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THE SOUTH POLE ATMOSPHERIC RADIATION AND CLOUD LIDAR EXPERIMENT (SPARCLE)

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1. INTRODUCTION

Longwave radiation spectra emitted by clouds, greenhouse gases, and the snow surface are being measured at South Pole Station using the Polar Atmospheric Emitted Radiance Interferometer (PAERI). This experiment is currently underway from November 2000 to November 2001. The PAERI spectra are being used to improve atmospheric radiation models of the water-vapor greenhouse effect, and to quantify the contributions of water vapor, carbon dioxide, ozone, and clouds to the longwave energy budget of the Antarctic Plateau. The spectra are also being used for ground-based remote sensing of cloud base heights, cloud optical depths, and sizes of cloud ice crystals and water droplets. The interferometer can be configured as a transmissometer to measure absorption of water vapor along a horizontal path near the surface. The vertical distribution of backscattering by ice crystals in clouds is measured by a micropulse lidar. Ice crystals in clouds, as well in diamond dust and blowing snow, are sampled by a hydrometeor videosonde (HYVIS) flying on a tethered balloon, and are also collected at the surface as they fall, for photomicroscopy. The balloon also carries a frost-point hygrometer to measure humidity in the lowest kilometer of the atmosphere, for use in explaining the ice crystal shapes observed and to constrain the radiation modeling.

2. INSTRUMENTATION

The Polar Atmospheric Emitted Radiance Interferometer measures longwave radiation emission at a spectral resolution of 1 cm^{-1} from 3 to 22 micrometers wavelength. This instrument is similar to the AERI instrument in use at the North Slope of Alaska Atmospheric Radiation Measurement (ARM) site and to the AERI used during the Surface Heat Budget of the Arctic Ocean (SHEBA) experiment, in that it has an extra-longwave detector. The PAERI differs from the Arctic AERIs in that it can potentially view scenes over a 180-degree range, from vertically upward to vertically downward. In its present configuration at South Pole Station, it can view from vertically upward to approximately 45 degrees from nadir. Therefore, it is capable of measuring radiation from both the atmosphere and the snow surface.

The interferometer, used as part of the PAERI, can be re-configured as a transmissometer. In this alternative configuration, an infrared beam from a hot source is sent through the interferometer, which modulates the source radiation. This radiation is then sent out of the instrument horizontally by a collimating telescope at a height of 1 meter above the snow surface. A 50 cm by 50 cm array of retroreflectors is then used to reflect the infrared beam back into the telescope and to an infrared detector (2 – 25 μm). The retroreflector is placed at various distances along a horizontal path to measure transmission. The transmission is calculated by taking the ratio of a measurement with a retroreflector far from the instrument (up to 1 km away) to that of a measurement with a retroreflector near the instrument (10 m).

A micropulse lidar (MPL) is being operated in collaboration with the Cloud and Aerosol Lidar group of NASA Goddard (Spinhirne, 1993). The MPL was originally developed as an instrument for the ARM program. It operates in the visible spectral region at 0.523 nm, and has a vertical resolution of 30 meters.

The hydrometeor videosonde (HYVIS) is normally operated as a balloonborne instrument (Murakami and Matsuo, 1990). In collaboration with NCAR, we are

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using the HYVIS on a tethered balloon to measure the sizes and shapes of particles within boundary-layer clouds. The HYVIS uses two CCD cameras for near-angle and wide-angle views. These two magnifications are continuously switched electronically during flight. At high magnification, particle dimensions larger than about 7 μm can be resolved. A Vaisala RS-80 radiosonde is flown with the HYVIS to record the temperature and humidity as a function of pressure.

Frost-point hygrometers (from Meteolabor) are being operated both near the ground and on the tethered balloon. In conjunction with the South Pole Weather Office (SPWO), the response times of the humidity sensors on various radiosondes (Vaisala RS-80, AIR-4A, AIR-5A), as well as that of the frost-point hygrometers, are being measured by recording data as the instruments equilibrate when moved outdoors, then indoors. Preliminary analysis shows that the response times of the hygrometers on the RS-80 and the AIR-4A are about 30 seconds, whereas it is several minutes for the AIR-5A, the current sonde in use by the SPWO.

Two strings of closely-spaced thermistors are measuring temperature variations in the lowest two meters of the atmosphere. The lowest of these thermistors measures the snow surface temperature, and both strings are manually reset as snow accumulates, so that the bottom thermistor is always at the air-snow interface.

