4.9 THE AOE2001 METEOROLOGICAL EXPERIMENT IN THE HIGH ARCTIC

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1. INTRODUCTION

The Arctic is one of a few remaining areas on Earth where relatively little is know about the current climate and about the most important climate governing processes. Consequently, numerical simulations of the present climate are often found lacking in the Arctic while projections of anthropogenic climate change display more inter-model scatter than elsewhere (Källén et al. 2001). The reason for the lack of understanding is partly the same as that for the uncertainty in climate sensitivity between models: the fact that drifting sea ice covers much of the area. The ice has a pronounced effect on the climate while also, combined with a generally harsh environment, makes long-term measurements of even the most basic meteorological variables a logistic challenge.

A significant improvement to this problem came with the SHEBA experiment in 1997 - 1998 (Perovich et al. 1999), with a whole year of continuous measurements on the drifting pack ice. However, while SHEBA had significant surface-layer turbulence and PBL cloud components (Persson et al. 2002; Curry et al. 2000), it lacks in covering the structure of the entire depth of the PBL. Moreover, SHEBA was carried out relatively far south.

2. ARCTIC OCEAN 2001

The Swedish Secretariat for Polar Research has a tradition of icebreaker based research in the high Arctic (http://www.polar.se). Atmospheric programs focusing on atmospheric chemistry, aerosol production and other issues relating to the formation of the Arctic low-level clouds, were carried out in the summers of 1991 and 1996 (Leck et al. 1996 and 2002). A main conclusion from these expeditions was that boundary layer and mesoscale dynamics play such an important role in the Arctic, that interpreting atmospheric chemistry measurements is difficult without a good understanding of the concurrent PBL dynamics. Observed temporal variability in practically all measured chemical constituents, and in aerosols, on a variety of time-scales indicates the importance of mesoscale and PBL dynamics. An unexpected abundance of aerosols also points to the importance of open leads during the Arctic summer.

Thus the Arctic Ocean Experiment 2001 (AOE2001[1]) expedition carried a significantly augmented atmospheric boundary layer program compared to previous Swedish expeditions. AOE2001 took place between 29 June and 26 August 2001, and was based on the Swedish icebreaker Oden. The expedition as a whole consisted of several programs, on marine biology, environmental chemistry, oceanography, seismology and atmospheric sciences. The track of the cruise is shown in Figure 1.

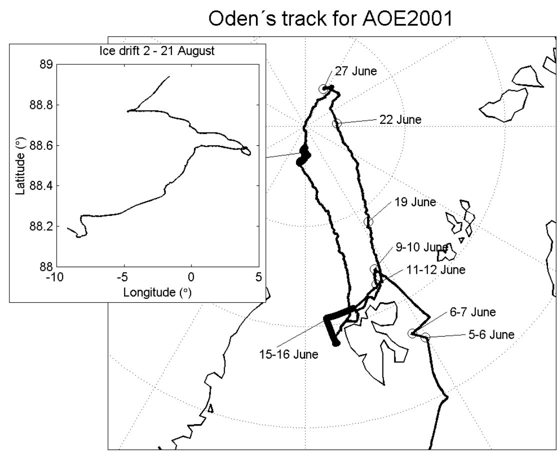

Figure 1 A map of the northern North Atlantic and Arctic with the track of the AOE2001. To the left is northern Greenland and in the bottom center portion is Svalbard. The insert shows the track during the ice-drift.

Atmospheric measurements of some kind were carried out continuously during the whole cruise, more extensively during a few research stations around Svalbard and on the transit north into the pack ice. At such stations, Oden was lying still for prolonged periods. The main atmospheric event was , however, a three-week ice-drift program between 2 - 21 August.

