt 11% of the catchment area). The Savijoki catchment (15 km²) is representative of intensively cultivated lowlands in south-western Finland. Fields cover 36% of the catchment area and are located on clay soils along the stream network.

In both catchments, the calibrated and tested model was used to simulate the hydrological pattern and inorganic N losses in the new equilibrium climate (representing period 2071–2100) with four climate change scenarios developed within the PRUDENCE-EU project (Christensen et al., 2007). The selected scenarios suggest an increase of 2.8–4.7 °C in annual mean temperature and 10.1–23.6% increase in annual precipitation. The considerable increase in winter (December-February) temperatures (3.4–6.2 °C) and precipitation (26–56%) predicted by the different scenarios influenced strongly the hydrological regime in both catchments. In Savijoki, the modelled snow water equivalent (SWE) decreased and the winter runoff increased considerably. In Mustajoki, the air temperature in winter remained below zero during most scenario years and therefore, the increased precipitation caused higher SWE and snowmelt runoff peak compared to present conditions.

The modelled annual inorganic N load increased by 32–68% in Savijoki and 9–32% in Mustajoki according to different scenarios. This was due to higher mineralization rate and increased water flow through the catchment soils. The changes were more pronounced in agricultural Savijoki than in forested Mustajoki particularly during dormant period, from November to February (Fig. 1). Efficient catchment scale mitigation measures are needed, especially on the agricultural sector, to prevent eutrophication of surface waters in future climate conditions.

![Figure 1](image-url)

Figure 1. Simulated inorganic N loads from a) Savijoki and b) Mustajoki catchments in present (Base) and future (Mean of four scenarios, Scen mean) climate conditions. Scaled monthly load values are presented.

References


Investigation of methyl bromide and methyl chloride flux from Scottish and sub-arctic wetlands

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Methyl bromide and methyl chloride (MeX) contribute to ozone destruction in the stratosphere. These gases are naturally produced from a range of environments which may also act as sinks. The natural source and sink terms for MeX are poorly constrained and a better understanding of these terms is required for predicting ozone recovery. In this research MeX flux has been monitored for more than 1 year at several sites in four Scottish wetlands. Air samples were regularly collected from each site and were analysed for MeX using gas chromatography with electron capture detection. External parameters, including air temperature, soil temperature, water level, solar flux and photosynthetically active radiation, were recorded during each sampling event. In addition, a study over two summers was performed at a sub-arctic wetland near Abisko, Sweden. Our aims were to improve the global database of wetland MeX flux measurements, to study seasonal and diurnal trends in MeX flux and to determine if external environmental parameters drive MeX flux.

Fig. 1 shows the seasonal trends in average MeX net flux from all sampling points in the Scottish wetlands. For all sites there were greater emissions during the growing season compared with the winter, suggesting a plant or a plant-mediated source of MeX. The magnitude of emissions varied between sites and there was also variation within the sites depending on the type of vegetation present. The greatest MeBr emissions were observed from a *Phragmites australis* reed-bed. The average emission was 4700 ng m\(^{-2}\) h\(^{-1}\) over one year. Large MeBr and MeCl net emissions were observed from raised peat bog sites dominated by *Calluna vulgaris*. The average MeBr emission was 592 ng m\(^{-2}\) h\(^{-1}\) over one year and the average MeCl emission was 35100 ng m\(^{-2}\) h\(^{-1}\) over nine months. At some sites, a diurnal cycle of MeX flux, with greater emissions during the day, was observed. No substantive correlation was observed between MeX emission and any of the measured external parameters. Very low rates of MeBr uptake and MeCl emission and uptake were measured at the sub-arctic wetlands, although a seasonal cycle of MeX flux was likewise observed.

Current work includes analysis of the separate plant and soil components of wetlands in order to determine the contribution of each to the overall flux. Geographic Information Systems (GIS) are also being used to up-scale MeX flux from site measurements more accurately to global budgets.

![Fig. 1. Average MeBr and MeCl net fluxes over time from sites at four Scottish wetlands. Error bars represent the standard error in MeX analysis. Note the different scales for MeBr and MeCl.](image-url)
Optimal Land Use Pattern of Zhifanggou Watershed on Hilly Region of Loess Plateau, China: application of a Process-Based Water Balance Model

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For purpose of landscape sustainability of hilly region of Loess Plateau, optimal land use pattern based on water balance was addressed in Zhifanggou watershed of Shaanxi Province in northwestern China. A process-based water balance model for loess landform was developed, and soil water movement, evaporation, transpiration, and runoff could be simulated both in ecosystem and watershed scales. Up-scaling from ecosystem to watershed was in terms of spatial variability of landform, soil type, and vegetation. Four scenarios of land use pattern were designed, two based on actual situation in 1975 and 1997, respectively, and the others according to the suggested plans of returning cropland to woodland and grassland, with the allocation proportions of cropland, woodland, and grassland area being 1:0.13:0.84, 1:0.88:0.85, 1:4.6:6, and 1:28:17, respectively. Modeling results show that more woodland and grassland there are, more precipitation is intercepted in the watershed, and more water returns to the atmosphere by soil evaporation and plant transpiration within the current year, with the decrease of average annual soil water content. As a result, the ecosystem would be unstable due to the severe water deficit in dry years when the proportion of woodland reached about 55%, although it might be optimal for the water-and-soil conservation. Preliminary conclusion may be drawn that, to make sustainable use of water resource and achieve optimal ecological benefit, the reasonable proportion of woodland should be around 36% in the Watershed, while the suitable ratio of cropland, woodland, and grassland area be 1:4.6:6.
Net ecosystem exchange in a rewetted, episodically flooded brackish fen - modelled potential vs monitored field data

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Whilst there is a number of studies regarding carbon stocks and exchange in intertidal saline wetland soils (Chmura et al. 2003), coastal freshwater peatlands have been rarely investigated (Henman & Poulter 2008). However, they might be susceptible to inundation driven peat consumption that possibly feeds back to climate change. Our investigation site in the Northeast of Rostock (Germany) is episodically flooded with brackish baltic sea water. Therefore the vegetation as well as the according biogeochemical processes can be seen as representative for coastal ecosystems susceptible to flooding because of future sea level rise and the expected developments can already be studied here in detail. Enduring protection against flooding might be very expensive. Furthermore, a reanimation of naturally provided ecosystem services (as carbon storage) may be aspired. Therefore it is crucial to investigate what happens to vegetation composition, matter (carbon) storage and GHG emissions in these ecosystems under dynamic flooding regimes and therewith potentially higher salinities.

We will present one year eddy covariance flux data from the site and compare the annual net ecosystem exchange to the modelled annual net ecosystem exchange that can be expected from litter incubation experiments in the lab. This data is derived from 25 litter samples (5 vegetation types with 5 replicates each) that have been taken in the area that is covered by the eddy flux measurements. 10 g of the litter samples (plant material, soil, etc.) are filled into 500 ml Erlenmeyer flasks and 50 ml of original water are added so that the litter material is covered with water. These samples are stored in the lab (they are weighed every day and dest water ist added if necessary to keep liquid/solid relation stable). Air sampling from these flasks is carried out for 40 days beginning with daily sampling and decreasing the rate subsequently depending on GHG development to stay in the measurable range. The air samples are analyzed with gas chromatography for CH$_4$, N$_2$O, and CO$_2$. The same laboratory setup is repeated with adding 25 ml of original water and 25 ml of Baltic Sea water. Thus, future higher salinity can be evaluated regarding its influence on potential trace gas emissions.

The resulting CO$_2$ emissions are scaled up to the eddy tower scale using a detailed vegetation map of the site reflecting the distribution of the litter (vegetation) types. The map is derived from a combination of field sampling within a systematic grid of plots and remotely sensed data (multi-spectral airborne imagery). The latter is subjected to a object-oriented supervised classification under consideration of the vegetation field data. Eddy flux and lab data are compared to compare field fluxes against potential fluxes and modelled future potential fluxes.

References
Modeling of calcium dynamics in north taiga forest soils

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Calcium is a major nutrient regulating metabolism in a plant. Deficiency of calcium results in a growth decline of plant tissues. Plant-available calcium compounds are in the soil cation exchange complex and soil waters. We simulated calcium dynamics in the northern taiga forest soils linking it with the model of soil organic matter dynamics ROMUL (Chertov et al., 2001). ROMUL describes the mineralization and humification of the fraction of fresh litter which is further transformed into complex of partially humified substance (CHS) and then to stable humus (H) in dependence on temperature, soil moisture and chemical composition of the fraction (nitrogen, lignin and ash contents). Rates of decomposition and humification being coefficients in the system of ordinary differential equations are evaluated using laboratory experiments and verified on a set of field experiments (Chertov et al., 2007).

