AG Klimatologie
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Measuring turbulent exchange of trace gases/-substances using the eddy covariance technique.

Background

Debates on climate change often center around increasing trace gas and particle concentrations. These substances differ not only in their admixture to the atmosphere, but also in their sources, chemical composition and climate forcing. Thus, recent studies focus on substances, which have a high warming potential.

Presently the Climatology Working Group studies the turbulent exchange of methane, carbon dioxide, water vapor, and energy (latent- and sensible heat) in Siberia (SASCHA) as well as exchange fluxes of aerosol particles over the urban area of Münster.

Aerosol particles – also known as particulate matter (PM_x) – not only affect climate, but also cause respiratory and cardiovascular diseases through deposition in the lung and infiltration into the blood circuit. Therefore, PM should be carefully monitored.

With the eddy covariance (EC) method, we are able to quantify the turbulent exchange of trace gases between a homogeneous surface and the adjacent atmosphere (boundary layer). Here, the quantity of substance X, transported through a specific area in a specific time [*e.g.*, mmol · m^{-2} · s^{-1}], is called flux.

An EC setup consists of 2 key elements: The trace substance concentration measurement sensor and the ultra sonic anemometer, measuring the turbulence (wind velocities in 3-dimensional flow). Both units must sample at high frequencies, usually around 10-50 Hz.

Fluxes (F_x) can then be calculated as the covariance of the instantaneous deviation of the trace substance's concentration from it's mean (χ') and the current vertical wind movement (w'). This covariance is averaged over a specific time window (mostly 30 min).

$$F_\chi = \overline{\chi' * w'}$$

Particle Fluxes

Particle concentrations are currently measured on a 62 m above ground level high radio tower, located in the Manfred-von-Richthofen military compound, southeast to the city center of Münster. Two optical particle counter sample particles in the 0.06 – 10 µm diameter size range. The devices illuminate the sampled particles with a solid state laser (~700 nm) and perform single particle sizing in up to 140 size channels as a function of the intensity of scattered light.

Fig. 1: Measurement Tower.

Results

Particle number fluxes exhibit a pronounced daily pattern, strongly stamped by anthropogenic activity such as traffic, hence peaking during the morning rush hour (fig. 3). Mass fluxes show a completely opposite pattern. Here, the net flux is negative and peaks in the afternoon hours, suggesting that these two fluxes are driven by different sources. Fig. 4 shows that there is a rather sharp border between mostly up- or downward transported particles at 170 nm.

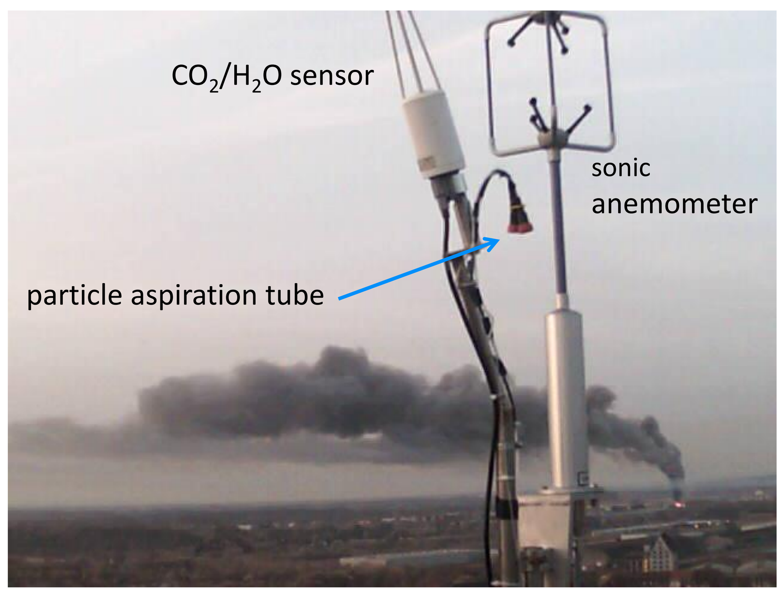

Fig. 2: Fire at the Hansaviertel with soot plume.

