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Aerosols over the Siberian Forest: The ZOTTO project

Jost Heintzenberg*, Wolfram Birmili

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At the new long-term Tall Tower monitoring facility near Zotino, Siberia (ZOTTO, 90° E, 60° N) a unique fine particle monitoring system has been set up. Through two inlets at the tower in 50 m and 300 m height aerosol particle number size distributions are measured since September 2006 in the size range of 15 to 835 nanometer dry diameter. They are representative for the aerosol over a large part of Eurasia. Up to fall 2008 the results cover a wide range of concentrations reaching from very low Arctic to suburban polluted levels. In summer there are indications of new particle formation in conditions with low pre-existing particulate surface.

1. Introduction

One of the major hot spots of the Earth system lies in the boreal and Arctic zone of Eurasia [1]. Large amounts of carbon are stored in the Siberian forests, soils and permafrost. Predicted by climate models and measured over the past decades [e.g., 2] Siberia is one of the boreal and polar regions that experience the strongest climate change, in particular a significant warming [3] which is bound to affect the carbon cycle over this hot spot.

In order to monitor on a regional scale ongoing and future changes in carbon cycle, the Zotino Tall Tower Observatory (ZOTTO) in central Siberia near 60° N, 90° E has been established in a cooperation project between the German Max-Planck-Society, represented by The Max-Planck-Institute for Biogeochemistry, Jena and the V. I. Sukachev Institute of Forest, Krasnoyarsk [4] (cf. Fig. 1).

As an associated partner the Leibniz-Institute for Tropospheric Research (IfT) adds an aerosol component to the ZOTTO project because aerosols over the Siberian forest are of considerable interest to atmospheric aerosol research for mainly two reasons. First, biogenic emissions from boreal forest are strongly suspected to lead to new particle formation after their photo-chemical oxidation [5, 6]. Second, large areas of Siberian forest are affected by fires every year causing strong emissions of smoke aerosols that are distributed around the globe in the free troposphere [7, 8].

This report discusses the value of ZOTTO in terms of regional aerosol information, then addresses the challenges of conducting aerosol measurements from a 300 m tower before giving an overview of fine particle results from the first two years of operation.

Figure 1 : The 300 m ZOTTO tower at 90° E 60° N.

Leibniz-Institute for Tropospheric Research
Permoserstr. 15, 04318 Leipzig, Germany
*: currently at Dept. of Meteorology, Stockholm University, S-10691
Stockholm, Sweden, Email jost@misu.su.se

2. Representativeness of ZOTTO

A sampling point in 300 m height over the Siberian forest raises the questions: Where does the air come at this point and how representative would aerosol measurements be at ZOTTO? To answer these questions a three-year statistical study of back trajectories from ZOTTO was conducted. With the HYSPLIT model (http://www.arl.noaa.gov/ready/hysplit4.html) 144 h back trajectories were calculated every 12 h for the years 2004–2006. The results are discussed in [9] and show that about 50% of the area of the Russian federation (mostly south and west of ZOTTO) and over 90% of the area of Kazakhstan are covered by these back trajectories.

3. Instrumental

Doing aerosol measurements or particle sampling on any 300 m tower presents serious challenges concerning power supply, risk of lightning strikes, in cloud situations and service access. At ZOTTO the 80 degrees annual swing in temperature poses an additional challenge. These risks and challenges excluded the operation of any aerosol sensor on top of the tower. Thus, we were forced to consider the possibility of drawing sample air from 300 m to aerosol instrumentation in the underground laboratory at the foot of the tower.

To our knowledge any aerosol inlet length approaching 300 m has never been reported in the literature. Preliminary model calculations and cost estimates suggested an outer diameter of 3.0 cm (1¼ in) slick stainless steel pipe with a laminar flow of some tens of liters per minute.

In a horizontal position and with a few bends this 300 m pipe was set up at IfT to measure its size-dependent particle penetration at different flows with ambient aerosol particles. The results published in [10] showed that the useful size range covered diameters from about 15 nm to about 1 μm. In fall 2006 this 300 m inlet together with an additional 50 m inlet were set up at the newly erected Zotino tower.

For the measurement of particle number size distributions a differential mobility particle spectrometer (DMPS) was constructed at IfT following the design principles given in [11]. Automatic operation, low maintenance and long-term stability were main design factors. This spectrometer switched automatically about every six minutes between the two inlets.

4. Results

With some interruptions due to lack of transportation to and staff at ZOTTO and due to computer failure there are size distributions available at both heights from the end of September 2006 until October 2008. A first overview of the results can be gleaned from the time series of total number and volume concentrations in Fig. 2 that shows a high variability. Whereas median concentrations were cm^{-3} and μm^3 cm^{-3}, respectively the corresponding 5% and 95% percentiles were cm^{-3} and μm^3 cm^{-3}, respectively. Thus, conditions reaching from clean remote to non-urban continental were recorded.

