P3.6 OBSERVATIONS OF CLOUD PROPERTIES AND SURFACE FLUXES DURING THE MIXED-PHASE ARCTIC CLOUD EXPERIMENT

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1. INTRODUCTION

The Atmospheric Radiation Measurement (ARM) program operates a climate monitoring sites at Barrow, Alaska (Stamnes et al., 1999). Data from this site and from the Surface Heat Budget of the Arctic Ocean (SHEBA) experiment (Uttal et al., 2002) have shown that mixed phase clouds play an important role in the arctic (Intrieri et al., 2002). In September/October, 2004, ARM sponsored the Mixed-Phase Arctic Cloud Experiment (M-PACE) to provide detailed observations of mixed phase clouds. This experiment included two aircraft, the North Dakota Citation and the Department of Energy sponsored Proteus. The Citation carried a suite of in situ microphysics sensors. The Proteus is a high altitude aircraft and carried a variety of sensors but was used primarily as a remote sensing platform. M-PACE also included a second ground station to augment the observations being made at Barrow. The second ground station was located at Oliktok Point, on the Arctic Ocean coast approximately 300 km southeast of Barrow and 50 km northwest of Prudhoe Bay. The Oliktok Point site was instrumented by the PNNL Atmospheric Remote Sensing Laboratory (PARSL). PARSL includes a cloud radar, a cloud/aerosol lidar and most of the passive instruments found at the Barrow ARM site. In this paper, preliminary M-PACE data from the PARSL instruments will be shown.

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2. SURFACE FLUXES AND THE ATMOSPHERIC STATE

PARSL is a mobile suite of instruments designed to measure the surface radiation budget and profiles of water vapor, aerosol, and cloud properties to study the impact of clouds and aerosol on atmospheric radiation. During M-PACE, PARSL was deployed to provide a second set of atmospheric measurements and, in particular, to provide these measurements in a remote location where air space restrictions were less stringent than at Barrow. Air space

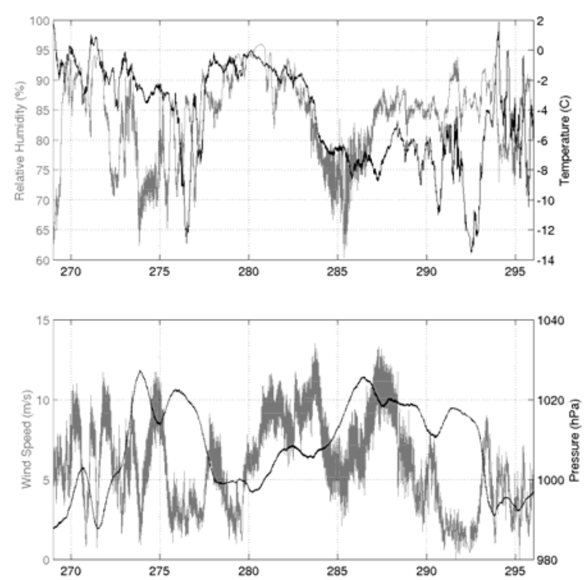

Figure 1. PARSL meteorological observations beginning September 25 (Day 269). All data plotted are 1-minute averages. The upper panel includes Relative Humidity (gray) and Temperature (black) and the lower panel includes wind speed (gray) and pressure (black).

availability over the site was important because of the use of aircraft over the sites and because a tethersonde operated by Sandia National Laboratory was also deployed adjacent to the PARSL instruments.

M-PACE ran from September 27 through October 22. PARSL was operational by September 25. In Figure 1, data from the PARSL surface meteorology sensors shows the evolution of conditions through the experiment. Over the course of the 4 weeks, the region went through a significant meteorological transition. Immediately prior to the experiment, the ground was snow free, the ocean was ice free, and there was little ice on the many ponds that are found in the tundra. The winter season's first significant snowfall occurred a few days prior to the beginning of data collection.

