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The Mixed-Phase Arctic Cloud Experiment (M-PACE)

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Findings Report

1. Introduction

Funded by the Department of Energy (DOE)'s Atmospheric Radiation Measurement (ARM) Program, the Mixed-Phase Arctic Cloud Experiment (M-PACE) was conducted on the North Slope of Alaska (NSA) in October 2004. The experimental domain (Figure 1) simulated a single-column modeling grid-box. The NSA site at Barrow was supplemented with the High Spectral Resolution Lidar from the University of Wisconsin and the University of Alaska, Fairbanks, depolarization lidar. The Pacific Northwest National Laboratory Atmospheric Remote Sensing Laboratory (PARSL) was deployed at Oliktok Point, supplemented with a rapid scan atmospheric emitted radiance interferometer (AERI) from the University of Wisconsin. Radiosonde launches were conducted from the four surface sites.

Figure 1. The M-PACE experimental domain.

Two instrumented aircraft participated in the experiment: the University of North Dakota Citation served as an in situ platform, while the piloted Scaled Composites Proteus, sponsored by the DOE's Unmanned Aerospace Vehicle (UAV) program served as a remote sensing aircraft flying above the cloud decks.

2. Weather Description

The NSA locale was under, essentially, three different synoptic regimes during M-PACE. The first regime, between September 24 and October 4, was unsettled. The North Slope was affected by a small, low-pressure center (~990 hPa) with a large high-pressure system northwest of the Alaskan coast over the Arctic Ocean. The first 2 case days, September 29 and 30, occurred in the heart of this weather regime. On September 27, the low pressure center tracked west out of northern Canada stalling to the south of Barrow with deep clouds. Oliktok and Toolik were clear because these regions were in the dry slot. On September 28, the stalled low began to track back eastward bringing with it our first shot of low-level mixed-phase clouds.

After October 4, the synoptic regime changed considerably with high pressure building in over the pack ice to the northeast of the Alaska coast that dominated the synoptic regime until the 15th. Initially (October 4-8), flow associated with the high pressure system came out of the east-northeast with considerable fetch along the Arctic Ocean before impinging on the Alaska coast. This was the source of the cloudiness experienced during the flight operation days of October 5 and 6. By October 8, temperatures over the pack ice had dropped considerably reaching ~ -20°C (Figure 2) with a strengthening of the high. The flow that reached the Alaska coast now came directly from the pack ice (Figure 2) and, along with it, boundary layer roll clouds (Figure 3). These rolls likely produced periodic oscillations in cloud depth observed at Barrow and Oliktok. This regime was the main driver of cloudiness during the October 8-10 and October 12 case days.

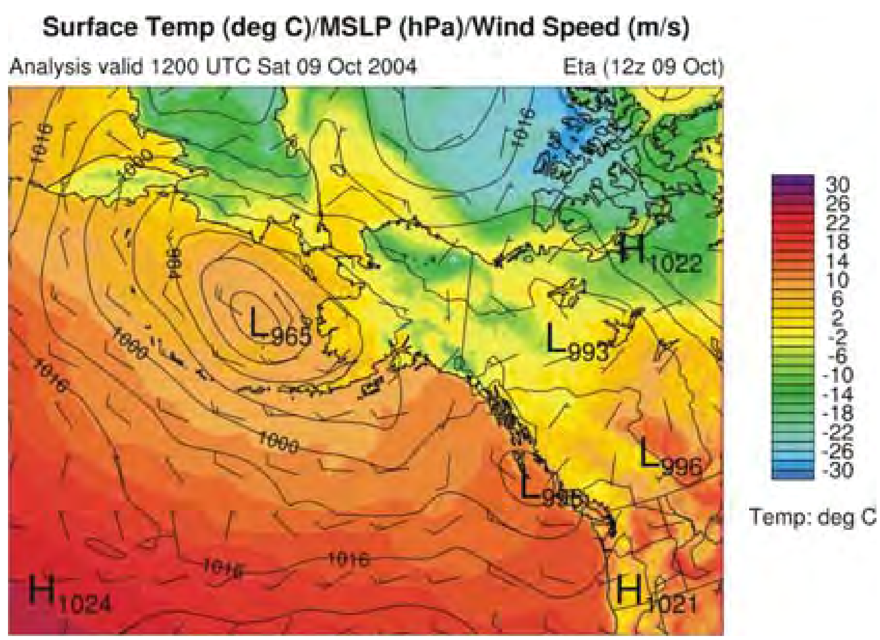

Figure 2. ETA analysis for 1200 UTC Saturday October 9, 2004. Shown are temperatures (shaded), mean sea level pressure (contoured) and windbarbs.