Main pools of calcium taken into consideration are as follow: L_{Ca} is calcium in the fraction of fresh litter, [kg/m^2]. At mineralization of soil organic matter with monthly rate R1 part of calcium moves into the pool of available calcium Av and rest part is transformed into the pool of calcium F_{Ca} (calcium bonded with CHS) with rate R3. F_{Ca} is mineralized with rate R2 into Av and is also transformed into H_{Ca} (calcium bonded with organic-mineral complex of stable humus). Last transformation goes different ways with monthly rates R4 and R5 in dependence on activities of microorganisms and different groups of soil fauna as it has been done in ROMUL. R5, for instance, describes activity of earthwarms which produce humus with relatively narrow C/N ratio. H_{Ca} is mineralized with monthly rate R6 and comes into Av. Av consists also of calcium weathering from minerals, which could be evaluated from other models, PROFILE (Sverdrup, 1996) as an example.

Calcium input with bulk precipitation and throughfall is also included into Av pool.

Such a model structure allows for describing the calcium dynamics as a system of ordinary differential equations. Moreover, at some assumptions we can link the calcium model with ROMUL through the soil organic matter pool. It allows for using of some ROMUL coefficients and provides a feedback with carbon and nitrogen dynamics. Calcium compounds are related to the soil acidity which regulates the decomposition and humification rates. The dynamics of calcium influences on the carbon and nitrogen cycles in forest ecosystems.

The model is calibrated and verified for the northern taiga forests on the Kola peninsula.

References
Evolution and present-day climatic-driven dynamics of the thermokarst lakes in West Siberian cryolitozone

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Lakes, ponds and drained thaw lake basins are major elements of the Northern landscape. These ecosystems are integrators of their surrounding catchment properties including geomorphology, limnology, hydrology, vegetation and permafrost soil dynamics. Many of these properties are strongly dependent of climate thus making boreal lakes sensitive indicators of its changes (Vincent, Pienitz, 2006).

Plateaux palsas cover extensive areas in the West-Siberian sub-arctic. All the stages and the smallest nuances of the endogeneous cyclic succession process are visible over space in remarkable images (Kirpotin et al., 2007). The positions of the edges of the landscape precisely reflect the time series of its development: (1) during the first stage of the cyclic decay of flat palsa complexes, thermokarst lakes may appear as a result of the appearance of different sized melted subsidences; (2) these lakes can increase in size due to shore erosion since lake water acts as a heat source which induces further thawing of permafrost layers; (3) the thermokarst lakes can also turn into a chasyreis (drained lakes without water); (4) at the empty lake basin stage, the heaving by renewed permafrost goes on, the isolated small mounds merge into a uniform system and they turn into typical flat palsa plateaux. We investigated the chemical and microbiological evolution of thermokarst lake water ecosystems chronosequences and found a systematic trend of the decrease of dissolved organic carbon concentration from palsa complex decay stage to the chasyrei stage. At every stage of lake development, important net flux of \( \text{CO}_2 \) from the lake water to the atmosphere and dominance of the mineralization over primary production was observed.

The thermal karst and the heaving of the permafrost have been peculiar to the Western-Siberian sub-arctic region for a long time. There has been a steady balance of cryogenic processes. These days, we observe that the cyclic succession has taken a linear character directed towards the strengthening of the thermokarst.

During the expedition of 2008 carried out within the framework of Russian-French network project CAR-WET-SIB, one of possible mechanisms of drainage of thermokarst lakes in the north of Western Siberia was revealed. The discovered natural processes are significantly amplified by the climate warming and thus require a special attention.

Satellite monitoring (1973–2008) has revealed zonal specifics of geocryologicat processes. In the zone of continuous permafrost, thermokarst lakes expanded their areas by about 10-12\%, but in the zone of discontinuous permafrost the process of their drainage prevails. These features are connected with the thickness of peat layers which gradually decreases to the North, where the lakes have reduced opportunity for drainage.

References


Assessing critical load and exceedance in south-central Ontario: application of new weathering determination methods to the Steady-State Mass Balance and MAGIC models

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Previous acidification research in Ontario has focused on a few intensively studied sites with high-resolution data, whereas, regional acidification studies generally rely on low-resolution data from soil maps. In the most recent Canadian Acid Rain Assessment (2004), base cation weathering rates were estimated using a simple empirical clay based model (Ouimet et al. 2006); however the model has not been validated for southern Ontario, which receives some of the highest acid deposition levels in Canada. A new Ontario Weathering Model (OWM) was developed to estimate regional weathering rates (eq∙ha⁻¹∙a⁻¹) for forest soils in south central Ontario using soil clay content (%) and loss on ignition (LOI, %)—soil properties that are available at the regional scale:

\[ r_{\text{weathering}} = (1.9798 + 0.3126 \cdot \text{Clay} - 0.1567 \cdot \text{LOI}) \cdot \text{depth} \]

Weathering rates obtained using OWM for the rooting zone at 19 forested catchments (252–892 eq∙ha⁻¹∙a⁻¹) were consistent with estimates from catchment mass balance at these sites (273–2,131 eq∙ha⁻¹∙a⁻¹).

Weathering rates obtained using the OWM were used to estimate critical loads and exceedances in south-central Ontario. Steady-state critical loads were estimated at 116 sites using the Steady-State Mass Balance (SSMB). Uncertainty in critical load estimates was addressed with a multi-criterion approach combined with modifications in model parameters. Further, exceedance was estimated using two regional acid deposition fields. Depending on assumptions in the model and deposition estimates, between 0% and 36% of the study sites received acid deposition in excess of the critical load, values much lower than reported in the recent Acid Rain Assessment. Site-specific weathering estimates obtained using PROFILE and mineralogy data estimated from total oxide using the Analysis to Mineralogy (A2M) model (Posch and Kurz 2007) were applied to dynamic simulations at 52 study sites. The response of soil chemistry at these sites to proposed changes in sulphur and nitrogen deposition was evaluated using the Model of Acidification of Groundwater in Catchments (MAGIC).

References
Stream benthic macroinvertebrates of nine selected catchments of the Czech GEOMON network

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This contribution examines relationships between stream chemical and physical characteristics, whole-stream metabolism, and the associated biotic communities in nine small (22-261 ha) headwater streams of the GEOMON network of forest catchments (Oulehle et al. 2008). At each catchment, a 100-m reach was established and 3 replicate samples were collected from each major habitat type (pool, riffle, run), for a total of 9 samples per site. Benthic macroinvertebrates were collected using a net and by scrubbing all rocks and disturbing sediment within 30 cm of the net frame. Specimens were usually identified to the family level. The benthic macroinvertebrates found at each site were documented (Kram et al. 2008). Streamwater pH at the time of sampling ranged from 4.0 (Lysina) to 7.7 (Pluhuv Bor). As expected, taxa richness declined with increasing acidity (Fig. 1). The lowest biodiversity (9 taxons) was at Lysina, the highest (22 taxons) at Salacova Lhota. The flies (Diptera) from families Chironomidae (non-biting midges) and Simuliidae (black flies), the stoneflies (Plecoptera) from families Leuctridae (needleflies) and Nemouridae (spring stoneflies), the caddisflies (Trichoptera) from families Limnephilidae (northern caddisflies) and Polycentropodidae (tube-making caddisflies), and the worms (Vermes) from class Oligochaeta (earth worms) were present in all streams. However, acid-sensitive taxa such as mayflies (Ephemeroptera) were absent from the two most acidic streams at Lysina and Loukov.

![Fig. 1. Taxa richness of benthic macroinvertebrates declined with decreasing pH (increasing acidity) in the forested catchments of the Czech Republic.](image)

References


Comparison of backward trajectories of selected elements in samples of wet deposition collected at three differing sites in Bohemia

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Pathways of major elements representing the bulk chemistry of precipitation over western part of the Czech Republic (CR) were studied in samples collected at three different sampling sites. The study was based on the evaluation of significance of transport trajectories using the HYSPLIT model (Draxler and Rolph 2003). Precipitation samples from individual rain events were collected and concentrations of Na, K, Ca, Mg, S, P, Si, Fe, Al, Mn, Pb, As, Cu, Zn and Cd were analyzed. For the sampled rain events we identified air mass trajectories from the satellite data with respect to the event duration. Precipitation samples were collected at localities Lesni potok (LP, approx. 30 km SE from Prague at 49°58’48”N, 14°46’12”E, 420 m a.s.l.), Milesovka (MI, in the Bohemian Central Highlands at 50°33’17”N, 13°55’57”E, 837 m a.s.l.), and Kopisty (KO, at 50°32’54”N, 13°37’31”E, 240 m a.s.l.) in period 2005–2008 (see Figure).

