



Energy research Centre of the Netherlands

Nitrogen oxides and ozone exchange above a coniferous forest in the Netherlands

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Introduction

The fluxes of nitrogen oxides and ozone still remain unclear above forests, due to a lack of good quality flux measurements and the unclear influence of chemical reactions between some compounds on fluxes and gradient. The atmosphere-biosphere exchanges of nitrogen oxides and ozone have been studied by taking concentration measurements of these constituents along a vertical profile at a Douglas fir site (Speuld) in the Netherlands within the framework of the NitroEurope Integrated Project (EC FP6, 2006-2011). To avoid bias in the surface fluxes derived from measurements of fluxes and gradients above the canopy, chemical reactions should be taken into account during interpretation of these measurements. A better understanding of these interactions is needed to understand the nitrogen cycle in forests. Therefore it is crucial to derive accurate surface fluxes.

Data and Methods

Concentration measurements of nitrogen oxides and ozone were conducted above the forest canopy (30m) along a vertical profile (33, 37 and 45 m) for three years (2008-2010) and within trunk space (5m) for the second half of the campaign. At the same time, forest floor exchange of these constituents was obtained by dynamic chamber measurements. Surface flux-profile relations adapted for the roughness layer at this site are derived from measurements of momentum and sensible heat flux and wind and temperature profiles. Fluxes of nitrogen oxides and ozone are obtained from these gradients and the influence of chemical reactions will be investigated by the application of a simple model describing the exchanges by consideration of two conceptual layers, a canopy crown and trunk layer (Duyzer et al. 2005). The reaction of NO with O₃ and photolysis of NO₂ are considered within the trunk space and ignored at the other compartments modelled (e.g. turbulent timescales are much smaller above the forest). Similarly, slower reactions, such as due to biogenic VOC, influencing the ozone flux, have been ignored due to their overall low concentrations. Positioning of the instruments as well as details are provided by Figure 1.

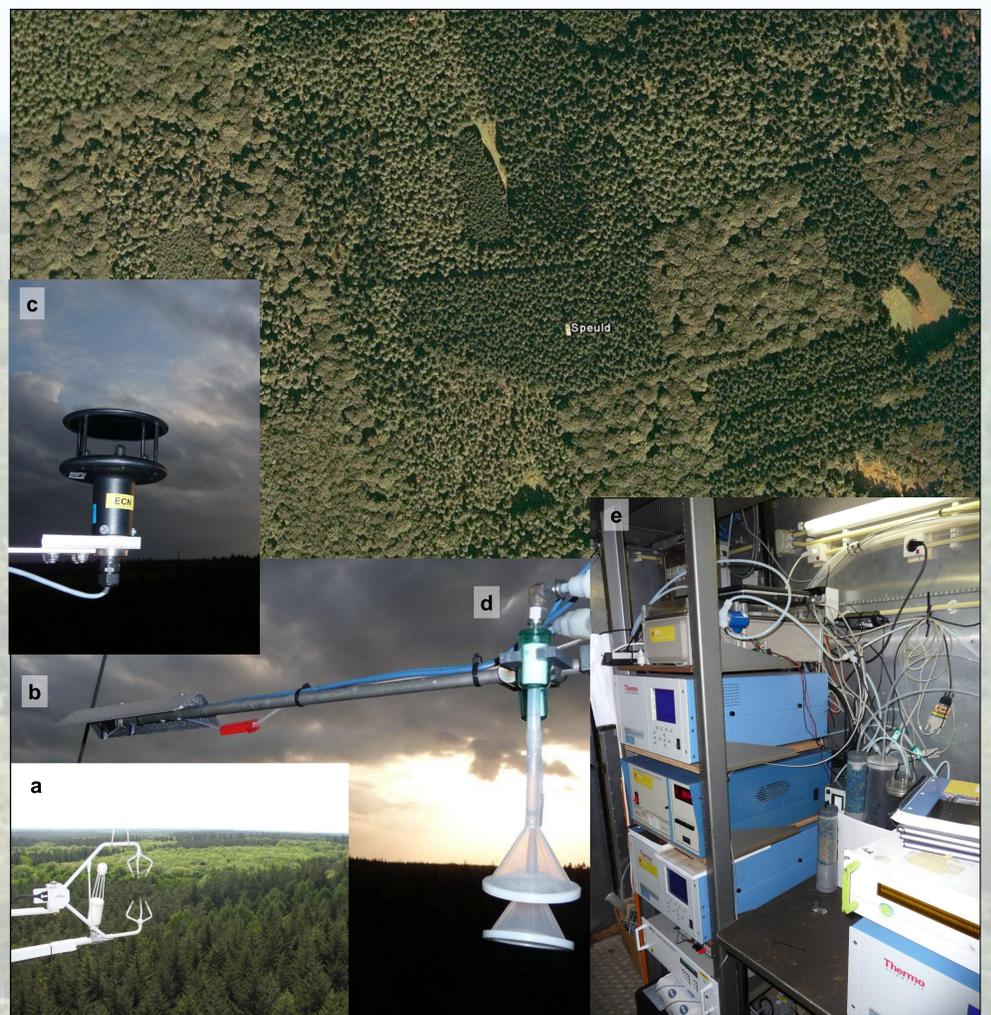


Figure 1: Top: Aerial photo of the Speulder forest site. Left: Instruments flux-profile relations: Sonic CSAT and Licor 7500 at 47 m and forest fetch to SSW (a), Thermocouples (b) and Gill 2D (c) at 45, 37, 33 m. Right: NO_x and O₃ measurements: Tower Inlets (d) & Thermo 49i, 42s, 42i monitors within forest floor container (e).

