Standing on the shoulders of giants – Research infrastructures as modular platforms for reactive nitrogen deposition monitoring

Frederik Schrader[1], Christian Brümmer[1]

[1]Thünen Institute of Climate-Smart Agriculture, Braunschweig, Germany

E-mail: frederik.schrader@thuenen.de

Abstract

The need for large-scale monitoring of greenhouse gas emissions has led to the emergence of highly standardised, globally distributed research networks that measure the biosphere-atmosphere exchange of CO_2, N_2O, and CH_4 with micrometeorological methods. We argue that an effort towards monitoring reactive nitrogen (N_r) exchange should aim to build on these existing infrastructures. Recent developments allow for the implementation of a low-cost N_r deposition monitoring network based on inferential modelling in the short-term, and for equipping existing micrometeorological towers with fast-response analysers for continuous N_r flux measurements in the mid- to long-term.

Keywords: deposition monitoring, research infrastructures, inferential modelling

1. The need for large-scale N_r monitoring

Large-scale, representative, and nation-wide N_r deposition monitoring is desperately needed to evaluate the impacts of environmental protection efforts, and to identify ecosystems threatened by critical load exceedances. This need is not met across a wide range of different ecosystems due to significant challenges involved with measuring N_r deposition.

2. Research infrastructures as modular platforms

Continent-wide research infrastructures focusing on greenhouse gas (GHG) exchange, like ICOS in Europe, or NEON in the US, are now operational (Fig. 1). They routinely apply the eddy-covariance (EC) technique to measure the surface-atmosphere exchange of CO_2 and energy, and they are readily equipped with the necessary instrumentation to either estimate N_r dry deposition using low-cost samplers and inferential modelling for individual compounds, or to directly measure it with the addition of a fast-response total N_r sampler, such as the Total Reactive Atmospheric Nitrogen Converter (TRANC; Marx *et al.*, 2012) to the existing EC setups.

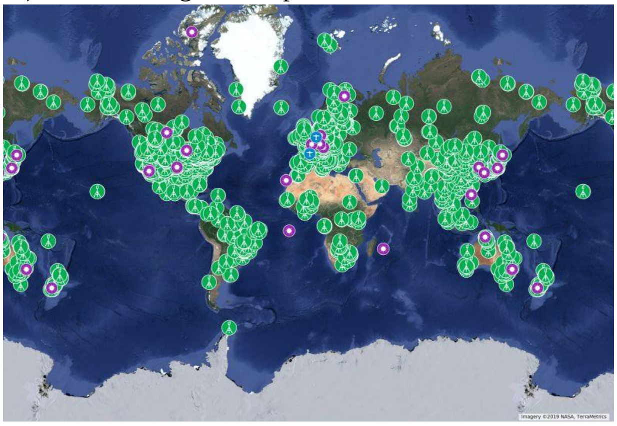

Fig. 1: Past and present locations of existing flux towers (green), airborne flux measurements (blue) and CO_2 column measurements within TCCON (purple) (Burba, 2019).

3. Recent developments and short-term perspectives

State-of-the-art implementations of N_r biosphere-atmosphere exchange models, especially for the case of NH_3, are nowadays able to reproduce measured fluxes to a reasonable degree of accuracy. Recent publications have aimed at applying these models on the plot-scale as a means of interpreting and gap-filling directly measured fluxes (Hansen *et al.*, 2017; Zöll *et al.*, 2016), and remedies for statistical issues with the application of inferential models with low-cost, low-resolution concentration input data are being developed (Fig. 2; Schrader *et al.*, 2018). These developments paint a promising picture for applying site-specific, data-driven parameterisations of N_r dry deposition inferential models at existing GHG monitoring flux towers with little additional cost and effort, thereby creating a first step towards a global N_r deposition monitoring network.

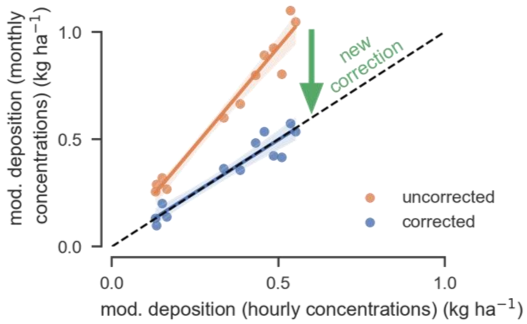

Fig. 2: Correction of statistical errors associated with inferring NH_3 dry deposition from low-resolution concentration samples. The method uses temporary high-frequency concentration measurements to derive site-specific correction functions (modified after Schrader *et al*, 2018).

4. Long-term outlook

Considerable efforts have been made at demonstrating new technologies for long-term observation of total atmospheric N_r deposition with micrometeorological techniques. The Total Reactive Atmospheric Nitrogen Converter (TRANC) coupled to a fast-response chemiluminescence detector (CLD) can nowadays accurately and continuously measure N_r biosphere-atmosphere exchange within an EC system (Brümmer *et al.*, 2013; Zöll *et al.*, 2019). In the future, selected sites from existing infrastructures may be retrofitted with TRANC-CLD systems to generate long-term time-series of N_r deposition for a wide array of ecosystem. An upgraded TRANC-CLD system that separately measures reduced and oxidised N_r species and thus allows to differentiate between agricultural and industrial fluxes is currently being tested.

Acknowledgements

We greatly acknowledge financial support by the German Umweltbundesamt (UBA) under support code FKZ 3715512110 and the German Federal Ministry of Education and Research (BMBF) within the Junior Research Group NITROSPHERE under support code FKZ 01LN1308A.

Many thanks to J. W. Erisman, who supervised the PhD thesis that the ideas presented here build on.

References

Burba G 2019 Illustrative Maps of Past and Present Eddy Covariance Measurement Locations: II. High-Resolution Images *DOI:10.13140/RG.2.2.33191.70561*

Brümmer C, Marx O, Kutsch W, Ammann C, Wolff V, Flechard C R and Freibauer A 2013 Fluxes of total reactive atmospheric nitrogen (ΣN_r) using eddy covariance above arable land *Tellus B: Chemical and Physical Meteorology* **65**, 1–20

Hansen K, Personne E, Skjøth C A, Loubet B, Ibrom A, Jensen R, Sørensen L L and Boegh E 2017 Investigating sources of measured forest-atmosphere ammonia fluxes using two-layer bi-directional modelling *Agricultural and Forest Meteorology* **273** 80–94

Marx O, Brümmer C, Ammann C, Wolff V and Freibauer A 2012 TRANC – a novel fast-response converter to measure total reactive atmospheric nitrogen *Atmospheric Measurement Techniques* **5** 1045–1057

Schrader F, Schaap M, Zöll U, Kranenburg R and Brümmer C 2018 The hidden cost of using low-resolution concentration data in the estimation of NH_3 dry deposition fluxes *Scientific Reports* **8** 969

Zöll U, Brümmer C, Schrader F, Ammann C. Ibrom A, Flechard C R, Nelson D D, Zahniser M and Kutsch W L 2016 Surface–atmosphere exchange of ammonia over peatland using QCL-based eddy-covariance measurements and inferential modeling *Atmospheric Chemistry and Physics* **16** 11283–11299

Zöll U, Lucas-Moffat A M, Wintjen P, Schrader F, Beudert B and Brümmer C 2019 Is the biosphere-atmosphere exchange of total reactive nitrogen above forest driven by the same factors as carbon dioxide? An analysis using artificial neural networks *Atmospheric Environment* **206** 108–118