NOTES AND CORRESPONDENCE

Airborne Lidar Observations during AGASP-2

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ABSTRACT

Sample observations of the lower troposphere made by airborne lidar during the Arctic Gas and Aerosol Sampling Program-2 (AGASP-2) are shown for the area of Thule, Greenland. The lidar detected multiple haze layers, dense water clouds, ice crystal precipitation, and other features of interest over northern Greenland and the pack ice of Baffin Bay. The observations attest to the utility of a relatively simple airborne aerosol backscatter lidar in support of atmospheric studies in Arctic and Antarctic regions.

1. Introduction

During the Arctic Gas and Aerosol Sampling Program-2 (AGASP-2), SRI International's Airborne Lidar Plume and Haze Analyzer (ALPHA-2) was flown on board the University of Washington's C-131 aircraft to map the structure of lower atmospheric haze layers. The airborne lidar system was operated out of Thule, Greenland, during April 1986, and data were collected for a total period of 29 hours. Two flights of 5 to 6 hours duration were made directly to Alert, Northwest Territories, Canada (82°30′N, 62°18′W). All data, including those collected on the way to Thule from Bangor, Maine and along the return route from Thule to Seattle, Washington, were processed as pictorial displays showing atmospheric aerosol structure to be integrated into the AGASP-2 database. The purpose of this note is to present several data examples that show interesting features observed by the lidar in the area of Baffin Island and northern Greenland. In situ measurements and other observations made by the aircraft were not available but will be integrated at a later time. Thus, no data on atmospheric ambient temperature or stability and on the composition of lidar-observed clouds are included.

2. Equipment

The ALPHA-2 is a compact, lightweight aerosol-backscatter lidar system designed for installation in a variety of large and small aircraft. A LSI-11/73 microprocessor system is used to digitize, record, and display the data for real-time viewing of atmospheric structure. During AGASP-2, the ALPHA-2 lidar was operated at the near-infrared wavelength of 1.064 μm. Laser pulses were normally emitted at a rate of 2 s^{-1}. Backscattered laser light for each pulse was collected by a 14-inch Dall–Kirkman telescope and focused on a solid-state detector after background light was filtered from the backscatter signature. Within a distance of about 200 m from the lidar, the receiver and transmitter beams do not fully overlap and, therefore, no backscatter data can be obtained. The signal output from the detector for distances beyond 200 m was logarithmically amplified and then digitized. Each lidar signal was digitized at 20-ns (3 m) or 50-ns (7.5 m) resolution to generate a backscatter profile of 1000 data points and a block of housekeeping information. These data were recorded on a 60-megabyte, one-quarter-inch digital cartridge tape. The data records were processed and displayed on height/time facsimile gray-scale charts with 500-m range marks in the vertical and 5-minute time marks in the horizontal. During AGASP-2, these height/time data plots were presented in real time on a graphic color video display to show atmospheric backscatter and terrain features and to help direct aircraft traverses of interest. Application of aerosol backscatter lidar observations to atmospheric investigations has been discussed by Uthe (1983).

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3. Observations

Figures 1 through 3 show height/time atmospheric cross sections that highlight various features observed by the lidar. The aircraft flight altitude is at the top of each cross section. The gray-scale indicates the strength of the lidar signal such that stronger backscatter signals produce darker areas.

Figure 1 shows lidar observations of "arctic sea smoke" fog plumes that developed over open leads in the pack ice about 50 miles northwest of Thule on 4 April. These phenomena were visually seen from the aircraft. The data of Fig. 1 cover a flight period of 40