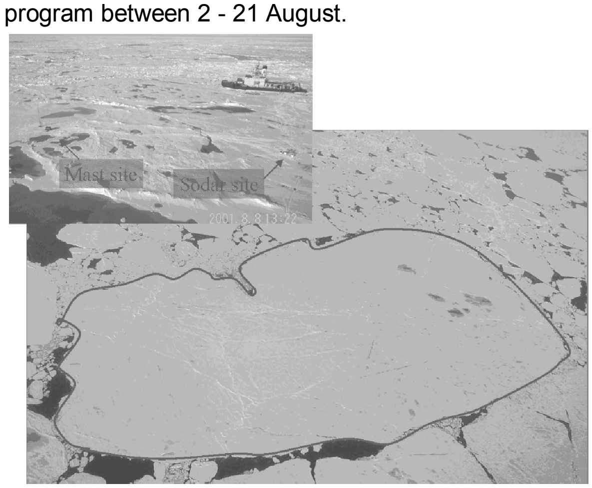

Figure 2. Photo of the ice floe used for the ice drift during AOE2001. The lower portion shows the ice floe; the experiment was conducted mostly in upper left quadrant of the floe and Oden's L-shaped harbor can be seen in the upper edge of the floe. The insert shows Oden from across the ice floe, with the measurement site.

The atmospheric program was designed to both provide a continuous record of the lower atmosphere during the entire experiment, using mainly remote sensing, and

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[1] http:// www.fysik.lu.se/eriksw/aoe2001/aoe2001.html

to resolve important mixing events in greater detail using *in situ* turbulence instruments.

3. THE ICE-DRIFT

The ice-drift experiment was conceived to minimize the effect of the icebreaker itself on the measurements, in particular for the turbulence measurements. A reasonably large ice floe (1.5-by-3 km) was located around N89° E00°. Figure 2 shows a birds-eye view of our home for the three weeks of the ice-drift taken from the helicopter that was also part of the expedition. This ice floe was fairly level with several melt-ponds of varying size, a few through the ice. The ice thickness varied from ~1.5 m to > 6 m of single-year ice.

Figure 3. View of the Oden foredeck from the topmost 7th deck, showing the square-shaped antenna for the NOAA/ETL 915MHz Wind Profiler, and the round antenna for the S-band cloud radar partly hidden aft of the forward container housing the electronics for both systems.

Almost all atmospheric chemistry and aerosol measurements continued to be taken onboard Oden, in container-housed laboratories located forward on Oden's 4th deck. The same is true also for some of the remote sensing equipment: the wind profiler and the S-band cloud radar (White et al. 2000) located on the foredeck (Figure 3) and the scanning microwave radiometer (Westwater et al. 1999). The latter was mounted topside on the 7th deck with a 270° free view in the vertical plane (Figure 4). The wind profiler carried a motion pack for correction of the winds measured while the ship was moving.

Several instrument systems were deployed on the ice during the ice-drift (Figures 5-8). Power to the ice camp instrumentation was fed from Oden via a 300-m long cable. The NOAA/ETL Sodars were disturbed by noise on Oden's foredeck, and were moved to the ice (Figure 5). Two Sodar systems were deployed: a monostatic system, to record the PBL structure, and a Doppler system for horizontal winds. Combining the Doppler winds from the wind profiler and from the Sodar should resolve much of the PBL winds continuously, while a continuous record of the temperature profile for the lowest 600 m is available from the scanning radiometer. In addition, regular radio soundings using GPS for wind measurements were launched every six hours during the ice drift.

Figure 4. Scanning microwave radiometer mounted on the starboard side of the 7th deck, with a free view over the ocean.

Alongside with the Sodar system, the CIRES tethered lifting system (TLS, Balsley et al. 1998) was deployed (Figure 6). This system was used for three different payloads: A basic met-payload for mean profiles of temperature, humidity and wind, a newly developed turbulence package and a new simplified aerosol package. It was also used to lift the inlet for an atmospheric chemistry instrument to ~200 m. It uses either an airfoil or an aerodynamic balloon, for stronger and weaker winds,

Figure 5. View of the ice-camp instruments, showing the Sodar and tethered sounding site in the foreground to the left and the tower site further back. Also seen is the helicopter that was sometimes used for aerosol profile measurements.