Sampling site LP represents a typical Central Bohemian background locality located near the forested National Nature Reserve – Voděradské bučiny, affected mostly by the emissions of the industrial urban area of Prague. The site MI is located on the top of conical mountain in one of the most polluted regions of Bohemia. Similarly, the site KO with low altitude is situated also in the heavily industrialized NW part of the CR, characteristic with relatively significant local air pollution.

Chemical composition of monitored precipitation events generally reflects the combined impact of anthropogenic and natural emission sources, affected by the location and orography of the sampling sites. The results indicate that prevailing transport trajectories of the most of monitored elements agree with the location of their supposed sources. The analysis of trajectories indicated major source of Na and Mg marine aerosol, while those of K and Mn signify their most probable and dominant local biogenic origin (Vach et al. 2008). There is not a single dominant trajectory, but more important trajectories from different directions for the elements Al and Fe. Correlation of Al and Fe concentrations indicates their probable common source, the terrigenous dust. No significant predominant course of trajectories was identified for S. This is presumably caused by different position of major S sources towards the sampling sites.

The comparison of results obtained at the individual sampling sites shows dominant impact of the principal low-distance emission sources (at MI and KO large extent of coal burning powerplants) and also especially at MI the terrain orography. Predominant courses of transport trajectories were identified from the southwest - northwest directions.

References
Decreasing DOC trends in soil solution along the hill slopes at two IM sites in southern Sweden

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Numerous studies report increased concentrations of dissolved organic carbon (DOC) during the last two decades in boreal lakes and streams in Europe, Canada and the US. Many different processes have been proposed to explain these trends e.g. weather induced shallower groundwater flow paths, recovery from acidification due to reduced sulphur deposition, changed land use, increased forest production etc. Swedish surface waters and soils show clear signs of recovery from acidification, indicating that the increased levels of DOC could be attributed to increased soil pH and decreased levels of aluminium in the soil solution, both factors affecting the solubility of soil organic matter (SOM). Additionally, the decreased ionic strength coupled to the reduced sulphate concentrations might increase the DOC-flux. If this recovery hypothesis is correct, the DOC levels should increase both in the soil solution as well as in the surrounding surface waters as pH rises and the input of ions such as sulphate decline. However and in contrast to the surface waters, the soil waters in recharge areas (50 cm soil depth) in southern Sweden exhibits decreased DOC concentrations during the period 1986–2008, indicating increased coagulation of DOC in the upper soil horizon (see Zetterberg & Löfgren this volume). Therefore, it was hypothesized that processes in discharge areas and peat lands rather than dry soils uphill govern the surface water DOC trends (op. cit.). In this study, this hypothesis was tested on soil water data from two transects along the hill slopes at the integrated monitoring sites at Aneboda and Kindla in southern Sweden, covering the time period 1996–2007.

Soil water was collected with tension lysimeters (ceramic suction cups, P80, 1 µm cut-off, installed 1994) in E- and B-horizons in the recharge areas and at 30–40 cm soil depth in the discharge areas. At Aneboda, data origins from April, August and November, while it origins from May, August and October at Kindla. The water from each lysimeter was analysed separately and according to Swedish standards. The non-parametric Seasonal Kendall was used for analyzing statistical significant trends (p<0.05) for each lysimeter and the annual trends were quantified with Theils slope. In the table below, the number of statistically significant positive and negative trends as well as the minimum and maximum values on Theils slope are listed. Only 11 out of 28 lysimeters showed statistically significant DOC trends, with predominance of decreasing concentrations. pH, sulphate and ionic strength (=conductivity) exhibit clear signs of recovery from acidification, with slightly increasing (pH) and decreasing (SO\textsubscript{4} and cond.) trends in most lysimeters. Hence, the hypothesis of increased DOC concentrations due to recovery from acidification is not verified by the trends in soil water either in recharge or discharge areas at the IM sites in Aneboda and Kindla. The DOC trends are in agreement with the findings of Zetterberg & Löfgren (this volume). Theoretically and regardless of decreasing DOC concentrations in soil water, shallower groundwater flow paths could compensate for this and explain the surface water DOC trends.

<table>
<thead>
<tr>
<th>Kindla</th>
<th>E-horizon</th>
<th>B-horizon</th>
<th>Discharge area</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>+/- trends</td>
<td>+/- trends</td>
<td>+/- trends</td>
</tr>
<tr>
<td></td>
<td>min; max slope*</td>
<td>min; max slope*</td>
<td>min; max slope*</td>
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<tr>
<td>Kindla</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>pH</td>
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<td>5/0</td>
<td>5/0</td>
</tr>
<tr>
<td>Cond., mS/m</td>
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<td>0/9</td>
<td>0/6</td>
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<td>0/6</td>
<td>0/6</td>
</tr>
<tr>
<td>DOC, mg/l</td>
<td>0/2</td>
<td>1/3</td>
<td>1/2</td>
</tr>
<tr>
<td>Aneboda</td>
<td></td>
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<tr>
<td></td>
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<td>4</td>
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</tr>
<tr>
<td>Cond., mS/m</td>
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<td>no trends</td>
</tr>
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<td>0/7</td>
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<td>DOC, mg/l</td>
<td>nd</td>
<td>1/3</td>
<td>0/1</td>
</tr>
</tbody>
</table>

*Annual change e.g. µeq/l, yr.
Forest ecosystem leaching in a climate change perspective for the Nordic region

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Forest ecosystem conditions are influenced by climate change primarily targeting precipitation and temperature. This will have impacts on hydrology and further among other things organic matter, acidity and nitrogen. Turnover of elements is to a large extent dependent on hydrological conditions. In a climate change perspective, it is foreseen frequently more extreme variations e.g. regarding wetness and drought. In a northern climate, the historically ordinary hydrological pattern includes a dormant period often being snow covered and a vegetation period in summer with relatively high temperature and evapotranspiration. This pattern already has changed to mild winters including snow melt during the whole period, resulting in the absence of a high snow melt spring flood. Instead high element runoffs occur during the dormant period meaning a rather high flow to surface waters and the sea. In summer, variations between high precipitation and periods of drought occur at different geographical locations and with time. The consequences for element turnover could be drastic.

Soil organic matter would play a key role. Increased growth would furnish more litterfall and root production. A higher temperature could change the stand tree composition and in case of a change from pine to spruce increase the soil organic matter storage. In moist and wet areas this would mean enhanced accumulation of organic carbon. A high nitrogen input furnishes additional organic matter storage possibilities. Under moist or wet condition more organic matter would influence water quality with higher colour, lower pH and hazardous conditions for metals. In case of changes in soil moisture conditions, i.e. drier periods, the decomposition of stored organic matter will start and could be considerable. This would release stored elements, increase nitrate production and leakage. After the drier period, again precipitation will fall and flush out the released elements with strong effects on e.g. pH, N and metals.

These conditions need to be followed on the whole ecosystem level where a catchment approach should provide the most appropriate unit and perhaps in several spatial scales. In the Integrated monitoring (IM) approach for natural forests, this is ongoing but for the majority of land, where ongoing land-use such as forestry exists, the monitoring is on a low level and needs development. Future monitoring has to include these facts and address tree composition, forestry activities, especially in a higher biofuel use perspective, and follow the soil organic matter storage change together with its composition.
A 3D structure model of an artificially constructed soil-geo-system

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The initial development stages of artificially constructed soil-geo-systems are characterized by the absence of vegetation, soil organic matter and soil horizons. This results in increased surface runoff and favors erosion processes that dominate the initial phase of structure dynamics. The quantification and visualization of sediment relocation by erosive and depositional processes can be accomplished in a 3D structure model. However, studies in this regard have hardly been undertaken.

The objective of this study was the digital visualization and quantification of sediment mass balances based on the initial 3D structure and exemplified for the small hydrological catchment “Huehnerwasser” near Cottbus, Germany. Photogrammetric surveys of surface and internal structural units (clay basis liner) during the construction phase provided data for digital elevation models (DEM). Interpolated physical and chemical soil properties obtained at a borehole grid (e.g., texture) are used for the visualization of spatial distribution of parameters. The data are merged in a database and visualized in a 3D-GIS application (GoCAD).

The initial internal structure is characterized by the technological construction processes. The resulting differences in bulk density and texture are supposed to have considerable impact on hydraulic properties. Hence, a structure generator program was used to reproduce the initial structure of the sediment layer. The results of digital structure generation are checked with non-invasive geophysical measurements, on-site boreholes data and off-site 2D vertical spoil exploration.