3. PRELIMINARY RESULTS

The horizontal uniformity of the surface of the Antarctic Plateau makes it suitable as a natural laboratory for measurement of the continuum absorption spectrum of water vapor and its temperature dependence at low temperatures. The continuum absorption coefficients are needed for climate modeling to compute cooling to space by upper tropospheric water vapor worldwide. For this experiment, the transmissometer will be operated during two intensive operating periods of one month each. The water vapor density is measured by frost-point hygrometers spaced along the horizontal path. Figure 1 shows a comparison of time series of two frost-point hygrometers that were 250 meters apart along the horizontal path. The differences in frost-point temperature between the two instruments are less than 0.2 K, which corresponds to about 1.5% in water vapor density. This indicates that there are times when transmissometer measurements can be made for periods of hours when the water vapor density is very stable along the path.

The HYVIS flights from the austral summer of 2000/2001 show that some boundary-layer stratocumulus clouds consist solely of supercooled liquid water droplets at temperatures of –27 to –30 C. Figure 2 shows examples of water droplets as measured by the HYVIS. Images such as this one will be used to determine size distributions of water droplets in summertime clouds over the Antarctic Plateau. Figure 3 shows examples of ice crystals measured by the HYVIS in late summer.

The austral summer flights of the tethered frost-point hygrometers show that the relative humidity with respect to liquid water is typically 40-50% on clear days, and 70-75% (translating to 100% with respect to ice) on days with ice-crystal precipitation.

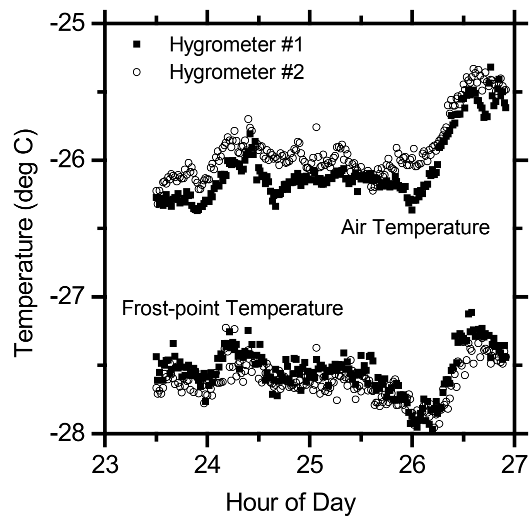

Figure 1. Comparison of near-surface air temperature and frost-point temperature as measured by two frost-point hygrometers on 7-8 December 2000 at South Pole Station. Hygrometer #1 and Hygrometer #2 are approximately 250 meters apart.

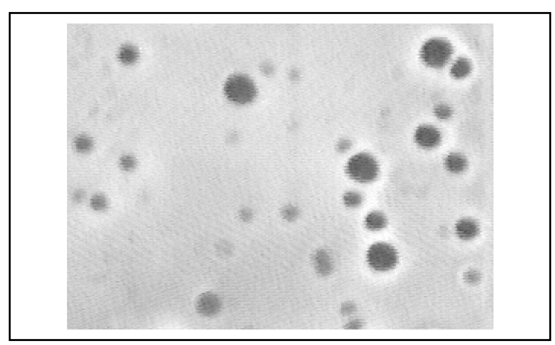

Figure 2. Impacts from water droplets onto a tape coated with silicon oil inside the hydrometeor videosonde. This image, measured at high magnification, was taken on 2 February 2001 at South Pole Station. The sizes of the water droplets are yet to be determined. Preliminary estimates of their radii are in the range of 10 to 25 microns.

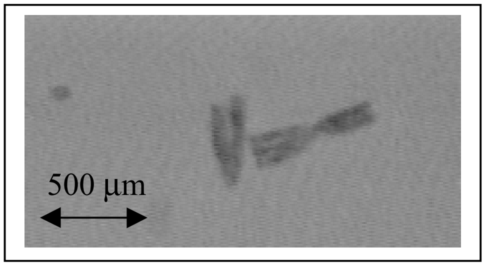

Figure 3. Ice crystals as measured the hydrometeor videosonde. This image, measured at low magnification, was taken on 29 January 2001 at South Pole Station.

4. FUTURE WORK

PAERI observations of the snow surface will be used to infer simultaneously the spectral longwave emissivity and the surface temperature of snow and surface frost. The emissivity experiment is designed to resolve a conflict between theoretical predictions and laboratory measurements of the dependence of emissivity on snow grain size. Data from the thermistor strings will be used support the emissivity experiment and to investigate the surface-to-2-meter temperature difference and its dependence on wind speed and cloud cover.

Spectra measured by the PAERI will also be used to provide an annual cycle of spectral downward longwave radiation, as well as cloud properties using the methods of Mahesh et al. (2001a,b).

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