Cloud Cover and Phase During Arctic Winter from DABUL Lidar

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Introduction

The characteristics of wintertime Arctic clouds are not well understood because opportunities for observations are rare and perpetual darkness prevails (Curry et al. 1996). The study of cloud properties and their effect on radiative transfer is an important component of the Surface HEat Budget of the Arctic (SHEBA) experiment (Moritz et al. 1993), which began in October 1997 and will continue for 1 year. One of the main instruments at SHEBA is a scanning version (Eberhard et al. 1998) of the Depolarization and Backscatter Unattended Lidar (DABUL; Grund and Sandberg 1996; Alvarez et al. 1998). It operates from the deck of Des Groseilliers, a Canadian icebreaker and research vessel, as it drifts with the ice pack in the Arctic Ocean north of Alaska. Our laboratory is simultaneously observing clouds with an 8-mm wavelength cloud radar identical to the millimeter wave cloud radar (MMCR; Moran et al. 1998) used at Cloud and Radiation Testbed (CART) sites. The combination of data from these instruments and others will reveal much about the geometrical and microphysical features of Arctic clouds.

Lidar Description

The DABUL system is an eye-safe, automated lidar designed to obtain research-grade measurements of clouds and aerosols using elastic backscatter. Basic specifications are listed in Table 1, and more information and data examples are given in Grund and Sandberg (1996), Alvarez et al. (1998), and Eberhard et al. (1998). DABUL uses "micropulse" technology similar to that in the micropulse lidar (MPL) at CART sites (Spinhirne et al. 1997). Eye safety at a visible wavelength (green) is attained through low pulse energy and expanded beam. Adequate signal-to-noise ratio is achieved by high pulse rate and averaging of pulses (seconds to minutes), in which photon counting gives linear accumulation and large dynamic range. A narrow bandpass filter and very small field of view adequately reject background light for daytime operation. However, DABUL has several important capabilities beyond those of the current MPL:

Table 1. DABUL specifications.

Laser	Spectra Physics Nd:YLF×2
Wavelength	523 nm
Pulse energy	40 μJ
Pulse rep rate	2000 Hz
Polarization	alternating linear
Telescope diameter	0.35 m
Spectral bandpass	0.3 nm
Fields of view	100,640 μrad (simultaneous)
Detectors	EMI 9863 PMTs
Range resolution	30 m
Averaging time	1 s to 60 s
Scan range	±110 from zenith
Scan rate	0.1 s^{-1} to 1.2 s^{-1}

1. DABUL measures linear depolarization ratio in the backscatter, which reveals the phase (water or ice) of clouds (Sassen 1991). The linear depolarization ratio δ from pure water clouds, molecules, and most aerosol particles is at most a few percent, whereas δ from ice particles, which are very nonspherical, is typically 30% to 60%.

2. DABUL operates from its own all-weather housing, which permits great flexibility in siting. This avoids the trouble of providing a new housing and window for each deployment.

3. Optional scanning by DABUL (in one vertical plane) considerably expands the lidar's capabilities. It greatly enlarges the probed volume of the atmosphere. Minimum range limitations are circumvented, permitting high quality data all the way to the surface

(e.g., fog). Multi-angle techniques (e.g., Gutkowicz-Krusin 1993) can be applied for more quantitative information on aerosol optical properties.

Lidar and radar provide complementary information on cloud layers. Precipitation, which is present a high percentage of the time in the Arctic, swamps the radar's cloud signal. The lidar can differentiate between the two, and depolarization measurements identify the phase of cloud and precipitation. The radar can observe the entire extent of optically thick clouds that the lidar can only partly penetrate. Lidar becomes a particularly important part of this duo in the cold Arctic, where optically thin clouds are proportionately more common than in warmer climates.

Preliminary Results

As data from SHEBA first became available, DABUL and radar data were perused to obtain a preliminary description of the presence of clouds and precipitation from November through January. Some resulting statistics are presented by month in Table 2. This analysis is for the whole vertical column, so the presence of both water and ice could be from either mixed-phase clouds/precipitation or from separated layers of ice and water cloud.

Table 2. Frequency of cloud and precipitation during winter at SHEBA.

	Nov.	**Dec.**	**Jan.**
Fractional cloud/precip cover (F)	0.75	0.46	0.52
% of F water only	5	1	9
% of F ice only	39	75	32
% of F both water and ice	55	24	59

Clouds were definitely more prevalent in November. The increase from December to January in both cloud cover and the percentage of water-containing clouds is interesting—whether this has climatological significance or is only a result of shifts in weather patterns should be investigated.

A remarkable result is the prevalence of water and mixed-phase clouds, especially in January. Although pure water clouds were relatively rare, mixed-phase clouds with ice precipitation beneath were quite common. Sometimes mixed-phase clouds were embedded in a field of ice precipitation, which raises interesting questions about the formation and evolution of clouds in such a complex manner. The DABUL data indicate that the frequency and optical thickness of water-containing clouds make them important to radiative transfer in the Arctic even during the winter.

Future Work

The DABUL measurements in the Arctic will be used to prepare a seasonal climatology of cloud characteristics, study their radiative effects, and determine their role in the surface heat budget. The data will also help improve the interpretation of satellite data for cloud properties in the special and difficult circumstances of the Arctic. DABUL observations will also be incorporated into modeling studies of cloud processes.

DABUL is scheduled for two experiments of interest to ARM in addition to SHEBA. The first is to study Arctic haze at Barrow during spring 1999 under National Oceanic and Atmospheric Administration (NOAA) sponsorship. Collaboration with North Slope of Alaska (NSA) site scientists on cloud, radiation, and MPL measurements would be a desirable adjunct. The second experiment is the deployment of DABUL on the NOAA ship Ron Brown together with other instruments from our laboratory and elsewhere. The objective is to evaluate how well the Nauru CART measurements from the island represent conditions over the nearby ocean and throughout the larger region.

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