



Abstract Volume

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18. Greenhouse Gases: Linkages between biosphere and climate

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18. Greenhouse Gases: Linkages between Biosphere and Climate

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*ACP – Commission on Atmospheric Chemistry and Physics,
ProClim – Forum for Climate and Global Change,
IGBP- Swiss Committee*

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18.1

A decade of continuous greenhouse gas exchange measurements at the Oensingen grassland site

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Managed grassland ecosystems form a significant part of the European and global land cover. However, long-term greenhouse gas flux monitoring on grassland sites is still rare in comparison to forest sites. Beside climatic factors, also the management regime (and history) have an influence on the trace gas exchange of agricultural ecosystems. We have monitored the greenhouse gas exchange together with the carbon, nitrogen, and water cycle of a sown grassland site on the Swiss Central Plateau since 2002. The experimental field had been divided in two plots, one undergoing intensive management (high nitrogen input), the other extensive management (no fertilization). Continuous eddy covariance measurements of the CO₂ exchange and the quantification of carbon export and import by harvest and manure application allowed for the assessment of the complete carbon budget of both plots (Ammann et al., 2007) which was compared to the temporal change of soil carbon investigated by repeated soil inventory (Leifeld et al., 2011).

Over the entire observation period, the intensive management led to a carbon sequestration, while the extensive management caused a net carbon loss. A positive correlation between C and N sequestration was observed for the two fields corresponding approximately to the soil C/N ratio (Ammann et al., 2009). Although the different management led to a systematic difference between the two fields, it had only little influence on the inter-annual variation of the carbon budget. The latter shows a positive correlation with the net ecosystem productivity and the harvest yield. They mainly depend on the spring temperature and the length of the growing season as well as on the soil moisture content during summer.

The carbon sequestration of the intensive field was counterbalanced to a minor part by an increased N₂O emission mainly related to fertiliser applications (Flechard et al., 2005; Neftel et al., 2007). Therefore and due to the very small methane fluxes, the total greenhouse gas budget of the grassland fields was clearly dominated by the carbon exchange.

The Oensingen data set has also been used in various synthesis studies together with other FLUXNET sites to investigate the effect of environmental drivers and climate variations on the ecosystem and their greenhouse gas exchange on the European and global scale (e.g. Flechard et al., 2007; Soussana et al., 2007; Teuling et al., 2010; Mahecha et al., 2010).

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18.2

Long-term monitoring of CO₂ and H₂O dynamics using Eddy Covariance technique in peatlands of lake Yeniçağa (Bolu-Turkey)

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Peatlands are wetland ecosystems where the rate of production of organic matter exceeds its rate of decomposition (Bubier et al., 1995). The global area of the peatlands is limited (ca. 5-8 %); however, they play a significant role in global carbon (C) cycle. As an important example; Northern peatlands cover only 3 % of the earth's land area, however they store 30 % of the world's soil C as peat (Gorham, 1991). Due to the enormous amounts of C available in the peat great attention has been paid to the quantification of whether peatlands will continue to sequester carbon or will be C sources to the atmosphere.

Eddy covariance is a method that permits direct measurements CO₂ and H₂O fluxes between the surface and the atmosphere. This technique has some advantages that make it popular. Being direct measurement technique, and having a chance to do measurement around the small scale (hundred meters) to large scale (several kilometers) area are the most important reasons for being the popular technique (Baldoch, 2003).

Despite there have been many studies around the world peatlands area especially in the subarctic area, there is no study about peatlands in Turkey. In fact the peatlands that are determined around Turkey is a unclear topic, the objective of the project was to determine the H₂O and CO₂ fluxes over two years (2011 and 2013) using an eddy covariance (EC) system in a Yeniçağa peatland, Turkey. The Yenicaga peatland is located about 38 km east of the city of Bolu (40°47'N, 32°1'E) in the western Black Sea region of Turkey (Figure 1).

The central to this objective is investigation of seasonal, annual and interannual variation in peatland ecosystem CO₂ and H₂O fluxes and to determine the behavior of the Yeniçağa peatland whether it is sink or source. In addition, with ancillary measurements, the structure of the vegetation and peat soil is aimed to determine for observing valuable information about the characteristic of the system.