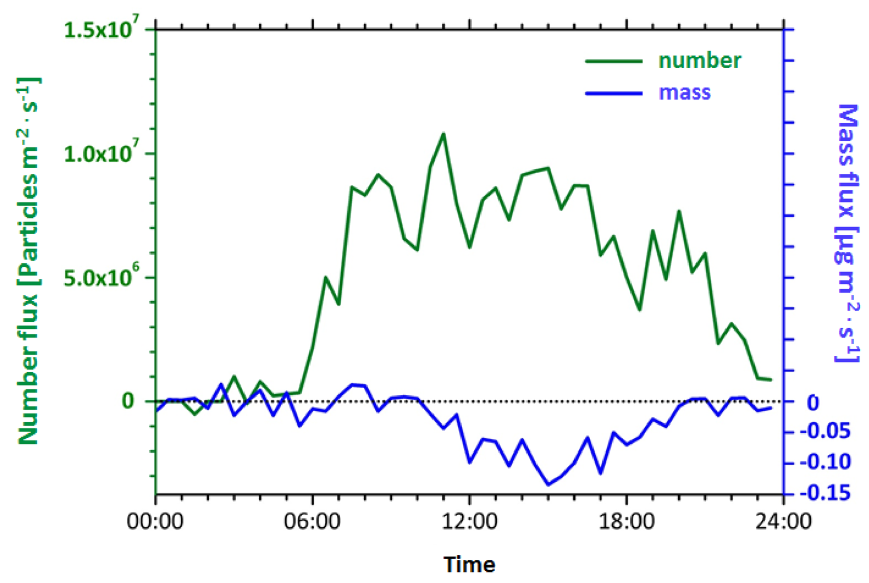

Fig. 3: Average diurnal course of number- and mass fluxes (all channels combined).

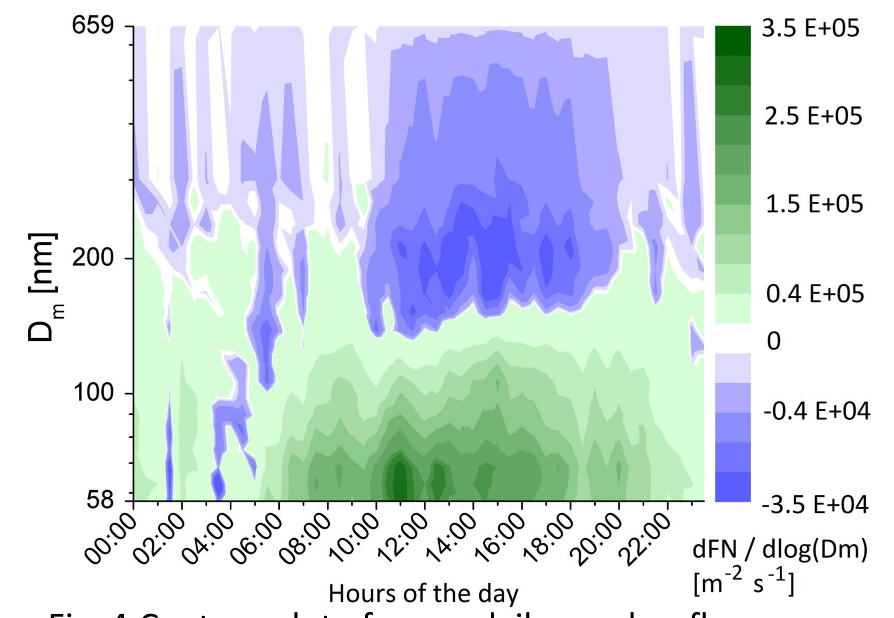

Fig. 4:Contour plot of mean daily number fluxes (normalized). Y-axes in log scale.

Summary

- The city of Münster is a distinct source for particles with a mean daily emission of 2.49 · $10^8/(m^2$ d).
- Observation of simultaneous occurrence of two fluxes in opposing directions (upward and downward)
- Emission (upward) is mostly driven by fine particles (< 170 nm)
- Bigger particles (> 170 nm) are main drivers for deposition (downward).
- Given the cubic growth of volume by diameter, the particles (› 170 nm) have a significantly higher mass, resulting in a downward directed mass flux
- Tipping point between mostly up- and downward transported particles at 170 nm

SASCHA

The interface between the steppe and the northern forest zone in Western Siberia plays a significant role in the global carbon cycle. Induced by a changing climate and by changing socio-economic conditions, agricultural expansion and fundamental land-use changes are expected in these regions. Such changes have a great impact on the budgets of the greenhouse gases (GHGs) CO_2, and CH_4, which are the most important long-lived GHGs in the atmosphere.