The structure model serves as the base for deriving the 3D-distributions of hydraulic properties for the modelling of surface runoff, erosion and soil water and solute movement. It allows quantification of volumetric mass changes in time and a first approximation of the erosion-affected surface structural dynamic of the developing soil-geosystem. The structure model is strongly interlocked with an intense monitoring program that provides the necessary input data. Long-term observations and their integrative synopsis in the structure model will help to describe the initial development phases of soil-geosystems.

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Pan-European Programme for Intensive Monitoring of Forest Ecosystems, also called Level II European grid, provides updated information about forest condition and possible influence of factors as climate, biotic agents or air pollution at global scale. It also constitute a consistent database that support European policies in climate change, forest biodiversity and sustainable management of forest, giving information at general, regional and local level.

Research activity in the level II plots comprises: visual assessment of crown condition, soil and soil solution analysis, foliar nutrient contents, forest growth and increment, atmospheric deposition, including passive sampling of air pollutants, meteorological monitoring and phenology, inventory of ground vegetation, visual Ozone injury assessment, and others studies related to biodiversity, vitality and climate change.

Main goals of the deposition measurements are to obtain an accurate knowledge about the deposition process in forest ecosystems and to give information for the mapping of critical loads. Samples obtained in throughfall and stemflow collectors supplies long series of data about pH, conductivity, base cations, several anions, alkalinity and N total. Also Al, Mn, Fe and heavy metals are analyzed. There are available data from 1997, in 15 days periods as average.

Results show the variation in the atmospheric deposition data assessed in 13 Spanish plots, ranging from wet temperate northwest forest on acid subtract (Galicia) to arid Mediterranean pure calcareous ecosystems (Alicante), from the beginning of the sampling to now. Analysis of the results links the short-term meteorological data variations, mainly rainfall and temperature, with vegetation cover, taking account quality and quantity of atmospheric deposition in several elements, studying in addition variation in time and possible trends in a possible climate change scenario.
100 000 lakes in Sweden: monitoring data and the MAGIC library of 1200 modeled lakes used to assess past and future lake chemistry.

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There are about 100 000 lakes in Sweden (lake area > 1ha). During the 1980’s it became obvious that many of the lakes are being negatively impacted by air pollution. An ambitious lake monitoring program was put in place to assess lake water chemical changes. Since 1990 the chemistry of thousands of lakes has been monitored throughout the country (info1.ma.slu.se). The monitoring was designed to provide data representative for the country’s whole lake population. The sampling program includes lakes sampled repeatedly and lakes sampled only during a certain year. About 50% of Sweden’s area is covered by forests. Another monitoring program collects data on forests and forest soils throughout the country (www-markinfo.slu.se). These two programs provided data for 1200 lakes across Sweden for which past, present and future lake chemistry was modeled with the geochemical model MAGIC. Only lakes with time series of observed chemistry were modeled.

The model results were then built in to a database and assessment tool called the MAGIC library (www.ivl.se/magicbibliotek). The MAGIC library is based on the premise that similar lakes are likely to be similarly affected by air pollution. Similarity among lakes is determined by lake chemistry, land use, catchment soils and geology, lake size and geographical location, deposition history, and sensitivity to air pollution. To assess any lake with a known lake chemistry, annual runoff, and location (the assessment lake), the MAGIC library selects a similar lake from the catalogue of lakes (the library lake). The model prediction on the library lake is then assumed valid also for the assessment lake. By this procedure estimates of historical and future lake chemistry are provided for the assessment lake without modeling it directly. The extent to which a lake has been affected by air pollution is based on comparison of the estimated historical lake chemistry with observed present day chemistry. The anticipated future response of the assessment lake can similarly be estimated from the MAGIC simulation on the library lake. Present and future chemistry of the population of all lakes in Sweden was then assessed by using the MAGIC library containing the 1200 calibrated lakes.

Percentage of acidified lakes in Sweden (pH decreased by ≥0.4 units since pre-industrial time) estimated by extrapolating 1200 modeled lakes to ca 100 000 Swedish lakes using the MAGIC library. Limed lakes excluded.
Application of the INCA-N model to a steep forested alpine catchment in Austria

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The Integrated Nitrogen in Catchment Model INCA-N is a process-based model of the nitrogen cycle, and simulates the nitrogen export from different land-use types within a river system and the in-stream concentrations of nitrate and ammonium at daily time steps (Wade et al. 2002). INCA-N model has been successfully applied to various catchments across Europe, and - for the first time - it is here used to simulate the N-export from a steep forested alpine catchment in the Austrian Alps (Piburger See). The catchment has an area of about 1.5 km² and covers an elevation range of 900 to 2400 m a.s.l. More than 80% of the catchment area is covered by coniferous forest. In 2003, the lake tributary has been gauged, and average daily runoff during the calibration period was 8 L/s with minimum and maximum values of 2 and 65 L/s. Both intervals of high discharge, which are generally due to major snow melt or heavy precipitation events in summer, and low discharge periods during winter were simulated reasonably (Fig. 1). The big elevation range of the watershed represents a great challenge to the INCA-N model. In particular, the driving variable HER (hydrological effective rainfall) has to reflect the elevation dependent storage of precipitation in the snow cover during winter months as well as the increased water supply during major snowmelt. The assessment of HER was performed with the GWLF model (Generalized Watershed Loading Functions Model) (Schneiderman et al. 2002), which gives daily values of so-called rainmelt, i.e. the sum of rain- and snowmelt, for different elevation bands within the watershed area. Here, we apply INCA-N to simulate in-stream concentrations of nitrate back to the 1960s and we estimate nitrate fluxes under a projected future climate.

References


Can trends and short term changes in water quality and phytoplankton of large lakes be explained by land use, point source load and climate?

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The monitoring of lake water quality was started in the 1960s in Finland. We examined the development of water quality and phytoplankton of 10 large (>40 km$^2$) lakes in eastern Finland during 1975-2007. Four lake types, categorized according to their surface area, natural state water colour, and mean depth were distinguished. Two of the lakes are separate headwaters, and some form a sequence in the same watercourse. The samples were taken both during the open water and winter seasons. Data on water quality (TN, NO$_3$-N, TP, PO$_4$-P, colour, conductivity, pH, alkalinity, COD$_{Mn}$, chlorophyll-\textit{a}) and phytoplankton communities were analysed. In order to explain the trends or short-term excursions in water quality, we collected information on changes in atmospheric deposition, climate and land use. Land use developments in agriculture and peatland drainage within the immediate catchment of the lakes were estimated with help of statistics, map databases, and National Forest Inventory reports. Furthermore, records of loading from pulp mill industry, mines and municipal areas were screened.

The ca. 30 yr time series showed varying signals depending on the lake. Water quality parameters seemed to carry information of changes related to the activities in the catchment and the lake’s position in the watercourse below the loadings of rivers and point sources. An overarching trend in the large humic lakes was a decrease in TN and TP in the epilimnion both in winter and in summer, accompanied in some cases by increased Secchi depth. The improvement of water quality, more clear in 1990’s, could be a result of stopping the forest drainage and diminishing organic load from past forest drainages, but also of the decrease in atmospheric N deposition and lowered P loads from wood processing industry and municipal waste waters. Alkalinity and COD$_{Mn}$ may indicate a recent change in water quality perhaps related to warmer winters with increased leaching. As an example of a point source impact, effluents from copper mine in the recipient could explain a clear shift in water quality in Lake Juojärvi between 1970-1985, and a fading effect after the cessation. The phytoplankton showed large variability in seasonality and the assemblages differed according to lake’s TP concentration and colour. The low biomasses indicated oligotrophy with some exceptions.

The aim of our study is to resolve to what extent the changes in atmospheric deposition, climate, forest drainage, agriculture or point source loading may explain the trends and wiggles in the monitored time series of large lake chemistry and phytoplankton communities. Structural Equation Modelling (SEM) will be used to formulate and test several hypotheses on possible dependencies between water quality data, dynamics of external factors and lake characteristics for the different lake systems.
Changes in oxygen concentration in two small pristine boreal lakes, North Karelia, Finland

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Two small pristine lakes, L. Iso Hietajärvi and L. Pieni Hietajärvi, have been monitored for 21 years (1988–2008) in order to follow the long term variation of limnological parameters. The lakes are situated in the boreal forest zone in the same catchment area in Patvinsuo national park, North Karelia, Eastern Finland, and their immediate catchments belong to the Integrated Monitoring network (Kleemola and Forsius 2008). L. Pieni Hietajärvi is classified as humic-rich, while L. Iso Hietajärvi is a clear-water lake according to the Finnish lake typology. Ice-cover period lasts about 175 days. We discuss the variation of winter-time water quality of the lakes (temperature, oxygen O₂, total phosphorus TP, total nitrogen TN, chemical oxygen demand COD_Mn, and colour) during the monitoring period. We also describe oxygen conditions in summer and some other water quality features with chlorophyll-a data of the lakes. The aim of this work is to identify the effects of varying precipitation and leaching conditions to the rate of oxygen consumption in small lakes.