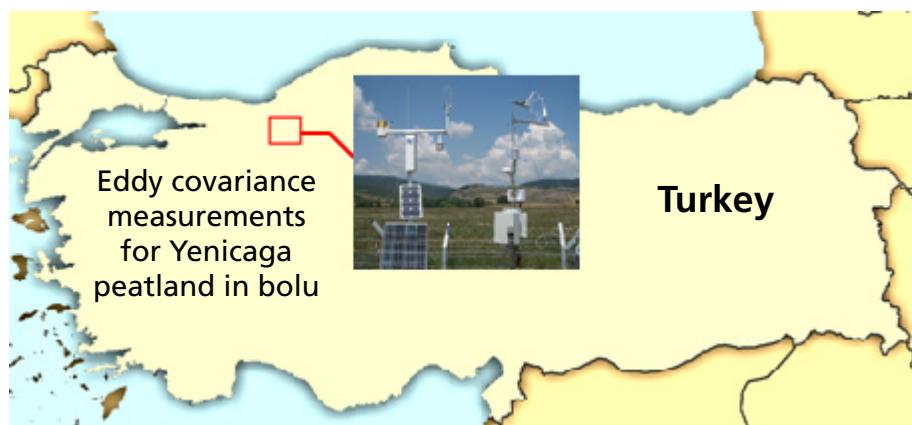


Figure 1. Location of the study site "Yenicaga peatland" in northwestern Turkey.

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18.3

A low-cost approach to measure ambient methane concentrations in preliminary studies

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Methane is the second most important greenhouse gas after CO₂ with a global warming potential that is 25 times larger per kg than that of CO₂. Although affordable high-quality sensors exist on the market, low-cost sensors normally were not sensitive enough to resolve ambient concentrations around 1.8 ppm. Recently, the TGS 2600 solid-state trace gas sensor has appeared on the market that is also sensitive to methane at ambient concentration levels. This sensor is a general-purpose smoke detector sensors that is not exclusively sensitive to methane concentrations.

We tested two such sensors in parallel with a high-quality integrated off-axis cavity ringdown spectrometer from Los Gatos Research (USA, model FMA-100) during two summer seasons in northern Alaska, USA, to assess its suitability for measuring seasonal variations in methane concentrations.

We will show a performance analysis and address the issue of interferences with temperature and relative humidity, and its possible cross-sensitivity to CO₂ concentrations and other components of smoke. Our results indicate that although this sensor is not yet perfect for high-quality applications it shows promising performance for preliminary studies as for example to find methane emission hot spots in the tundra that are only active at specific times during the summer season.

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18.4

Assessment of the Swiss methane inventory with the help of in situ aircraft measurements and backward Lagrangian particle dispersion simulations

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National greenhouse gas inventories are reported annually to the United Nations Framework Convention on Climate Change (UNFCCC) that monitors the progress of emission reductions defined in the Kyoto Protocol. In Switzerland, anthropogenic methane (CH_4) contributed 7% to the total reported greenhouse gas emissions for 2008. Most Swiss CH_4 emissions originated from the agricultural sector (83%), followed by waste treatment (10%) and the energy sector (7%) (FOEN, 2010). The major natural CH_4 sources are wetlands and lakes, which, in total are estimated to contribute 6% to the total Swiss CH_4 emissions (Hobi, 2011).

Here, we assessed the accuracy of the national inventory. Therefore, we spatially disaggregated the eight most important methane sources accounting for more than 90% of anthropogenic emissions using geostatistical information of source locations. The resulting spatially-explicit CH_4 emission inventory ("cadastre") is the first high resolution (500 m) spatial CH_4 inventory for Switzerland (see Figure 1). Aircraft measurements were performed on 18 days from May 2009 to September 2010, summing up to more than 90 flight hours. CH_4 was continuously measured with a Fast Methane Analyzer (Los Gatos Research Inc., Mountain View, USA) situated in one of the underwing pods of the small research aircraft METAIR-DIMO. To calculate the origin of the sampled air, Lagrangian backwards simulations were issued every 3 minutes along the flight tracks. The transport simulations of the model FLEXPART-COSMO were combined with the high resolution CH_4 inventory to calculate a bottom-up estimate and then compared to the continuous measurements. In an additional step, the available information was combined in a Bayesian framework to obtain a top-down CH_4 flux estimate for Switzerland.