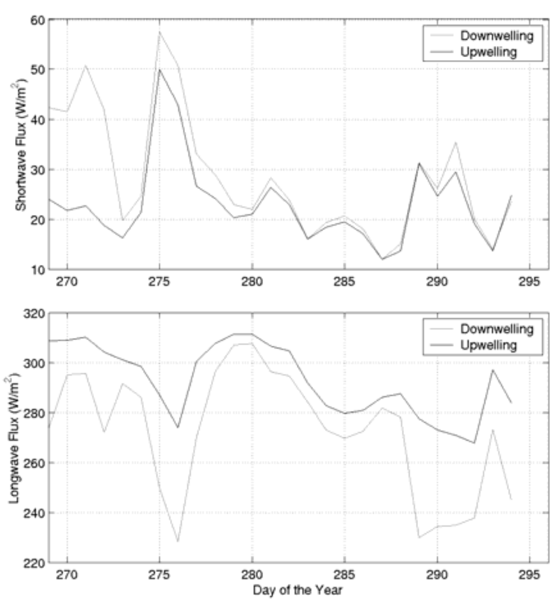

Figure 2. Shortwave (0.3-4 micrometers) and longwave (5-50 micrometers) surface radiative fluxes observed during M-PACE.

Broadband solar radiation data in Figures 2 and 3 show the surface albedo increasing rapidly in the first days of the experiment as the surface becomes fully snow-covered. After approximately October 6 (day 280) the albedo remained close to 1. On the last day plotted, the albedo is seen to exceed 1. This value is likely due to the cosine response of the upward-looking detector which produces a bias given a direct solar beam at low sun angles.

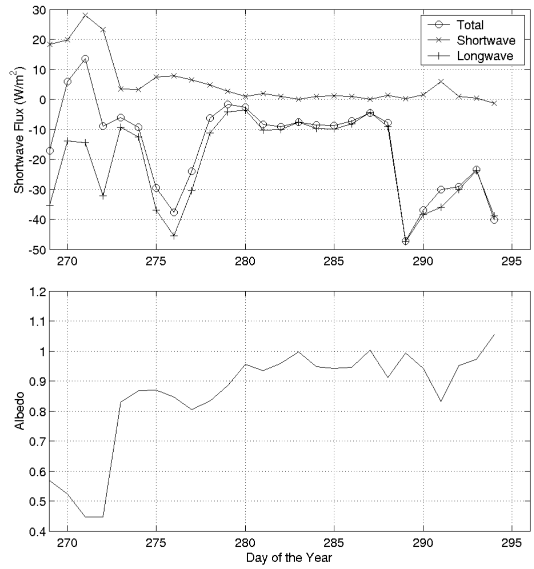

Figure 3. Net surface radiative flux (positive values indicate a net flux into the surface) and the surface albedo (upwelling shortwave flux/downwelling shortwave flux).

The middle portion of the experiment, from October 3 (Day 277) through October 14 (Day 288) was dominated by low clouds. A sounding from this period is shown in Figure 4.

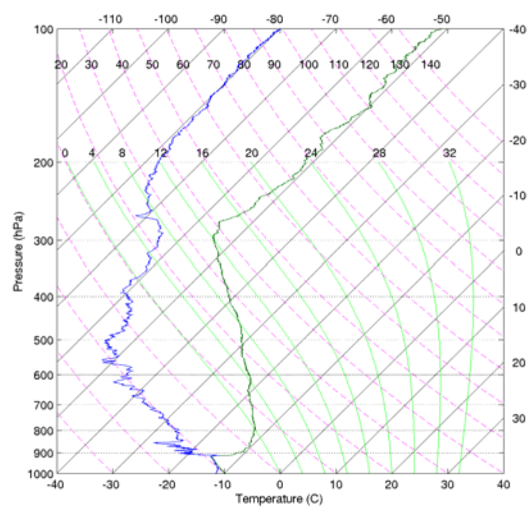

Figure 4. Skew-T plot of temperature and dew point data obtained from a radiosonde launched at 00 UTC on October 13.

The sounding data in Figure 4 illustrates the strong temperature inversion that was observed near the surface throughout much of the experiment. In this case, the inversion is found near 900 hPa.