Table 1. Hydrological features and some water quality characteristic of the study lakes.

<table>
<thead>
<tr>
<th>Lake</th>
<th>Water area, ha</th>
<th>Mean depth, m</th>
<th>Maximum depth, m</th>
<th>TP* µg l⁻¹</th>
<th>TN* µg l⁻¹</th>
<th>Colour* Pt mg l⁻¹</th>
<th>pH*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pieni Hietajärvi</td>
<td>2.4</td>
<td>3.5</td>
<td>7.0</td>
<td>12</td>
<td>270</td>
<td>120</td>
<td>5.85</td>
</tr>
<tr>
<td>Iso Hietajärvi</td>
<td>82</td>
<td>8.8</td>
<td>6</td>
<td>190</td>
<td>25</td>
<td>6</td>
<td>6.68</td>
</tr>
</tbody>
</table>


Fig. 1. Vertical oxygen concentration (O₂ mg l⁻¹) profiles in Lakes Iso and Pieni Hietajärvi in early and late winter: Mean with minimum and maximum values in January and in April during 1988-2008.

References
Influence of dissolved organic matter on stream water chemistry in two forested catchments in central Sweden

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The paucity of knowledge about headwaters has recently been discussed by Bishop et al. (2008) and Temnerud & Bishop (2005) have shown that the variability in stream water chemistry for catchments <15 km² may be in the same order of magnitude as the variability in boreal forest streams in all of northern Sweden.

The current study was conducted on two first-order streams in adjacent forested catchments during two growing seasons. The catchments were similar in shape, size and drainage density - all physical characteristics that influences storm runoff. Due to their location, they were also exposed to similar weather conditions and precipitation.

Previous studies (Vestin et al. 2008) conducted in the Fan catchment indicated a high association of cations with high molecular mass (HMM) DOC in soil. To further investigate these findings, the quantity and quality of DOC, its seasonal fluctuations and its influence on cation levels in the stream water of both catchments were studied. Furthermore, the study aimed to apply a recently developed method to analyse the presence of low molecular mass organic acids (LMMOAs) in stream water, an area that essentially lacks previous investigation.

The streams showed significant differences in the content and size distribution of DOC and in the distribution of cations between the different size fractions. The Fan stream, with high DOC concentration and low pH, had a greater amount of HMM DOC to which approximately 50% of the total Ca and Mg and 75% of Al and Fe was associated (Fig. 1a). The Ref stream, with lower DOC levels and a higher pH, had approximately 30% of Ca and Mg and 50% of Al and Fe associated to its HMM DOC fraction. As a consequence of the differences in DOC composition, the two streams also showed significant differences (p<0.05) in carboxylic content. Thirteen different LMMOAs were continuously recovered in the stream water, of which oxalic (Fig. 1b) and lactic acid were the most abundant.

Fig. 1a. Seasonal variation of cations (µeq/l) recovered in the HMM fraction of DOC (cumulative), and the total amount of COOH (µeq/l) (top line) in the Fan stream. b. Oxalic acid (µM) and DOC (mM) in the Fan stream 2003.

References
Deposition fluxes, soil and soil solution chemistry in a primeval mountain deciduous forest, Transcarpathia, Ukraine

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In the 1930s, soil chemistry and vegetation was studied in a primeval forest (mixed Fagus sylvatica and Acer pseudoplatanus) at the Javornik site in western Transcarpathia (Zlatnik, 1938). Since 2007, deposition, throughfall fluxes, soil solution chemistry and soil chemistry have been measured at this same site to assess long-term acidification in the area, which is expected to have been historically exposed to low acidic deposition.

Bulk deposition of inorganic nitrogen (N) and sulfur (S) was 13.3 and 8.6 kg ha\(^{-1}\) yr\(^{-1}\), respectively, which was more than in the formerly highly polluted western Czech Republic (Načetín) where N deposition was 10.9 kg ha\(^{-1}\) yr\(^{-1}\) and S deposition 5.7 kg ha\(^{-1}\) yr\(^{-1}\) in 2007. Precipitation pH was similar in Javornik and Načetín (4.77 vs. 4.71). Throughfall pH was 5.11 and N and S fluxes were 21.6 and 13.5 kg ha\(^{-1}\) yr\(^{-1}\), respectively, in Javornik. At the beech forest at Načetín, the throughfall pH was 5.13 and N and S fluxes were 17.2 and 8.2 kg ha\(^{-1}\) yr\(^{-1}\), respectively. Markedly higher bulk deposition of calcium (Ca) was measured at the Javornik site (5.9 kg ha\(^{-1}\) yr\(^{-1}\)) compared to the Načetín site (2.4 kg ha\(^{-1}\) yr\(^{-1}\)).

A high concentration of Ca and high pH in soil solution (Fig. 1) reflects the well-buffered bedrock (flysch). A surprisingly high concentration of nitrate (NO\(_3^-\)) was measured throughout the whole soil profile (Fig. 1). Soil exchangeable concentration of Ca and pH are also remarkably high (Fig. 2). Soil base saturation was 90% in the organic horizon and 28% in the mineral soil. The exchangeable soil pool of Ca, Mg and K was 1945, 200 and 272 kg ha\(^{-1}\), respectively.

References
Tree age related changes in needle morphology and photosynthesis: Norway spruce chronosequence

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Needle morphological and physiological characteristics were measured in Norway spruce forest chronosequence at Järvselja (eastern Estonia) in August, 2008. Study site is situated on a gleyed pseudopodsol soil formed on a loamy till and is characterized with large water storage capacity. We selected five different tree age-classes (10, 15, 21, 29 and 85 years old) and collected current year shoots growing in high light conditions of the upper canopy: average indirect site factor (ISF, characterizes diffuse light penetration) was 0.88. ISF was estimated by in situ hemispherical photography measurements. The shoots were then cut and photosynthetic (with Ciras-2 portable gas exchange system equipped with automatic conifer leaf cuvette) and morphological measurements were carried out. Trees were also measured for height and diameter at breast height.

ISF was not significantly influenced by tree age (P=0.092), indicating that the studied shoots were grown at similar light availability. Leaf mass per projected needle area (LMA) increased significantly with increasing tree age and height. This increase in LMA continued during the whole studied tree age span. Needle area-based photosynthetic capacity (maximum carboxylation rate ($V_{c_{\text{max}}}$) and maximum electron transport rate ($J_{\text{max}}$)) was not significantly influenced by tree age. However, tree age had a significant effect on the mass-based photosynthetic capacity. 10-y-old trees showed the highest values of mass-based $V_{c_{\text{max}}}$ and $J_{\text{max}}$, then a remarkable decrease (about 1.8 times) was evident in 15- and 21-y-old stands, followed by a further increase (1.4 times) in 29- and 85-y-old stands. Thus, the lowest mass-based photosynthetic capacity was detected in these stands that had recently become reproductive and produced cones.
Sensitivity and uncertainty analysis for the INCA-N application to two small Finnish catchments

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The semi-distributed, dynamic INCA-N (Integrated Nutrients from Catchments – Nitrogen) model (Wade et al., 2002; Whitehead et al., 1998) was applied to two research catchments in Finland, within the EU Euro-limpacs project. The aim was to simulate nitrogen (N) loads under different climate change scenarios. The Mustajoki site (78 km²) is a typical forested upstream catchment located in highlands in southern Finland, while the Savijoki catchment (15 km²) represents intensively cultivated lowlands in south-western Finland.

As climate change scenarios may lead to extreme conditions outside the circumstances where the model was calibrated, both parameter sensitivity and model structure were analysed. Sensitivity analysis tells how model output changes in response to changes in the model parameters. Uncertainty analysis aims to quantify the accuracy of one or more outputs. In this study the generalized sensitivity analysis of Spear and Hornberger (1980) was used. The method was applied in two stages. First, a set of Monte Carlo simulations with different parameter combinations were divided into behavioural (10% of the runs) and non-behavioural runs based on the goodness-of-fit value between observations and simulations. Second, the non-parametric Kolmogorov-Smirnov test was used to evaluate difference in parameter values between behavioural (B) and non-behavioural runs.

