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# Eddy covariance $N_2O$ flux measurements at low flux rates: results from the InGOS campaign in a Danish willow field.

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Nitrous oxide ($N_2O$) fluxes from soils are characterised by their high spatial and temporal variability. The fluxes depend on the availability of the substrates for nitrification and denitrification and soil physical and chemical conditions that control the metabolic microbial activity. The sporadic nature of the fluxes and their high sensitivity to alterations of the soil climate put very high demands on measurement approaches. Laser spectroscopy enables accurate and fast response detection of atmospheric $N_2O$ concentrations and is used for eddy covariance (EC) flux measurements. Alternatively $N_2O$ fluxes can be measured with chambers together with high precision analysers. Differences in the measurement approaches and system designs are expected to have a considerable influence on the accuracy of the flux estimation. This study investigates how three different eddy covariance systems perform in a situation of low $N_2O$ fluxes from a flat surface. Chamber flux measurements with differing chamber and analyser designs are used for comparison.

In April 2013, the EU research infrastructure project InGOS (http://www.ingos-infrastructure.eu/) organised a campaign of $N_2O$ flux measurements in a willow plantation close to the Risø Campus of the Technical University of Denmark. The willow field was harvested in February 2013 and received mineral fertiliser equivalent to 120 kg N $ha^{-1}$ before the campaign started. Three different eddy covariance systems took part in the campaign: two Aerodyne quantum cascade laser (QCL) based systems and one Los Gatos Research off-axis integrated-cavity-output spectroscopy (ICOS) system for $N_2O$ and CO. The sonic anemometers were all installed at 2 m height above the bare ground. Gill R3 type sonic anemometers were used with QCL systems and a Gil HS-50 with the ICOS system. The 10 Hz raw data were analysed with group specific softwares and procedures.

The local conditions in the exceptionally cold and dry spring 2013 did not lead to large $N_2O$ flux rates. All three EC systems showed 30 min. flux values varying around zero nmol $m^{-2}$ $s^{-1}$. This noise was considerably lower in the EC systems that used QCL analysers. The maximum daily averages of the uncorrected fluxes from two of the EC systems reached 0.26 (ICOS/HS50) and 0.28 (QCL/R3) nmol $m^{-2}$ $s^{-1}$.Spectral correction increased the flux estimates up to, e.g., 180% equivalent to 0.54 nmol $m^{-2}$ $s^{-1}$.

The flux estimates from the soil chambers were with one exception higher than the flux estimates obtained from the EC systems with highest daily averages ranging from 0.1 up to 2 nmol $m^{-2}$ $s^{-1}$. These large differences were unexpected, because at least two of the EC systems were shown to accurately measure fluxes at such higher levels at another InGOS campaign in a fertilised Scottish grazed meadow. We use spectral analysis to examine the raw data for the effects of sensor noise on the flux estimates and discuss strategies on how to correct or account for it. Furthermore possible causes for the observed differences between the observed EC and chamber flux estimates will be discussed.