3. REMOTE SENSING OBSERVATIONS

Data from the 94 GHz PARSL radar in Figure 5 illustrates the persistent low-lying cloud layer that dominated the middle portion of the experiment. Radar reflectivity and Doppler velocity data from the zenith pointing radar are plotted for October 10-14. The Doppler velocity data are only plotted where the reflectivity exceeds a threshold of -50 dBz. Throughout much of the layer shown in Figure 5, the Doppler velocities are positive indicating falling particles. These falling particles are likely relatively large ice particles which dominate the reflectivity signal through much of the layer. There is a thin layer near cloud top that exhibits lower lower radar reflectivity and Doppler velocities near zero. This is likely the liquid portion of the cloud.

The PARSL radar and lidar each operated nearly continuously throughout M-PACE. The only significant down time (approximately 10 hours) occurred on October 18 when the site's primary power source (a diesel generator) temporarily failed. The two instruments will provide an important component of the M-PACE data set. In addition to the Doppler moments, Doppler spectra were also collected from the radar at times when one of the aircraft was overhead.

The PARSL lidar is a single wavelength system operating at 532 nm (an ultraviolet channel is being added). There are two polarization channels that allow discrimination of liquid and ice phases. There is also a wide field of view channel.

Data from the radar and lidar are shown together in Figure 6 for the period October 14-19. The beginning of this record overlaps the radar image in Figure 5. The lidar data between 00 and 06 UTC on October 14 show a strong return near 400 m that likely corresponds to cloud base. The lidar return is quickly attenuated above this level. The radar data for this period shows a cloud top near 1 km with an ambiguous cloud base due to strong reflectivity associated with precipitation. As is often the case in the presence of moderate precipitation, the lidar here provides the better estimate of cloud base while the radar indicates the location of cloud top.

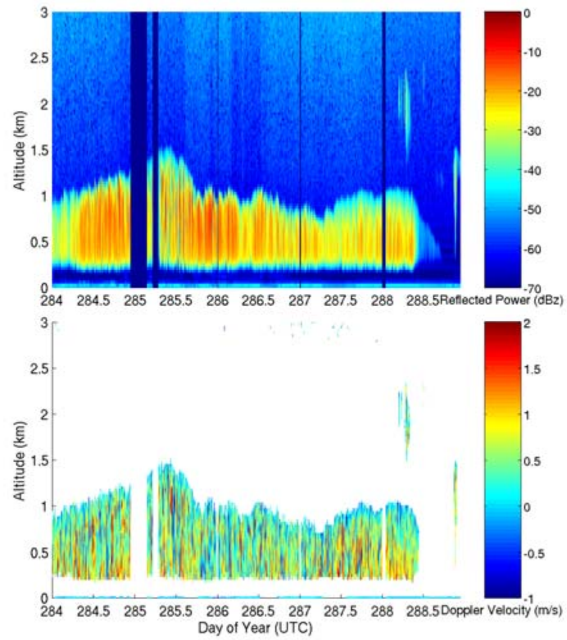

Figure 5. Radar reflectivity (top panel) and Doppler velocity (lower panel) from day 284 (October 10) through day 289 (October 14). In the Doppler velocity plot, values were only plotted where the reflectivity exceeded -50 dBz. Positive velocities are downward, toward the radar.

Later on October 14, the stratus layer dissipated. Over the next five days, no longer impeded by an optically thick stratus layer, the lidar frequently observed middle level clouds and cirrus. On October 17-28, a vertically thin layer in the lidar data beginning at 5 km and descending to 3 km appears to be associated with an aerosol layer.

4. CONCLUSIONS

The PNNL Atmospheric Remote Sensing Laboratory has collected approximately four weeks of data associated with the ARM Mixed-Phase Arctic Cloud Experiment. These data include surface fluxes, properties of the