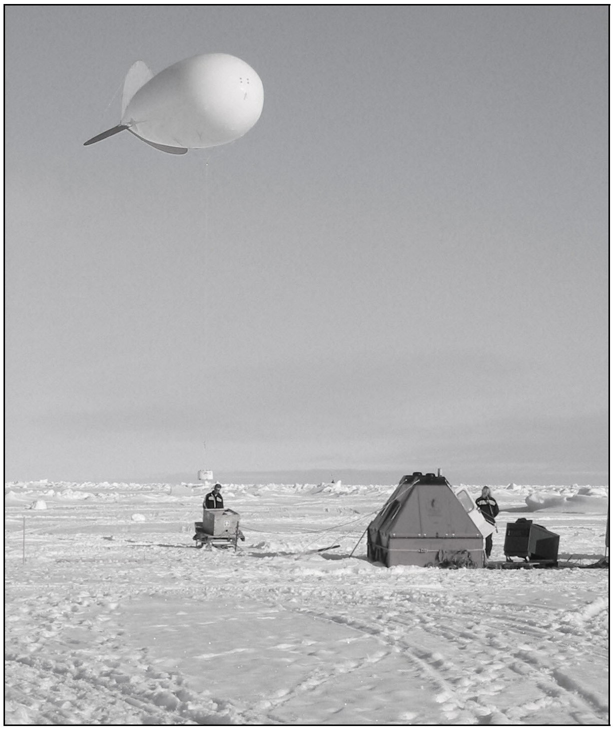

Figure 6. View of the tethered sounding system, with the kytoon being launched with the aerosol pack (visible just at the horizon).

respectively (Figure 6). Although icing on the tether was sometimes a problem, it typically reached 1 - 2 km.

One main system deployed on the ice was an 18-m mast with temperature and wind speed profiles, and sonic anemometers and krypton hygrometers at two levels for turbulence (Figure 5 and 7). Also included were wind direction, atmospheric pressure and moisture, radiometers and a temperature profile into the ice. An array of four micro-barographs, for detection of gravity waves, was also deployed here.

Figure 7. The 18-m telescopic mast, with profile and turbulence instrumentation. In front of the mast is the mandatory bear guard and to the right is the electronics hut. Oden is ~300 m away in the background.

To better describe horizontal heterogeneity and to track propagating mesoscale systems, two additional micro-meteorological systems (NCAR PAM-stations, Figure 8) were deployed on neighboring ice floes ~ 8 km away from Oden by helicopter.

Figure 8. Deployment of a PAM-station instrument stand (background), carrying one sonic anemometer and instruments for measuring mean temperature, humidity, and atmospheric pressure. The instruments are powered by batteries, fed by solar panels and a wind generator on the separate stand in the foreground.

3. SOME PRELIMINARY RESULTS

A time-height cross section of wind speed from the ice drift is shown in Figure 9. High winds were predominantly experienced in the beginning, associated with a series of synoptic scale weather systems; these can easily be seen in the cloud radar composite in Figure 10. While a few weaker systems passed during the later half of the drift, low-level clouds and fog dominated the period after Julian Day 220. The often-quoted Arctic low-level jet was mostly absent.

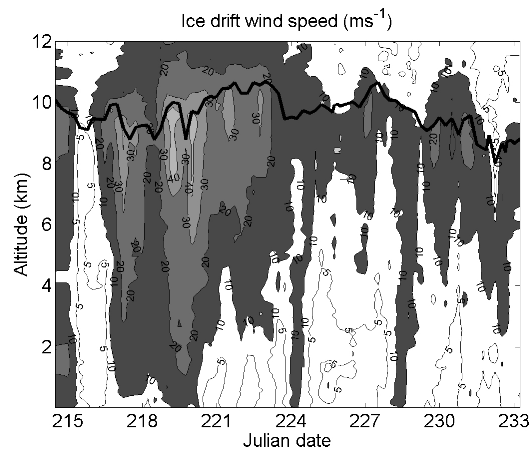

Figure 9. A time-height cross-section of scalar wind speed, from radio soundings for the ice drift. A wind speed >10 ms^{-1} are marked by shading and the tropopause is outlined by the thick solid line.