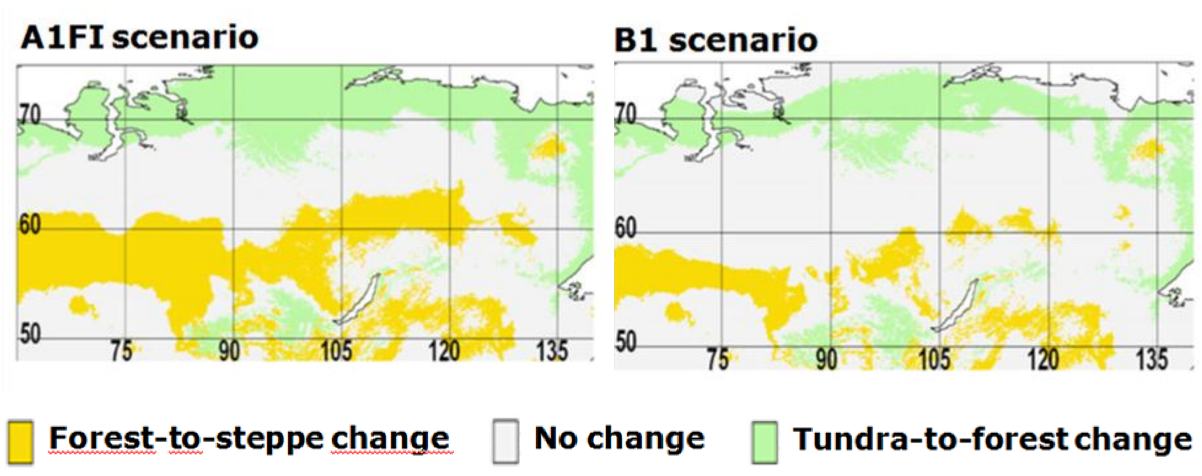

Fig. 4: Global warming effects on vegetation in Siberia. Source: Tchebakova et al. (2009).

In the framework of the recently started research project SASCHA (www.uni-muenster.de/SASCHA) the fluxes of the GHGs water vapor, carbon dioxide, and methane between surfaces of different land-use types and the atmosphere will be quantified and analyzed. The processes driving these fluxes will be studied and the potential contribution to global warming will be assessed. Moreover, this subproject aims at identifying feedback-mechanisms between the GHG fluxes on the one hand and climate and land-use change on the other. In synthesis of the obtained results, guidelines will be developed to minimize GHG emissions and to optimize GHG sequestration during the development of land-management strategies.

Methods

The project study areas are located in the Tyumen Oblast in Western Siberia. They include natural bogs and wetlands, but also areas under agricultural use. The concentrations of CO_2, H_2O and CH_4 will be measured by an enclosed and open-path gas analyzer, respectively. Two of such eddy covariance stations will be operated throughout the summer months of 2012, 2013 and 2014.

In addition, three full meteorological stations will be built up and measure continuously throughout the years 2012 to 2015.