Results

Forest floor annual emission of NO is as large as 3.46 and 2.92 kg N ha⁻¹ for 2008 and 2009 respectively. Emission of N₂O is relatively small with respectively 0.083 and 0.077 kg N ha⁻¹. These results agree well with earlier observations at the site, although flux magnitudes were about twice as large in 2002 (Pilegaard, 2006). The direction of the fluxes at the forest floor for NO₂ is more complicated with on average deposition (0.61 kg N ha⁻¹) for 2008 and emission (0.18 kg N ha⁻¹) for 2009.

Annual average concentrations above the forest canopy at 37m for NO, NO₂ and O₃ were respectively 1.23 (±3.6), 6.08 (±5.7) and 48.6 (±31.2) µg/m³ for 2009 and 1.02 (±2.8), 5.70 (±5.3), 46.4 (±29.5) µg/m³ for 2010. The above canopy O₃ concentration at 37m is reduced compared to that at 45m for both years (1.7 resp. 0.9 µg/m³). The O₃ concentration within trunk space is reduced compared to that at 37m (3.4 resp. 5.6 µg/m³), whereas ozone concentrations at 33m are at times (summer periods mainly) elevated compared to that at 37m. The NO profile has the highest concentrations at 45m and the lowest concentrations within trunk space for both years, although concentration differences are small. The profile for NO₂ is less distinct, with the lowest concentration within trunk space as well, but the above canopy profile is different for both years. Turbulent transport is one order of magnitude faster than chemical reaction times for the measurements at 45m (Figure 2c). As such, the fluxes of ozone and nitrogen oxides are calculated by the gradient method using the flux-profile relations without taking the influence of chemical reactions into account. Diurnals of the ozone and nitrogen dioxide flux at two levels above the canopy for May 2010 are given in Figure 2. Surface fluxes and within canopy exchanges will be investigated with a simple model (Duyzer et al. 2005).

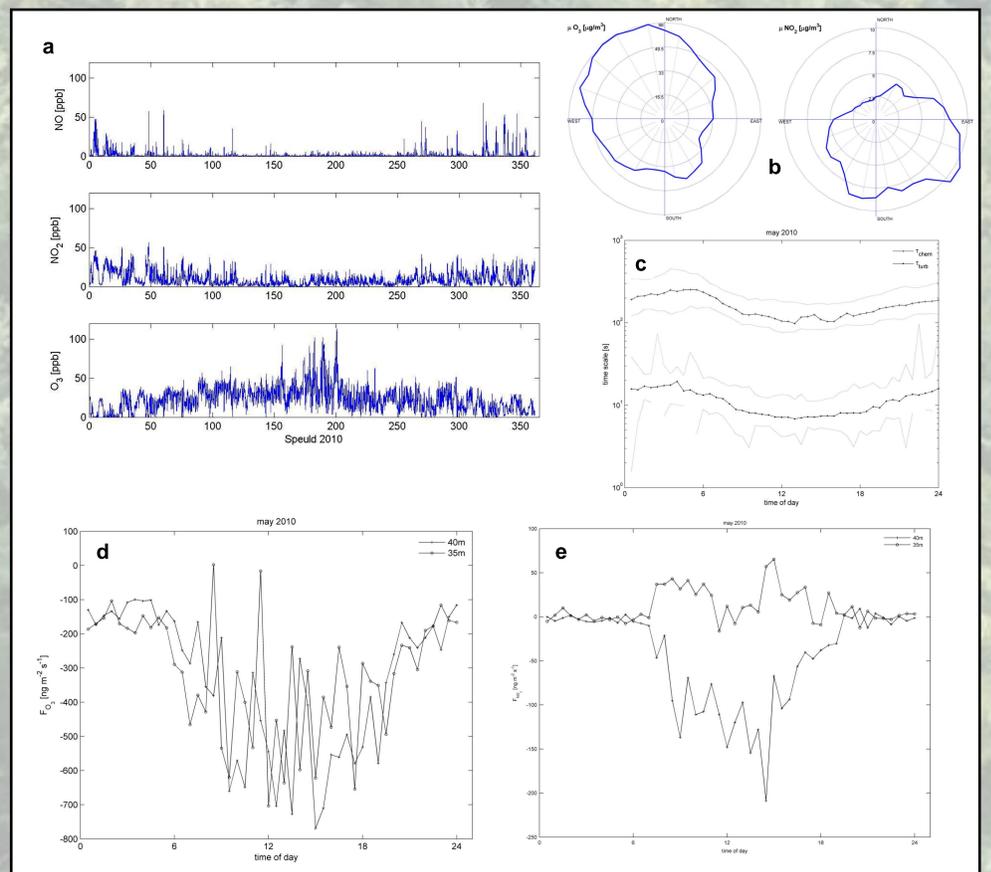


Figure 2: Top: NO_x and O₃ measurements 2010 (a) within wind rose (b) and timescales of turbulence and chemistry during May 2010 (c). Bottom: Diurnal of O₃ & NO₂ fluxes in May 2010 at 40 and 35m (d & e).

Acknowledgements

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References

Duyzer J. et al (2005); Exchange of ozone and nitrogen oxides between the atmosphere and coniferous forest. WASP, 85: 2065-2070.