In general, there were more influential parameters in the agricultural than in the forested catchment. In both model applications, most of the influential parameters were connected to temperature dependencies of N processes, some to N process rates and only few to moisture dependencies. Values of the sensitive parameters were based on long-term measurements, so they covered estimated future climate. In uncertainty analysis highest observed concentrations fell between the modelled minimum and maximum uncertainty bounds (Fig. 1). The lowest observed concentrations did not fall between those bounds indicating that some of the retention processes maybe missing in the current model structure. The lowest concentrations occurred mainly during low flow periods; so the effect on total load was small. Thus INCA-N can be used in climate change simulations as long as the interpretation of results is based on loads.

Fig. 1. Observed and simulated nitrate concentrations a) in the forested Mustajoki catchment and b) in the agricultural Savijoki catchment.

References
Application of catchment scale erosion and sediment delivery model INCA-SED to four small study catchments in Finland

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The term ‘sediment delivery’ has been widely used to describe the combined processes of sediment movement within a catchment, from soil erosion on slopes through to fluvial export at the catchment outlet. The INCA-SED (Integrated Nutrients from CAtchment- Sediment) model is based on semi-distributed approach which incorporates readily available environmental data of hydrometeorology, land use, erodibility and catchment and channel morphology at an appropriate level of spatial aggregation. In the INCA-SED model the main river channel is divided into series of reaches. The land area that drains into each of these reaches is then defined as a sub catchment. The basic modeling unit of land use specific soil erosion processes is then a land use class in the sub catchment.

The INCA-SED model is applied to four small study catchments in Finland. Three of the study sites are headwater catchments located in central Finland around the lake Pääjärvi. The rivers Mustajoki, Haarajoki and Luhdanjoki have different morphological characteristics varying from a ditch to a small river. Soil types in the area are relatively coarse, mainly moraine and silt loams. The Mustajoki (78 km²) and Haarajoki (58 km²) catchments are forested and only 10% of the area is under cultivation. In the Luhdanjoki catchment (25 km²) agricultural fields cover 40% of the area. The forth study site, the Savijoki catchment (15 km²) represents intensively cultivated areas in south-western Finland. Fields cover 40% of the catchment area, and they are located on clay soils along the river. The INCA-SED model is calibrated by using information of the Geographical Information System and water quality monitoring databases of Finnish Environment Institute. Hydrological input is derived from the results of the operational Watershed Forecasting and Simulation System.

The INCA-SED model is able to capture both the correct level and seasonal behaviour of suspended sediment concentrations in the rivers as well as the correct level of sediment load from different land use classes. Even small differences in river morphology and soil types between the catchments seem to have an influence on suspended sediment concentration in the rivers (Fig. 1). Correct timing of suspended sediment concentration peaks is not captured, which may be due to stochastic nature of erosion processes in a catchment scale. The highest simulated peaks occur usually in the beginning of runoff events and these peaks are usually missing from observation time series. This indicates that observation program (about 30 water samples per year) is probably not able to give a correct picture of sediment processes in the catchments.

![Fig. 1. Simulated and observed suspended sediment concentration vs. discharge in the rivers Haarajoki, Mustajoki and Luhdanjoki](image-url)
Precipitation amounts and the colour of water - A 25 yrs long study (1983–2008) of a drinking water supply in Norway

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A long term study of Lake Elvåga (59°N, 10°E, 196 m a.s.l.), a raw water source in Østmarka close to Oslo in south-eastern Norway, has revealed a significant increase in concentrations of coloured dissolved natural organic matter (DOM) throughout the past 25 years.

Along with the reduction of acid rain component concentrations, which was most pronounced in mid 1970s, the colour in Lake Elvåga has steadily increased. The amount of annual precipitation and the annual average sulphate and chloride concentrations in precipitation has for the period 1983 – 2005 been found to be the best predictors for the long term lake colour variation and development, by means of a best sub-set regression analysis among the available metrological and chemical parameters. However, at present the concentration of acid components is now very low and on pre World War II level. Due to the chemical composition of precipitation today, the annual precipitation amounts seem to the most important factor for the organic carbon concentration and the colour of Lake Elvåga.
How important is climate variability in determining the fate of N deposition in a remote Finnish forested catchment?

**Tuija Ruoho-Airola**, Tarja Hatakka, Antti-Jussi Lindroos, Riitta Niinioja, Mike Starr, Liisa Ukonmaanaho and Jussi Vuorenmaa

Acid deposition loads have strongly declined throughout Europe and North America over the last few decades, mainly as a result of a reduction in sulphur emissions. But while sulphate deposition has decreased, nitrogen (N) deposition loads have largely remained unaltered. Much of the N deposition in Finland is derived from overseas and transported long distances. Meteorological factors therefore play a strong role in determining deposition loads. The annual N deposition load was rather constant during the 1990’s (2–3 kg ha⁻¹), which is low compared to western and central Europe.

Because forest ecosystem productivity is usually limited by N, especially in boreal forests, relatively high loads of N are required in order for N deposition to break through into soil water and to appear in ground and surface waters. However, the fate of low but chronic loading of N deposition to boreal forest ecosystems under conditions of changing climate is unclear. We report on the variability in concentrations of N in various aqueous media (bulk deposition, throughfall, soil water, ground water, stream water and lake water) collected at the Hietajärvi Integrated Monitoring catchment over the last 20 years, and evaluate the results in relation to climatic factors. This time period has exhibited considerable interannual variation in climate, particularly in relation to summer rainfall and drought, and in snow cover duration.

Hietajärvi is an undisturbed forested headwater catchment (463 ha) located in the middle boreal coniferous region (63°09’N, 30°40’E). The terrestrial part of the catchment consists mainly of upland mature Scots pine forest and peatland. The climatic zone is continental subarctic. The mean annual temperature is 2 °C, the warmest month being July (mean 15.8 °C) and the coldest January (mean -12.0 °C). The effective sum of temperature during the growing season varied between 906 and 1328 d °C over the study period. The mean annual precipitation is 600 mm, the highest rainfall occurring during the summer and autumn months. The duration of the snow cover period during 1988–2007 varied between 92 and 195 days. Since there is a rapid release of N deposition from melting snow, we hypothesized that the length of the snow period would be an important factor in explaining the interannual differences in the flow of N through the ecosystem.
Predicting the effects of climate change on agriculture and consequent effects on water quality and quantity in the Kennet Catchment, UK

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There have been numerous studies on the potential effects of climate change on agriculture, and of agricultural change on water quality, and the effect of climate change on water quality is an active research topic. This paper reports a pioneering attempt to integrate all these aspects. The work started from a set of climate change scenarios and used a series of economic models of world and local agriculture to predict agricultural change in the catchment of the River Kennet in southern England. The changed land uses and climates were then used to drive water quantity and quality models to predict changes in discharge and nitrate concentrations in the river.

The A2 (“national enterprise”) and B2 (“local stewardship”) storylines from the IPCC Special Report on Emissions Scenarios (SRES) were used to estimate both climatic and socio-economic changes. Agricultural change was estimated using the University of Reading Climate and Land-Use Allocation Model (CLUAM). This is an established linear programming model of agriculture in England and Wales, which aims to calculate the economically optimum agricultural land use under given conditions. This in turn was fed by models of the world agricultural system driven by the SRES scenarios. Models were run with and without local climate change. The end product was a series of projections of agricultural land use in the Kennet catchment in the years 2020 and 2050 given a) coupled climate and socio-economic changes and b) socio-economic changes alone.

The pattern of predictions was complex. In all scenarios, cereals replaced most other arable crops in 2020 and 2050, but the overall arable area did not change much. In most scenarios, the area of temporary grasslands was significantly reduced, and permanent pasture was essentially eliminated. Fertiliser application was reduced in most scenarios, but more so in the A2 storylines than the B2. Socio-economic changes had the largest impacts, the effects of climate change being to modulate these.

The INCA-N Model was applied to these changes to explore the potential effects on N concentrations and flow in the River Kennet. The model was calibrated to give realistic concentrations under current conditions using observed data. Then it was run with appropriate changed land uses and climates, generated by downscaling predictions from the HADCM3 Model. Sixty annual “realisations” of each scenario were generated.