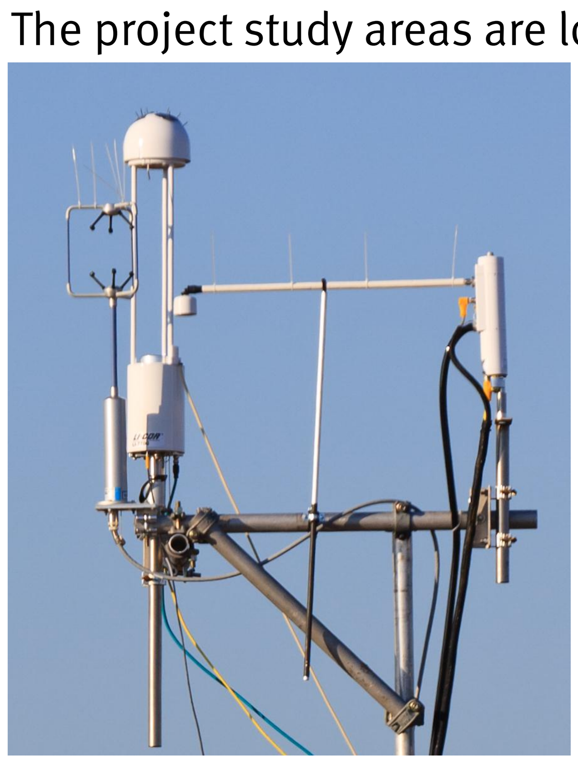

Fig. 5: Measurement setup of the eddy covariance stations.

All measurement stations will be equipped with instruments that operate with low power consumptions so that the stations can be supplied by solar and wind energy in combination with batteries.

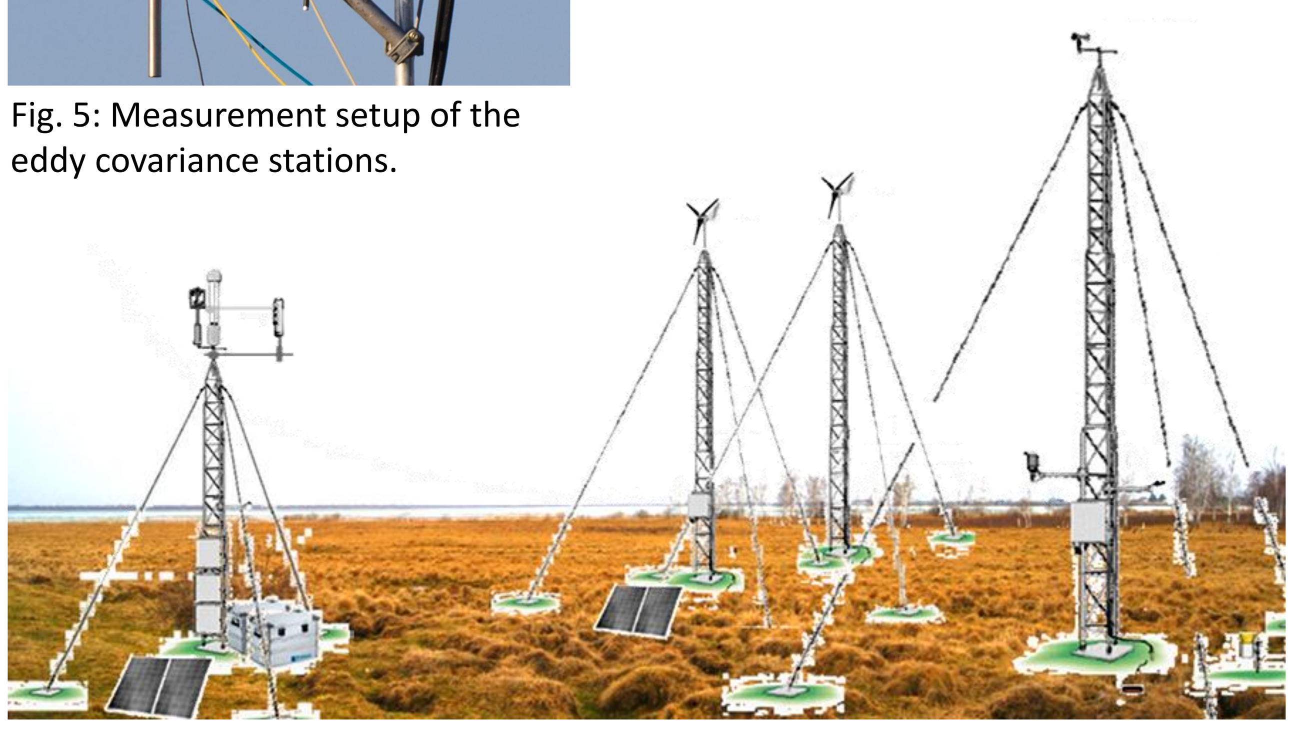

Fig. 6: Sketch of the measurement installation.

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