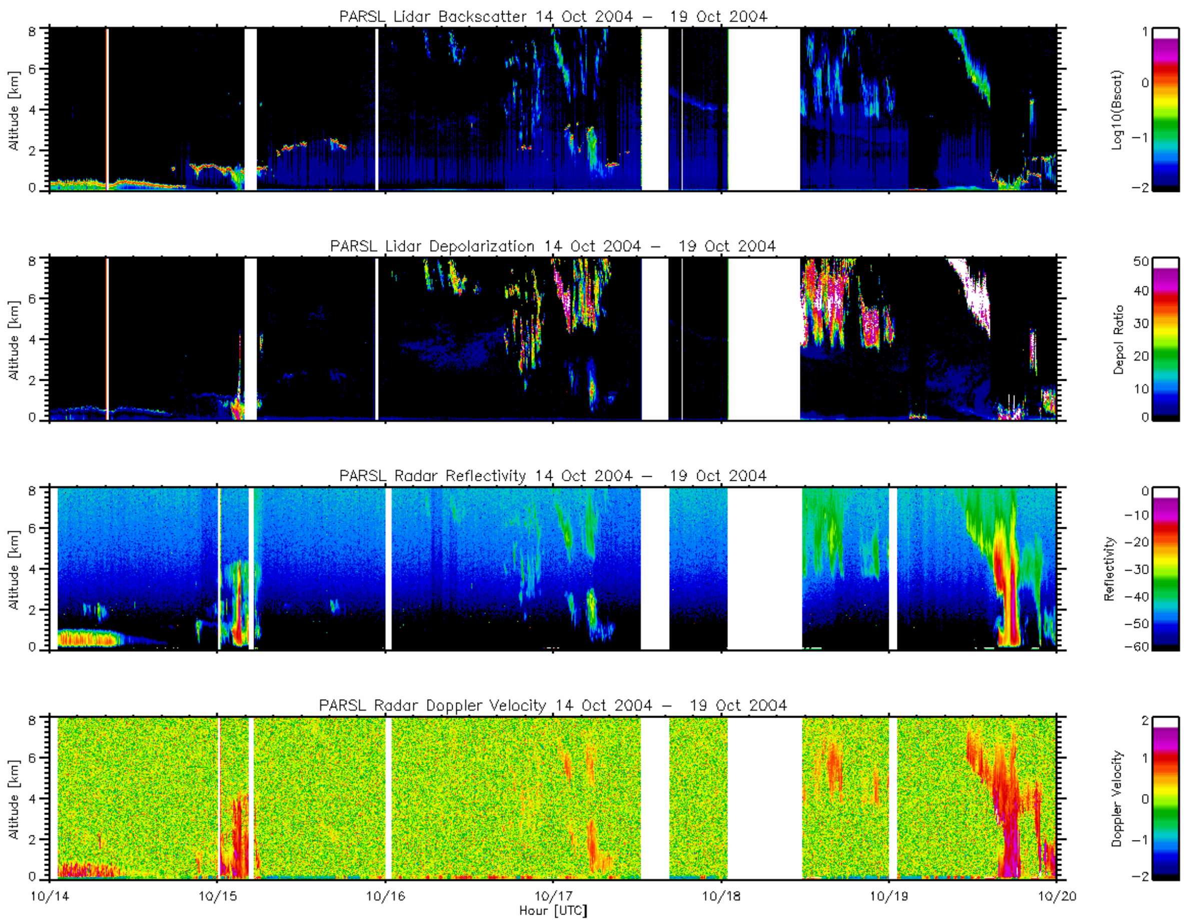

Figure 6. Radar and Lidar observations for the period October 14 through October 19. This period encompasses the end of the extended overcast conditions that dominated the middle part of the experiment and the end of the experiment which was dominated more by cirrus. The data gaps on October 17 and 18 were the only significant missing data periods for the experiment and are associated with loss of site power.

atmospheric state and active remote sensing data from a cloud radar and cloud lidar. These data will soon be made available through the ARM archive and will be a useful component of the M-PACE dataset.

5. REFERENCES

Intrieri, J.M., M.D. Shupe, T. Uttal, and B.J. McCarty, 2002: Annual cycle of arctic cloud geometry and phase from radar and lidar at SHEBA, *J. Geophys. Res*., **107**, 10.1029/2000JC000423.

Stamnes, K., R.G. Ellingson, J.A. Curry, J.E. Walsh, and B.D. Zak, 1999: Review of science issues, deployment strategy, and status for the ARM North Slope of Alaska-Adjacent Arctic Ocean climate research site. *J. Clim.*, **12**, 46-63.

Uttal, T., et al., 2002: Surface Heat Budget of the Arctic Ocean. *Bull. Amer. Met. Soc.,* **83***,* 255 – 275.