The 5% most (in terms of volume concentrations) and least polluted individual size distrubtions during the first three months were connected to their respective 144h back trajectories, which clearly showed the anthropogenic centers in southern and southwestern Siberia causing.

A simple classification of number concentrations at the 18 individual mobility diameters yields the 1%, 50% and 99% percentiles drawn in Fig. 3. In general concentrations are lower at 300 than at 50 m. The differences between the two heights in number concentrations increase with decreasing sizes, hinting at smaller, recently formed particles being more frequent at lower heights.

The 1% percentiles exhibit the shape of an extremely aged continental aerosol, which has lost both the smallest particles through diffusion and the largest particles through sedimentation, leaving behind accu-

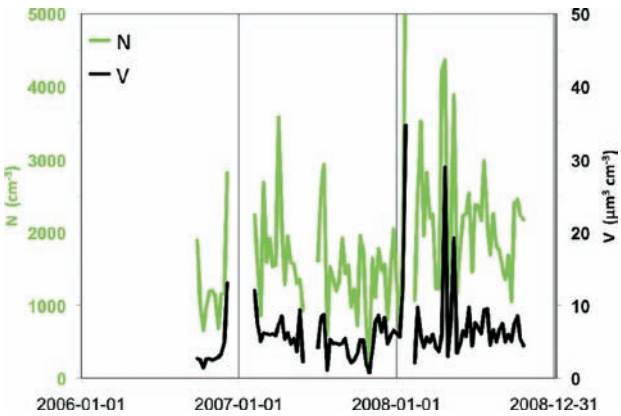

Figure 2 : Weekly averages of particle number (N, cm^{-3}, left scale), and volume (V, μm^3 cm^{-3}, right scale) concentrations between September 2006 and October 2008 at ZOTTO (90E, 60N).

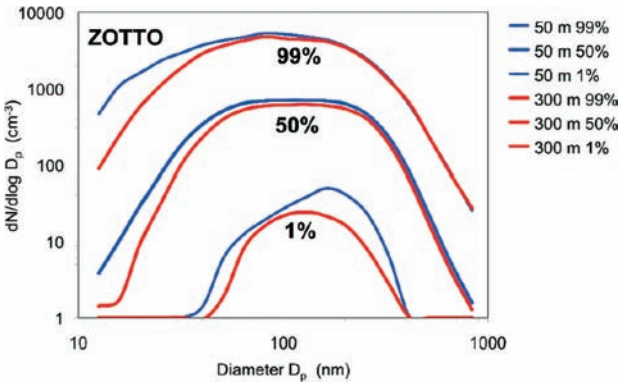

Figure 3：1%, 50%, and 99% percentiles of individual size dependent number concentrations between September 2006 and October 2008 at ZOTTO (90E, 60N). Blue: 50 m height, red: 300 m height.

mulation mode particles with the longest atmospheric lifetimes.

When surface concentrations of pre-existing particles are lowest we expect the highest probability of new particle nucleation from the gas phase (provided there a condensable vapors available).

Fig. 4 confirms this understanding with strong modes of ultrafine particles appearing at both heights when total surface concentrations at 300 m were below their 1% percentile.

5. Conclusion

The remote ZOTTO site appears ideal to monitor boundary layer and free-troposphere aerosol over large parts of Eurasia. ZOTTO experiences a wide range of atmospheric conditions. First indications of new particle formations have been seen in summer 2008 (cf. Fig. 2).

The field-proven feasibility of aerosol measurements through a 300 m inlet should encourage others to implement similar measurements at other tall towers in order to monitor the atmospheric aerosol over very wide regions from a single point.

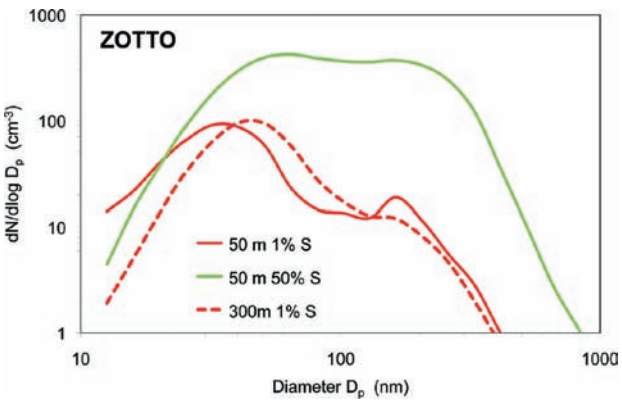

Figure 4：Average number concentrations at 50 m (solid line), and 300 m (broken line) for size distributions measured when total surface concentrations at 300 m ranged within their respective 1% percentiles. For comparison the median size distribution for all records with total surface concentrations below the surface median is given in green.

6. Acknowledgements

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