Temporal dynamics of reactive nitrogen fluxes over different ecosystems

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Abstract

Within the research projects NITROSPHERE and FORESTFLUX, field campaigns in different ecosystem types were carried out to investigate biosphere-atmosphere exchange of reactive nitrogen (N_r) compounds. The aim was to test novel measurement techniques in eddy-covariance setups and to investigate temporal flux dynamics on daily and seasonal time scales. Results show strong management-driven effects on phase and amplitude of fluxes and provide useful validation opportunities for field-scale inferential models. We recommend complementing long-term observations of greenhouse gases – as commonly conducted within research infrastructures such as ICOS – with high-frequency N_r measurements to strengthen process understanding of coupled nitrogen and carbon cycles.

Keywords: Eddy Covariance, TRANC, QCL, Land Surface–Atmosphere Fluxes, Cropland, Peatland, Forest

1. Challenges in N_r flux measurements

Reliable estimates of N_r budgets are crucial to assess impacts of critical load exceedances for a variety of ecosystems. While measurements of inert greenhouse gas fluxes are nowadays well established, the determination of N_r compounds and their exchange between biosphere and atmosphere is still challenging. Reasons are the lack of capable techniques for fast-response detection and issues regarding inlet design, thereby inducing sampling losses for highly reactive N_r species (Marx et al., 2012).

2. Campaigns and methods applied

Field campaigns were carried out to investigate biosphere-atmosphere exchange of reactive nitrogen compounds with the aim to test novel measurement techniques in eddy-covariance setups for continuous determination of ammonia (NH_3) and total reactive nitrogen (ΣN_r) fluxes. While high frequency concentrations of NH_3 were measured with a quantum cascade laser (QCL) absorption spectrometer (Zöll et al., 2016), a custom-built converter named TRANC (*cf*. Ammann et al., 2012; Brümmer et al., 2013) coupled to a chemiluminescence detector was used for the determination of ΣN_r.

Campaigns were conducted above cropland, forest and peatland ecosystems (Fig.1). Substantial high-frequency damping on fluxes in the range of 15-35% was observed. Damping was found to be dependent on land use and its specific setup, but appeared to be mainly invariant with wind speed and atmospheric stability (*cf*. Wintjen et al., 2019).

3. Temporal dynamics of N_r fluxes

Nitrogen fluxes showed strong diurnal variability after fertilization on arable land with peak emission during midday. Moderate diurnal courses with highest uptake around noon was found at a forest site located in a national park. Exchange patterns were mainly controlled by N_r concentration and to a lesser extent by light, vapour pressure deficit, and surface wetness depending on season and land use.

An analysis of multidimensional functional relationships with artificial neural networks showed that up to 50% of the variability in nitrogen fluxes could be explained when the two most dominating factors, i.e. mainly light and ΣN_r concentration, were used (Zöll et al., 2019).

While measured data and results from a state-of-the-art inferential exchange scheme compared fairly well, a combination of the two approaches could be used for determining seasonal nitrogen budgets for natural and semi-natural sites (Brümmer et al., 2019).

Fig. 1: Campaign setups – Left: Bourtanger Moor peatland site (BM) with QCL; Middle: cropland in Braunschweig (TI) with TRANC; Right: Bavarian Forest National Park (BF) with TRANC and CLD.

4. Conclusions

The results from field campaigns using QCL and TRANC instrumentation help improve our knowledge of the temporal variability of surface-atmosphere exchange over different ecosystems, thereby providing valuable validation opportunities for inferential models. It is highly desired to complement standard ICOS long-term observations of greenhouse gases – at least at some selected key sites – with high-frequency reactive nitrogen measurements to strengthen process understanding of coupled nitrogen and carbon cycles.

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