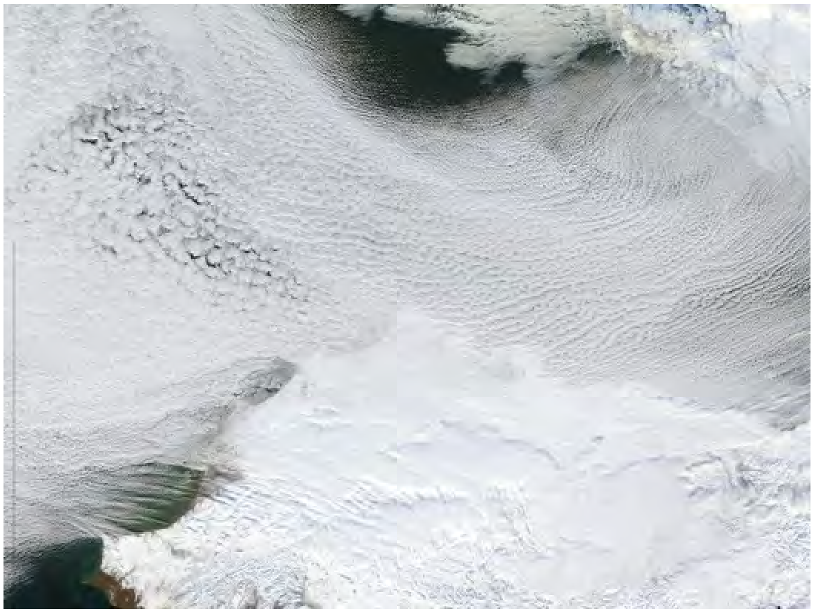

Figure 3. MODIS visible image of the Arctic Ocean and Northern Alaska on October 9, 2004.

After October 15, the high pressure over the pack ice slowly moved towards the southeast. With the block removed, strong low-pressure centers (~950 hPa) that were forming near Kamchatka and propagating north through the Bering could now affect the North Slope. Eventually, a low propagated into the northwestern portion of the Chukchi Sea producing southerly flow for much of the NSA (Figure 4). This kept much of the eastern NSA under partially cloudy, or even clear, skies.

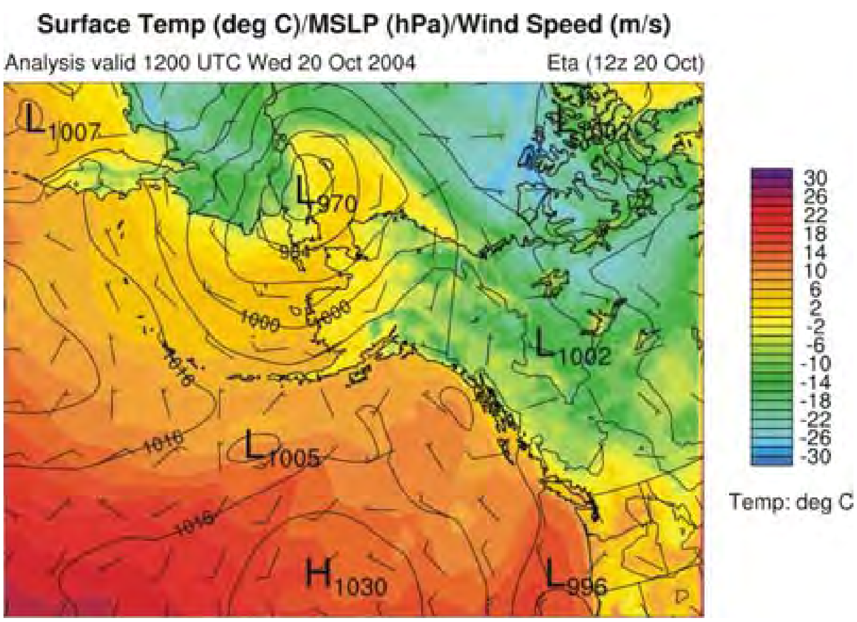

Figure 4. ETA analysis for 1200 UTC Wednesday, October 20, 2004. Shown are temperatures (shaded), mean sea-level pressure (contoured) and wind (barbs).

However, frontal systems spawned by the low strongly affected the NSA west of a line between Barrow and Oliktok. This produced deeper clouds near Barrow and plenty of high cirrus. This synoptic regime occurred throughout the remainder of the experiment.

3. Missions

The Citation flew 14 missions and the Proteus flew five missions in support of M-PACE. Summaries of the conditions for all flights are provided in Table 1. In total, 11 missions were dedicated to characterize M-PACE and two flights for cirrus. Ice freezing nuclei (IN) concentrations were measured on all October flights. Two flights were dedicated to documenting the cloud characteristics in close proximity to the location where IN concentrations were measured. Cloud top temperatures ranged from -6° to -30°C for the St/Sc cases sampled. Droplet concentrations were generally low, but two cases exhibited concentrations in the 100's cm^{-3}. Liquid water contents varied between ~.1 to 1 g m^{-3}. All these clouds had ice precipitation.

Table 1. Summary of M-PACE aircraft operations. All data are preliminary and may change with future quality control. Proteus flights are indicated with *, satellite coordination with &.

Date	Category	T_{min} (C)	FSSP (cm^{-3})
09/29	BL St	-15	70-90
09/30	Multi-layer St	-15.5	20-70
10/05	Multi-layer St	-6	100-400
10/06	Multi-layer St	-17	25-50
10/08*&	Multi-layer St	-11	20-30
10/09a*	BL St	-16	50-100
10/09b	BL St	-15	300-500
10/10*&	BL St	-17	20-40
10/12*&	BL St	-15	40-60
10/16	Aerosol		
10/17*&	Ci	-57	50 L^{-1} 2DC
10/18	Ci	-55	20 L^{-1} 2DC
10/20	Aerosol/Sc	-13.5	10-30
10/21	Aerosol/Sc	-23/-30	15

Data from all measurement sites are being collected at the ARM intensive operational period archive at http://iop.archive.arm.gov/mpaftp which, at this point, is still considered a closed archive until all principal investigators have cleared their data.