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Validation of nitrogen dry deposition modelling above forest using high-frequency flux measurements

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Background

Accurate modeling of nitrogen (N) deposition is essential for identifying exceedances of N and defining critical values in environmental protection guidelines. However, there are still uncertainties in modern deposition routines due to a limited availability of long-term flux measurements of reactive nitrogen compounds for model development and validation. We investigated the performance of dry deposition inferential models with regard to annual budgets and the exchange patterns of total reactive nitrogen (ΣN_r) at a low-polluted forest located in the Bavarian Forest National Park, Germany.

Measurements of ΣN_r were carried out with a custom-built converter coupled to a chemiluminescene detector (CLD). The Total Reactive Atmospheric Nitrogen Converter (TRANC) was used to convert all reactive nitrogen compounds (ΣN_r), except for nitrous oxide (N_2O) and molecular nitrogen (N_2), to nitrogen oxide (NO). We compared flux measurements to the deposition module DEPAC (DEPosition of Acidifying Compounds) with locally measured input variables, hereafter called DEPAC-1D, and to dry deposition fluxes using the deposition module DEPAC within the chemical transport model LOTOS-EUROS (LOng Term Ozone Simulation – EURopean Operational Smog. We further compared our results to ΣN_r deposition estimates obtained with canopy budget techniques (CBT).

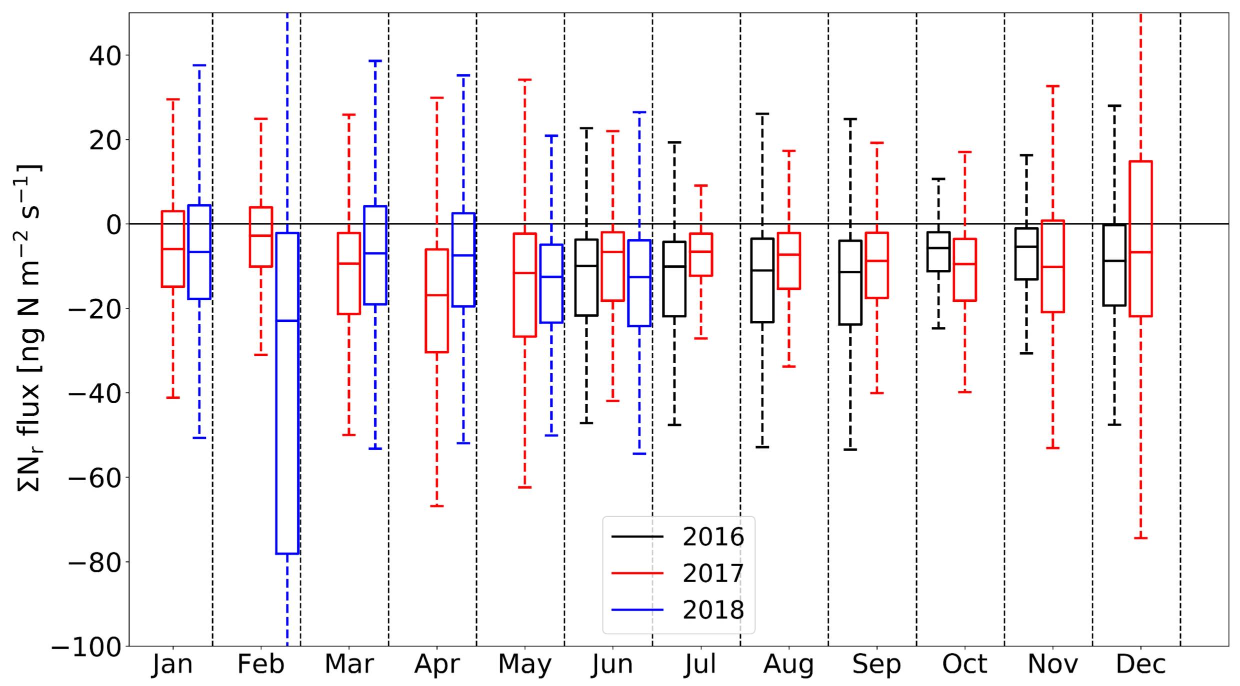

Fig. 1: Time series of measured ΣN_r fluxes depicted as box plots on monthly basis in ng N m^{-2}s^{-1}. Colors indicate different years. The displayed range was restricted from -100 to 50 ng N m^{-2}s^{-1}.