The results showed a reduction in river flows of 15–17% by 2050 due to increased evapotranspiration in the warmer predicted climates. The period during which the river was maintained solely by groundwater increased to over 6 months in 95% of modelled years by 2050. Predicted nitrate concentrations in the river decreased in both 2020 (15–19%) and 2050 (15–25%), depending on the scenario. These reductions were due partly to reductions in fertiliser inputs, and partly because the nitrogen sink processes in the catchment soils and waters were predicted to increase in rate more than the catchment nitrogen sources. These results will be discussed, as will the uncertainties in this chain of predictions, and the extent to which the models can be constrained to give a credible estimate of the effects of climate change on water quality. The results show, however, that potentially changes in the world agricultural system can affect water quality at the catchment scale, but it is hard to predict what that influence might be in individual cases.
Air pollution effects on aquatic ecosystems

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Many lakes and rivers are chemically and biologically very sensitive to changes in long-range transported air pollution and are thus highly suitable for monitoring effects of air pollution. This poster presents the major accomplishments from the International Cooperative Programme on Assessment and Monitoring Effects of Air Pollution on Rivers and Lakes (ICP Waters) under the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP). Long-term monitoring programmes are the basis for all activity in ICP Waters. The ICP Waters network is geographically extensive and includes long-term data series (10–25 years) for more than 200 sites. The sites include background sites in (semi-) natural ecosystems and are valuable also for detecting impacts of climate and global change.

Lakes and rivers show strong signs of recovery in response to reduced acid deposition in Europe and North America since the 1980s. The consistent pattern of chemical recovery across a large number of sites is the strongest evidence that emission control programmes are effective. In many areas, water quality is now sufficient for the return of acid-sensitive aquatic biota. Some areas, however, show a distinct lack of chemical recovery.

Biological monitoring in ICP Waters focuses on acid-sensitive invertebrate species. Improved chemical water quality has resulted in recovery of aquatic biota in the Nordic countries, Canada, the UK and the Czech Republic. Biological recovery is not as evident in other acidified regions in Europe. This may be related to insufficient chemical recovery but also to lacking long-term data biological records.

Chemical recovery of many ICP Waters sites will not be sufficient to sustain biological recovery by 2010. This is predicted by dynamic acidification models that calculate water chemistry assuming that S emissions are reduced according to the Gothenburg Protocol.

Nitrate in surface waters shows upward, downward and neutral trends, unlike the almost universal decreasing trends in sulphate. In some regions, declines in N deposition coincide with downward trends in surface water nitrate. Elsewhere, trends in nitrate in surface waters are thought to be related to climate, forest growth and N saturation, or are simply not understood. Acid-sensitive ecosystems continually enriched with nitrogen which increases the probability of future acidification and eutrophication due to nitrate leaching.

Surface waters in North America and Europe have become browner in the last decades due to increased concentrations of dissolved organic carbon (DOC). ICP Waters data document that upward DOC trends are related to declining deposition of sulphate.

Climate change may significantly influence the behaviour of both terrestrial and aquatic ecosystems significantly. Long-term data series show sea-salt episodes setting back biological recovery several years. Droughts lead to acidic episodes upon rewetting. The extent of N-retention in a warmer climate, and consequently the future influence of N on surface water acidification, represents a key uncertainty in recovery from acidification.
Snowmelt infiltration through partially frozen soil in Finnish Lapland

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Snowmelt timing is critical for tree growth in high latitudes. However, the threshold conditions with respect to root-zone soil water availability in spring are not well understood. We measured snowpack thickness, apparent snow water (ASW), air and soil temperature, as well as soil water content (SWC) in Moskuvaara (67°37’34''N, 27°10’30''E) and Järvijoki (68°02’17''N, 26°05’49''E) sites in spring 2008. The sites host mature Norway spruce stands underlain by Haplic Podzol developed on silty and sandy tills. Soil temperature probes (T107) and soil water content reflectometers (CS616) were placed at 20-cm-increments into the soil sequence. Snow depth was measured with (SR50A) sonic range sensors (Campbell; see photo below) and ASW with dielectric leaf wetness sensors (Decagon). All parameters were automatically logged with Campbell CR1000 data-logger in 3-h-intervals. The maximum snowpack thickness varied from 84 cm (on 30th of March) in Moskuvaara to 90 cm (on 14th of April) in Järvijoki. Due to air temperature rise notably above zero 0˚C on mid-April, the onset of snowmelt occurred on 29th of April 2008 at both sites. The observed maximum ASW was simultaneous with the maximum SWC on the 2nd of May (see graph below). At 60 cm depth soil remained unfrozen through winter. In contrast, soil temperature at 20-cm-depth was below zero 0˚C until 18th of May in Moskuvaara and 28th of May in Järvijoki. These dates were rather concurrent with snow disappearance; 15th of May in Moskuvaara and 25th of May in Järvijoki. Snowmelt water percolated through the soil such that SWC (at 20-cm-depth) had its maximum 16 days (Moskuvaara site) and 26 days (Järvijoki site) before the soil temperature exceeded 0˚C. We contend that snowmelt infiltration through partially frozen soil significantly contributes to ground water reserves and soil water availability, rather than soil temperature, is pivotal for the start of height increment of trees in northern boreal conditions.

Fig. 1. Changes in climatic variables and soil properties at Järvijoki spruce site during the late spring 2008. A. Snow temperature on ground surface (SWT1) and 30 cm above ground surface (SWT2), air temperature (Tair) as well as thickness of snowpack (snow). B. Apparent snow water on ground surface (LW1) and 30 cm above ground surface (LW2) as well as soil water content at 20-cm-depth (volW20cm) and 40-cm-depth (volW40cm).

References
Modelling of denitrification flux over a whole drainage network

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Denitrification is an important process of nitrogen cycling in river ecosystems as it can regulate nitrogen availability, and therefore primary production, controlling the degree of eutrophication. The strength of denitrification within a river network can alternate very rapidly in space and time and is essentially driven by the interactions between surface water, river geomorphology and microbial process rates. Thus, in order to better predict and quantify the importance of benthic denitrification in the removal of nitrogen from an entire drainage network, a deterministic sediment model (Thouvenot, M., Billen, G., Garnier, J., 2007. Modelling nutrient exchange at the sediment-water interface of river systems. Journal of Hydrology 341/1-2, p.55-78) was linked to a hydrological/biogeochemical model (Riverstrahler). The benthic model includes the calculation of nutrient exchanges across the sediment-water interface as a result of the sedimentation flux of organic material provided by Riverstrahler.

The application of the coupled model over the entire drainage network of the Seine river system, in France, indicated that the model simulated the observed increase of organic matter content in the sediment with stream order and its subsequent increase of oxygen and nutrients fluxes at the sediment water interface. Moreover, in the upper Seine, the model was able to reproduce the impact of point source pollution in terms of ammonium and nitrate concentrations in the river and fluxes across the sediment-water interface at a kilometric step (Fig. 1). The coupling of pelagic and benthic processes allows us to determine low and high denitrification spots/times along the river network during the year and to model benthic denitrification accordingly, in order to quantitatively predict its importance in the removal of nitrogen at the scale of the whole river system. The comparison of nitrogen budgets from two different hydrological years (wet and dry) shows the impact of the hydrology on the denitrification budget in terms of proportion and quantities. It also shows that although riparian denitrification is more important than benthic denitrification, the latter cannot be neglected during dry years as it contributes to up to 10% of the losses from river inputs (Fig. 2).
Modelling acidification recovery at long-term monitoring sites: a multi-model evaluation

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Multiple model frameworks have been widely used in air quality (Dentener et al., 2006) and climate (Randall et al., 2007) assessments. Ensemble simulations from multiple models provide an assessment of all possible future states based on current knowledge. In the current study, future soil and surface water chemistry at four long-term monitoring stations (Hubbard Brook, USA; Plastic Lake, Canada; Höglwald, Germany; Birkenes, Norway) were simulated using four process-oriented dynamic acidification models (MAGIC, PnET-BGC, SAFE, VSD). The chosen study sites are rich in data required for model calibration. They also represent different ecosystem types currently under acidification threats despite declining acid deposition.

The multi-model evaluation employed in the current study consists of three steps. First, uncertainty associated with observed model input data was addressed through Monte Carlo simulation wherein data were sampled from distributions based on site observations, and in turn translated into model-specific input formats. This ensured consistent inputs to each of the models. Comparison of the Monte Carlo runs among models provides insights into how structural differences may affect simulations (Tominaga et al., submitted). Second, the models were calibrated against the 20+ years of observations at each study site by filtering the Monte Carlo runs (i.e., criteria were set to assess if a particular model run agreed with observations). The calibrated parameter spaces were compared among the models in order to elucidate the relationship between the model input parameters and the models themselves. Third, soil and surface water chemistry through to 2100 were assessed under a legislated future emissions scenario for North America and Europe using the four calibrated models to assess the impact of current legislated emissions.