The vertical temperature profiles during the ice drift (Figure 11) show evidence of advection of warm and moist air from beyond the ice edge. Although near-surface temperature was never much above zero, several episodes with temperatures at 5 °C and higher at 1 km were encountered. During these, specific moisture often increased over the PBL inversion.

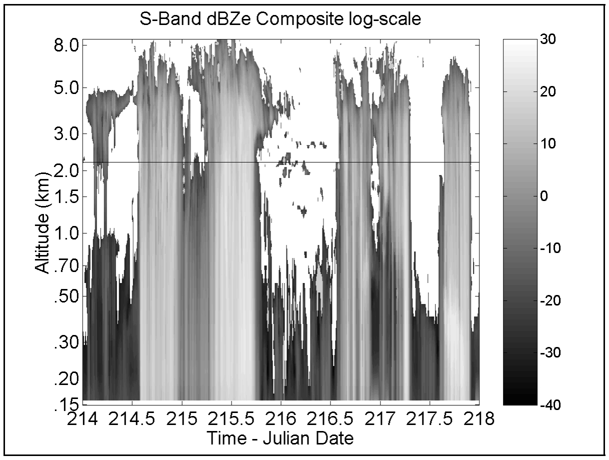

Figure 10. Time-height cross-section of radar reflectivity from the cloud radar for the first 4 days of the ice drift.

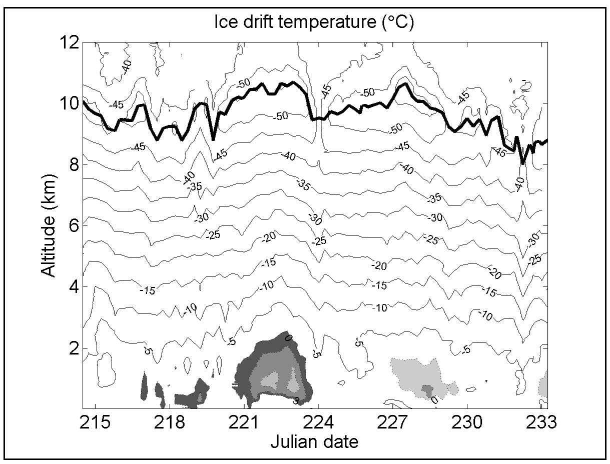

Figure 11. Same as Figure 9, but for temperature. Temperatures > 0 °C are marked by shading.

4. SUMMARY

The boundary-layer program during the AOE2001 summer experiment to the high Arctic was motivated by the need for a better understanding of the effects boundary-layer processes on atmospheric chemistry and aerosol processes relevant for the formation of low-level Arctic clouds. The expedition was based on the Swedish icebreaker Oden and lasted for two months, July and August 2001. The main focus on atmospheric measurements was during an ice-drift operation during the first three weeks of August. Instrumentation was set up to provide a continuous record of the state of the lower atmosphere, as well as detailed information on boundary layer processes during more interesting mixing events.

The continuous record is obtained from remote sensing (winds from wind profiler and Sodar, temperature from scanning microwave radiometer and clouds from S-band cloud radar) while more detailed measurements come from the echo structure from the monostatic Sodar, from turbulence sensors and profiles in an 18-m mast, on two PAM-stations and from the tethered sounding system. Additional information comes from the six-hourly soundings, background information (e.g. precipitation and visibility) from Oden's weather station and from a four-station array of micro-barographs. The analysis of the data is still in an early stage, but promises insight into processes important for PBL processes in the summertime high Arctic.

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