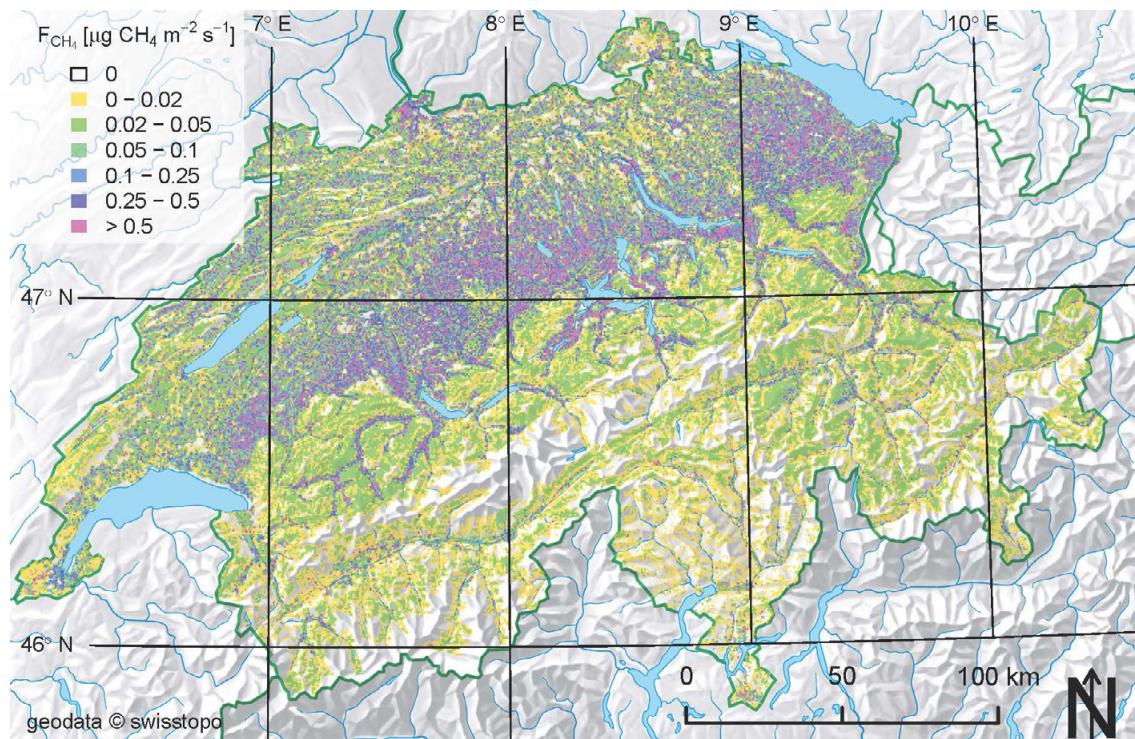


Figure 1: Spatially highly resolved CH_4 inventory for the eight most important anthropogenic sources accounting for 90% of the anthropogenic emissions. These include agriculture, landfills, and gas distribution in Switzerland.

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18.5

Greenhouse Gas flux budget of A managed Swiss grassland

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Despite their relatively low atmospheric concentrations, methane (CH_4) and nitrous oxide (N_2O) account for roughly 26% of the global warming. Little is however known about, how fluxes of CH_4 and N_2O from an intensively managed grassland influence the greenhouse gas (GHG) budget (CO_2 , CH_4 , and N_2O). Commonly used, manually operated static chambers only allow low sampling frequencies, e.g. daily to monthly intervals. Therefore, temporal integration between samplings of CH_4 and N_2O fluxes is required to estimate seasonal and annual budgets. Yet, the methodology of temporal extrapolation can have considerable influence on GHG specific budgets.

In this study we aim at identifying strengths and weaknesses among temporal integration methodologies for seasonal and annual budgets of chamber based CH_4 and N_2O fluxes. Methodologies vary in complexity, spanning from weekly mean flux integration to uni- and multivariate response functions.

CH_4 and N_2O fluxes were measured at an intensively managed grassland in Switzerland during a full 12 month period in years 2010/2011. Sampling frequency varied from weekly during the growing season to biweekly during the dormant season. CO_2 fluxes were additionally measured continuously using the eddy covariance (EC) technique.