Results I

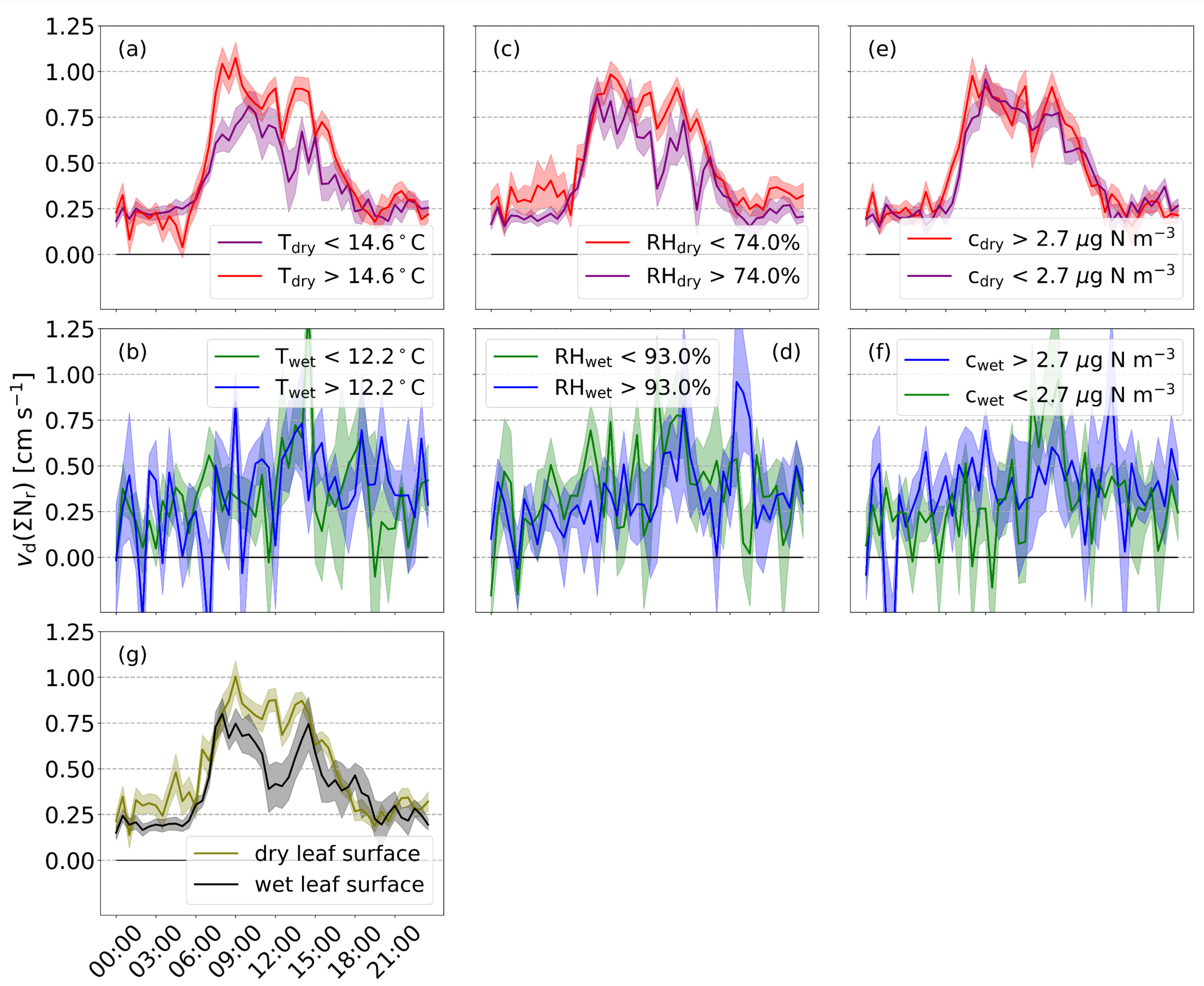

Fig. 2: Mean daily cycle of measured deposition velocities from May to September for low and high temperature, humidity, concentration, and dry and wet leaves. Median values of temperature, humidity, and concentration, which are derived for the same time period, are used as threshold values.

- We observed mostly deposition during 2.5 years of flux measurements. Median deposition ranges from -15 to -5 ng N m^{-2}s^{-1}. Highest deposition was observed during mid spring and summer, lowest deposition occurred during late autumn and winter.
- From May to September, measured deposition velocities of ΣN_r were enhanced by higher temperatures, lower relative humidity, dry leaf surfaces, and no precipitation.

Our study shows the benefits for robust N deposition and provides a better understanding of temporal dynamics in forest-atmosphere exchange by coupling long-term EC measurements and dry deposition modeling.