References
20 years of integrated monitoring at Kosetice Observatory

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Long-term monitoring and research activities in small forest tributary of Anenský brook in the western part of Czech-Moravian Highland have been implementing as a part of integrated monitoring at Kosetice observatory of the Czech Hydrometeorological Institute. The Observatory was established as a station specialised in the problems of regional environmental quality monitoring and research in 1988 and is situated at 49°35´ N latitude and 15°05´E longitude. Elevation above sea level is 534 m. The observatory is involved in following long-term programmes and projects of monitoring and assessment of natural environment at the background scale: ICP-IM (International Co-operative Programme on Integrated Monitoring), EMEP/ECE (Co-operative Programme for Monitoring and Evaluation of Long-range Transmission of Air Pollutants in Europe), GAW/WMO (Global Atmosphere Watch), ACCENT (Atmospheric Composition Change–The European Network of Excellence) and EUSAAR (European Supersites for Atmospheric Aerosol Research). Monitoring programme of Kosetice observatory includes meteorology, solar radiation, air chemistry, precipitation chemistry, hydrology and surface water chemistry, soil and soil water chemistry and POPs monitoring in all compartments of the environment. More detailed information is available at www.chmi.cz/uoco/struct/odd/ook/indexe or in (Vana, Holoubek 2007).

The results of long-term monitoring in the period 1989–2008 show that:

- The reduction of sulphur emissions in the Czech Republic has resulted in decreasing of background sulphur deposition. The greatest difference is observed in throughfall. A distinct reduction of sulphates occurs in the basin. Sulphur input was decreasing continuously from 20–30 kg.ha⁻¹.year⁻¹ in the first half of the nineties to 5–10 kg.ha⁻¹.year⁻¹ after 2000. Reduction of sulphur input by almost constant output caused basic changes in sulphur balance in the catchment. In the beginning of 1990s retention predominated very rapidly, but since 2000 leaching was found.

- There is not considerable trend observed in nitrogen deposition. The nitrogen budget provides evidence of large consumption by vegetation. Nitrogen runoff displays a characteristic annual course, with its maximum in the spring when the vegetation is still unable to consume this element and water runoff is high, the minimum occur in the summer and autumn.

- The output of basic cations exceeds their input. The sources of these cations currently include ion exchange process in the soils, with the primary weathering of minerals accounting probably for their smaller part. Their output increases in last years while acidity of precipitation is decreasing.

- The level of pH in precipitation water increased continuously during the period under review. The most significant increase was registering in throughfall (from 3,8 in 1990 to 4,7 currently), the figure in free area is from 4,4 in 1990 to 5,0 at present. The highest pH is read in cases when air masses have their origin in the west (4,7) and the lowest values are measured when they come from the north (4,3).

- The annual mean surface ozone concentration stabilised in the nineties at a relatively high level (60 to 70 µg.m⁻³) and has not increased further. Situations with rapid increase of ozone concentration, which then has a negative effect on human health, usually occur in longer periods of hot summer weather (extreme temperatures, high intensity of solar radiation). During such episodes extensive regions on a scale which goes beyond the borders of the Czech Republic are progressively affected.

References
Monitoring of ecosystem patterns and processes in an artificial catchment in Lusatia, Germany

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Long-term formation of structures and processes during the initial phase of ecosystem development is investigated in an artificial catchment ‘Chicken Creek’/‘Hühnerwasser’ in the lignite-mining area of Lusatia, Germany. The catchment has an area of 6 ha and including a small lake.

A comprehensive monitoring program is carried out in the catchment including: meteorology, atmospheric bulk deposition, dust deposition, grid soil sampling, soil solution chemistry (ions, DOC, TOC, grain size, etc.), soil water (TDR, tensiometers), hydrology (stream flow, groundwater, water quality, etc.), erosion, vegetation development (species, cover), soil fauna (species, abundance), and limnology (water quality). A mini-drone system is used for monitoring the vegetation pattern and surface structures. The gathered data are the basis for the calculation of water and element fluxes in the ecosystem and their interactions with the formation of observed structures. The data will be integrated in a structure-processes-model and hydrological models for further analysis. First results will be presented and discussed.
Dynamic modelling of the potential impacts of climate change on water quality and ecology in six UK rivers

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A modelling study has been undertaken to assess the likely impacts of climate change on Water Quality across the UK. A range of climate change scenarios have been used to generate future precipitation, evaporation and temperature time series at a range of catchments across the UK. These time series have then been used to drive the Integrated Catchment (INCA) suite of flow, water quality and ecological models to simulate flow, nitrate, ammonia, total and soluble reactive phosphorus, sediments, macrophytes and epiphytes in the Rivers Tamar, Lugg, Tame, Kennet, Tweed and Lambourn. A wide range of responses have been obtained with impacts varying depending on river character, catchment location, flow regime, type of scenario and the time into the future. Essentially upland reaches of river will respond differently to lowland reaches of river and the responses will vary depending on the water quality parameter of interest.
Multiple approaches for modelling topographically planar peatland dominated catchments: response to acidic deposition

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Acid-sensitive catchments in the Athabasca Oil Sands Region of northern Alberta, Canada are presently under a perceived threat due to elevated levels of acid deposition. Increased S and N deposition originate from localized industrial emissions associated with the extraction and processing of bitumen from the world’s second largest recoverable oil deposit. Industrialization of the region is a relatively recent (40 years) phenomenon, but rapid proliferation has occurred during the last decade and further expansion is anticipated for the first half of this century. Consequently, emissions of S and N in the region are expected to remain elevated indefinitely. Dynamic models are required to predict the future response of soil and surface water chemistry to acidic deposition to identify if and when critical chemical limits will be reached (i.e., the time-to-effects). The dynamic hydrogeochemical Model of Acidification of Groundwater in Catchments (MAGIC: Cosby et al. 1985) is being used in this assessment, and model output will be used in conjunction with monitoring data to guide emissions management policy.

This presentation will provide an overview of the methods used to apply MAGIC in the study region. Model application is a challenge in this complex environment and a novel approach is required owing to ill-defined hydrology, catchment heterogeneity, and extensive coverage of poorly understood fen complexes. Three approaches are used: a plot-scale application to forest soils, an interactive application to intensively studied catchments, and an automated application to regional lake catchments. The plot-scale application requires calibration to mineral soil chemistry (i.e. base saturation). The interactive application consists of a calibration to lake water chemistry at two well studied peatland dominated catchments receiving different levels of S deposition. Model parameterization at these catchments incorporates site-specific data from detailed physicochemical measurements of soils and surface waters. The techniques used for model calibration (e.g. flow routing, attribution of elemental sources and sinks) will be illustrated with reference to current understanding of the hydrologic behaviour of the two intensive catchments. The information gained from the interactive calibration is being extended to the regional application covering a large group of lake catchments (n = 48). It is anticipated that this exercise will enable assessment of the suitability of the approaches used in the site-specific calibration across a more diverse population. The regional application comprises lake catchments covering a range of data availability: those where mineral soil, fen and seasonal lake sampling took place to those where only annual lake chemistry was measured. This suite of approaches to MAGIC application enables prediction of time-to-effects under future emissions scenarios for the region.

References
The Flux of Nitrate from Great Britain 1974–2005 in the context of the terrestrial nitrogen budget of Great Britain

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This study compiles long term records of the concentration of nitrogen species from British rivers in order to assess the temporal change in the total fluvial flux of nitrogen in comparison to the other inputs to and outputs from the UK terrestrial biosphere. The study considers the following nitrogen species: ammonia, nitrate, nitrite, dissolved organic nitrogen and particulate organic nitrogen. Concentration and flow records could be reconstructed from 1974 to 2005 for ammonia, nitrate, nitrate and dissolved organic nitrogen (DON) and from 1992 for particulate organic nitrogen (PON). The reconstructed fluvial nitrogen time series was compared to records for inorganic fertiliser, atmospheric. The results of the study show that:

- The total dissolved nitrogen flux over the study period when flow corrected varied from 470 to 980 ktonnes N, the average composition of that flux is: 69% nitrate-N; 26% dissolved organic-N; 4% ammonia-N; and 1% nitrite-N.
- The total nitrogen flux including PON varied from 504–1004 Ktonnes N yr\(^{-1}\).
- The flux of ammonia-N shows a significant decline over the study period, but significant increases in both nitrate-N and dissolved organic-N mean that the total dissolved nitrogen flux shows a significant increase of 6.3 ktonnes N yr\(^{-1}\).
- The dissolved nitrogen flux record shows both a steady increase and sharp discrete rises in response to severe droughts. The rise in response to severe droughts is not consistent with a storage effect of reduced flows but appears to represent new production in the year of the drought.

The long term rise of fluvial nitrogen flux from British rivers is in contrast to declines in inputs and other outputs, that although Great Britain is an overall sink of total nitrogen the size of this sink is diminishing. The nitrogen budget for the UK is then compared to historic land-use change within the UK since the 1930’s and an export coefficient model is used to assess to what extent the present budget is still reponding to historic releases of nitrogen and therefore, what might be expected into the future.