Net uptake of CH_4 and release of N_2O were mostly observed during the 12 months measurement period, while eddy covariance derived CO_2 was characterized by net uptake during summer and net release during the dormant season. Annual sums of N_2O fluxes differed significantly among the applied temporal integration methods, ranging from 0.7 to 2.7 g N_2O $\text{m}^{-2} \text{a}^{-1}$. CH_4 sums did not show significant variations with varying integration methods, averaging ≈ 0 g CH_4 $\text{m}^{-2} \text{a}^{-1}$. EC derived annual carbon budgets for 2010 and 2011 indicated a mean net sink of 471 g CO_2 $\text{m}^{-2} \text{a}^{-1}$. Thus, the uncertainty contribution associated with N_2O to an integrated GHG budget is considerably higher than that of CH_4 . Depending on the temporal integration method, the annual net carbon sequestration was reduced by at least 44% when including N_2O and CH_4 to the budget. With higher annual sums of N_2O , the annual sequestration rate was completely used up and the grassland turned into GHG source.

18.6

Understanding Atmospheric Methane Variability between 2000 and 2008 using a Global Lagrangian Transport Model

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Methane (CH_4) is the second most important well-mixed greenhouse gas in terms of radiative forcing after carbon dioxide. To improve our understanding of recent CH_4 growth rate variability, focusing particularly on the latest increase since 2007 after a period of stagnation, we performed a global model simulation in combination with an emission inversion. This allowed us to quantify the temporal evolution of different methane sources during this period. In contrast to previous studies relying on Eulerian models, our simulations were performed with an enhanced version of the Lagrangian Particle Dispersion Model FLEXPART in a global domain filling mode and extended with a simple CH_4 chemistry. 3 mio particles (air parcels) were permanently transported in the model over the years 2000-2008 each carrying a set of 44 tracers representing 11 different CH_4 sources in 4 emission age classes each. A priori CH_4 emissions were taken from state-of-the-art inventories and a wetland emission model. In FLEXPART, these are picked up by the particles residing in the atmospheric boundary layer. CH_4 is subsequently lost by reactions with prescribed fields of OH and stratospheric Cl and O(1D) and deposition at the surface. Simulated concentrations are mostly in very good agreement with continuous in situ measurements and flask samples of the networks of NOAA, GAW and AGAGE. Finally, a posteriori emissions were inversely estimated using a fixed-lag Kalman smoother by analyzing modeled CH_4 concentrations against the in-situ measurements. Our results indicate that the renewed growth of CH_4 in 2007 and 2008 was mainly attributable to positive anomalies in CH_4 emissions from wet mineral soils in 2007/2008, tropical biomass burning emissions in 2006/2007, and an overall positive tendency in rice agriculture CH_4 emissions over the simulation period.

18.7

Quantification of methane emissions at the farm scale using boundary-layer volume budgets

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Agriculture plays an important role in the global greenhouse gas budget. Especially emissions of CH₄ from livestock and manure management are of key importance. In Switzerland, roughly 80% of all national methane emissions originate from the agricultural sector. However, methane emissions in Switzerland so far were not measured but were estimated via emission factors for enteric fermentation of livestock and for manure management. Since the uncertainties of these emission factors are high, the total uncertainty of the national methane emission estimate is also high (up to 55%). To improve the Swiss inventory estimates, direct field validation of regional-scale exchanges of methane are needed.

Our study aims at quantifying methane emissions at the farm-scale (0.5 – 5 km²). For assessing the source strength of a typical agricultural site, we measured methane concentrations in the lower atmosphere using a tethered balloon system combined with continuous profile measurements along a guy-wired 10-m mast at the ETH research station in Chamau (Canton of Zug). Based on these concentration profiles, we will present methane emission budgets from several campaigns carried out over two consecutive years (2011 and 2012).

We will show how boundary-layer budget quantifications of methane can be used for the validation of emission estimates, and hence for the reduction of associated uncertainties. The flux pattern of methane followed a clear diurnal course. During the night, when strong subsidence and stable stratification dominated, the CH₄ emissions from the agricultural sector (i.e., ruminants, manure) contributed the most to the flux budget. However, the different source terms did not contribute equally to the whole budget in term of time and space. The source strength estimates revealed a strong dependency of atmospheric processes and emissions on the temporal and spatial variabilities. As a result, budget quantifications differed up to 45% compared to the national inventory estimates.