Results II

- On average, annual TRANC dry deposition was 4.5 kg N ha^{-1}a^{-1} for two different gap-filling approaches.
- Values are close to dry deposition modeled by DEPAC-1D (5.3 kg N ha^{-1}a^{-1}). Difference of DEPAC-1D to TRANC can be related to parameterizations of reactive gases or the missing exchange path with soil.
- LOTOS-EUROS predicted 5.2 kg N ha^{-1}a^{-1} to 6.9 kg N ha^{-1}a^{-1} depending on the weighting of land-use classes within the site's grid cell. Modeled NH_3 concentrations used by LOTOS for deposition estimates were clearly overestimated in spring and autumn. They were the main reason for the discrepancy in dry deposition budgets between the different methods.
- 7.5 kg N ha^{-1}a^{-1} was estimated with the canopy budget technique for the period from 2016 to 2018 as upper estimate and 4.6 kg N ha^{-1}a^{-1} as lower estimate.

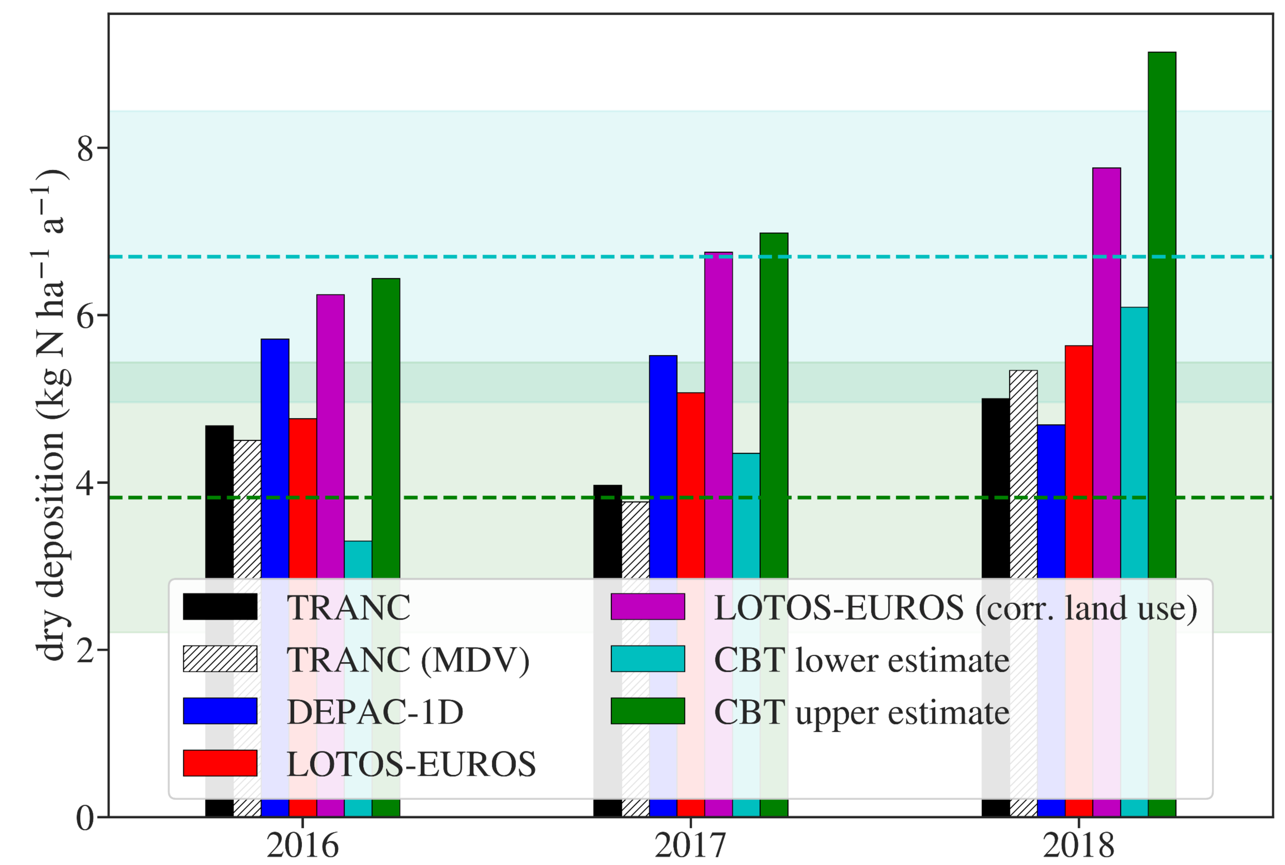

Fig. 3: Dry deposition for the years 2016, 2017, and 2018 displayed as bar chart. Colors indicate different methods. Flux measurements are gap filled with DEPAC-1D and Mean Diurnal Variation (MDV). Data from TRANC, DEPAC-1D, and LOTOS-EUROS are extrapolated for 2018. CBT lower and upper estimates were weighted according to the measured land use. The colored dashed lines indicate the averaged dry deposition of the lower and upper estimates from 2010 to 2018, the shaded areas represent their standard deviation.

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