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Boundary-layer and air quality study at “Station Nord” in Greenland

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Abstract

Knowledge on the forcing mechanisms (meteorological and chemical) that come into play in the Arctic environment is highly uncertain. We analyse data from measurements and mesoscale meteorological modelling for periods in summer 2011 and winter 2011/2012 to elucidate the boundary-layer features at Station Nord situated in Northern Greenland (81.6N, 16.7W). A major challenge for modelling is to connect local-scale observations with larger scales modelling of the atmosphere. In particular, in summer, bare soil in the vicinity of the station may not be present in the global boundary and surface conditions. Thus, in summer the deviations of modeled from measured values of temperature and humidity near the surface are larger compared to winter. We found that the underestimation of temperature near the ground is larger at clear sky compared to cloudy conditions; and the underestimation reached up to height 1-1,5 km at clear sky and up to the first 100 m for the cloudy days. The measured wind speed profiles showed high variability, while the modeled were smoothed. During summer the modeled wind speed was close to or larger than the measured without clear indication for the role of clouds. In winter, the over-estimation of wind speed was more pronounced.

1 CRAICC Network

CRAICC (Cryosphere-atmosphere interactions in a changing Arctic climate**)** is part of the Top-level Research Initiative (TRI), the largest joint Nordic research and innovation initiative to date, aiming to strengthen research and innovation regarding climate change issues in the Nordic Region.

2 Observational site and measurements campaigns

Station Nord in Greenland (81.6N; 16.7W) serves as a Danish background station for air pollution, Figure 1 (In warm summer conditions, the surface may be snow free, but the water is always frozen). Extensive meteorological measurements programme was organized, including cloud base height measurements using a CL51 Vaisala ceilometer from July 2011 until April 2013, Figure 2 (left panel). Radiosoundings were performed during a 10-day periods in summer 2011 and winter 2012 using a MODEM system, Figure 2.

Figure 1. Station Nord location and view in July/August 2011.

Figure 2. Ceilometer and the 10 m mast for flux and air quality measurements in the left panel. Releasing radio sonde, right panel.

One of the main results from the feasibility measurements at Station Nord was that the ceilometer used is a robust instrument that can stand the harsh Arctic conditions and that the aerosol backscatter signal allows to study the aerosol distribution in the area during the year, Figure 3. The ceilometer measurements are performed continuously from July 2011 until April 2013. Two radiosonde campaigns have been carried out, the first one from 28 July to 5 August 2011 and the second one for 3 weeks in March 2012. Simultaneously, Aarhus University was measuring gas and aerosol concentrations, Fenger et al, 2013. Concentrations in winter reached 0.6 ppb for NOx and 35 ppb for Ozone, and were found to be lower in summer.

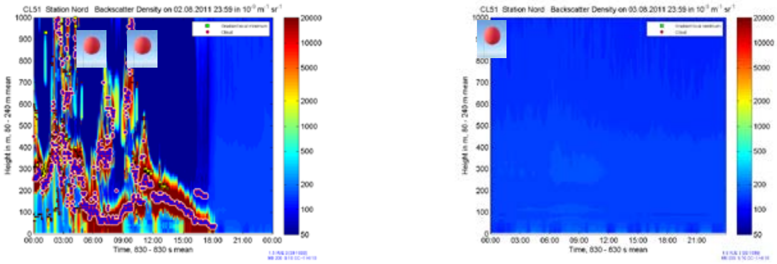

Figure 3. Ceilometer measurements on 2 August 2011 covering cloudy (left panel) and clear sky (right panel) periods. Times of radiosoundings are marked.

2 Mesoscale modeling results

Mesoscale modelling was performed with the Weather Research Forecasting model (with ARW core) WRF, v.3.3.1 (Skamarock et al, 2008). The domain and physics used for the simulations are shown in Figure 5. WRF was initialized with the US National Center for Environmental Prediction Global Analyses data (FNL), with space resolution 1x1 degree and time resolution of 6 hours. WRF was run with two-way nesting on 3 domains with horizontal grid resolution 36, 12, and 4 km, on 26 vertical levels up to 50 hPa (13 of them are below 2000 m). Land use categories of USGS 24-category data were used. The snow free surroundings of the Station Nord in summer are likely not accounted for in the surface conditions and poorly resolved with resolution of 4 km. WRF model temperature profiles are in general close to the observed temperature profiles. The model temperature near the ground is lower in summer with bigger difference at clear sky compared to cloudy conditions; and is closer to measurements in winter. The temperature under estimation reaches height of 1-1,5 km in clear skies and is within the first 100 m for the cloudy days, Figure 6 (upper panels). The measured wind speed profiles show high variability, while the modeled are smoothed; the wind modeled speed near the ground was close to or larger than the measured one without clear indication for the role of clouds. Larger discrepancies were found in winter, compared to summer, Figure 6 (lower panels).

Process	WRF parameter
Mycrophysics	8 (D3) = Thompson graupel; 4 (D1&D2)=WSM 5-class
Longwave radiation	1 = RRTM
Shortwave radiation	2 = Goddard
Surface layer	2 = Eta similarity
Land surface	Noah LSM
ABL	2 = Mellor-Yamada-Janjic
Cumulus parametrization	5 = New Grell scheme (D1&D2)

Figure 5. Model domains and physics options used.

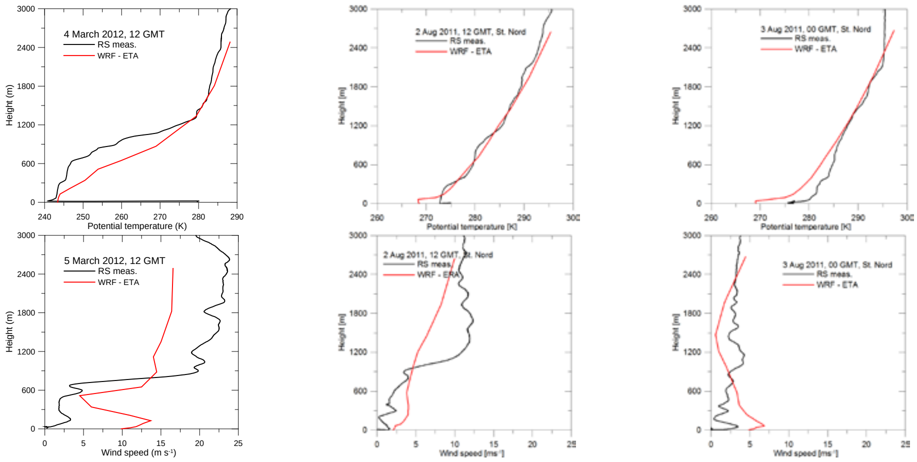

Figure 6. Comparison of modeled and measured profiles

Acknowledgments

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