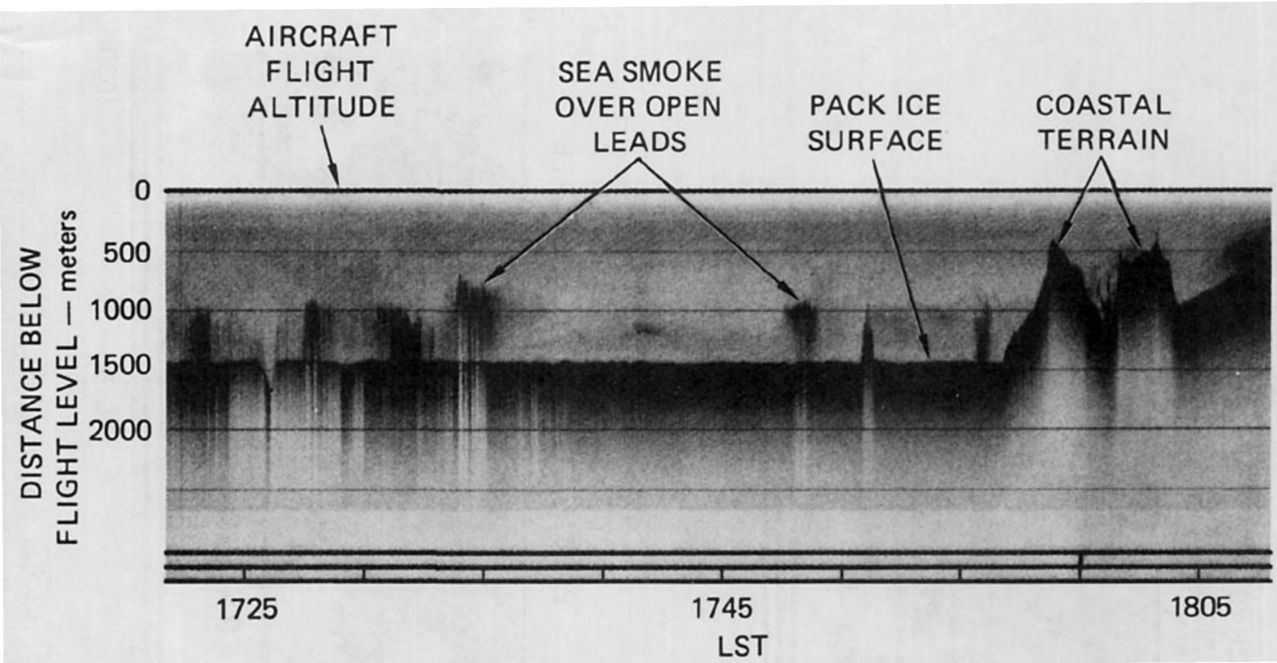

FIG. 1. Airborne lidar observations of arctic sea smoke over open leads in pack ice about 80 km northwest of Thule, Greenland on 4 April 1986. Aircraft altitude is at top of cross section. Coastal topography is evident on right side.

minutes, which equates to a horizontal distance of 200 km (124 miles). The coast near Thule is on the right-hand side of the plot. The flight altitude was 1600 m above the ice surface. The observed steam plumes rise straight up to 500 m above the areas of open water. Haze layers (indicated by variable gray-scale stratification) are present between the aircraft and the ice pack.

Figure 2 shows multiple haze layers observed by the lidar while the aircraft was descending into Thule from a location over the ice pack about 200 km to the southwest. When the aircraft descends, the observed atmo-

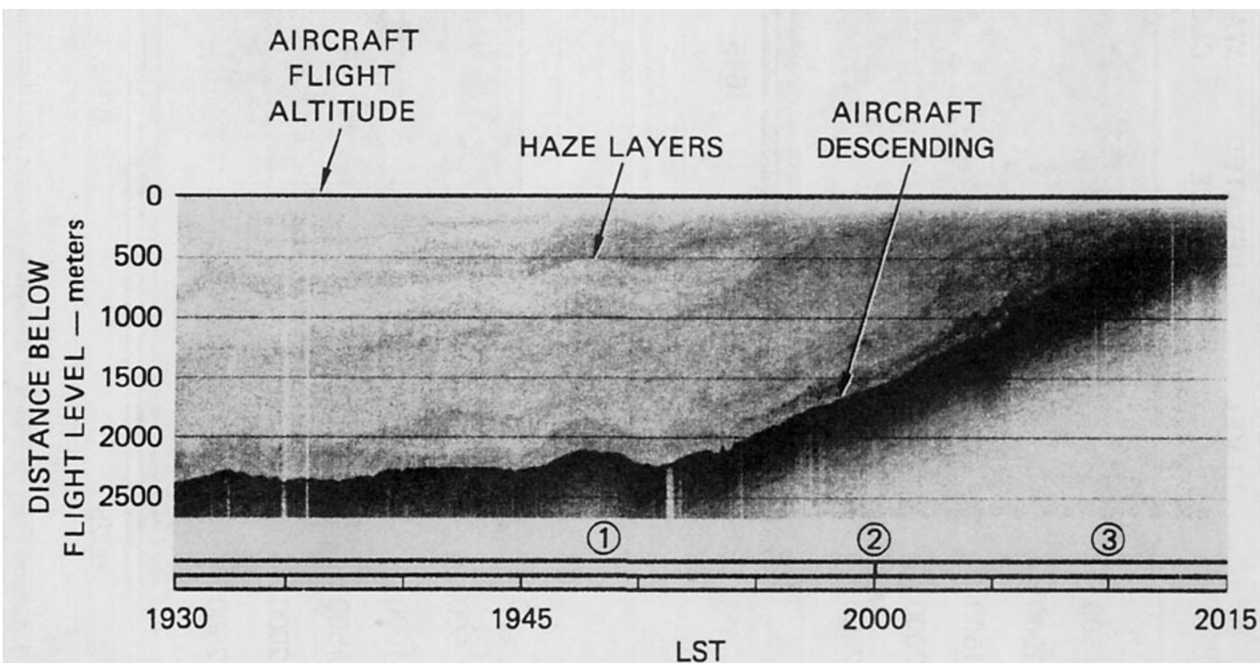

FIG. 2. Airborne lidar observations of multiple haze layers over pack ice about 200 km southwest of Thule, Greenland, 9 April 1986. "Increases" in height of the underlying surface are caused by aircraft's descent into Thule.

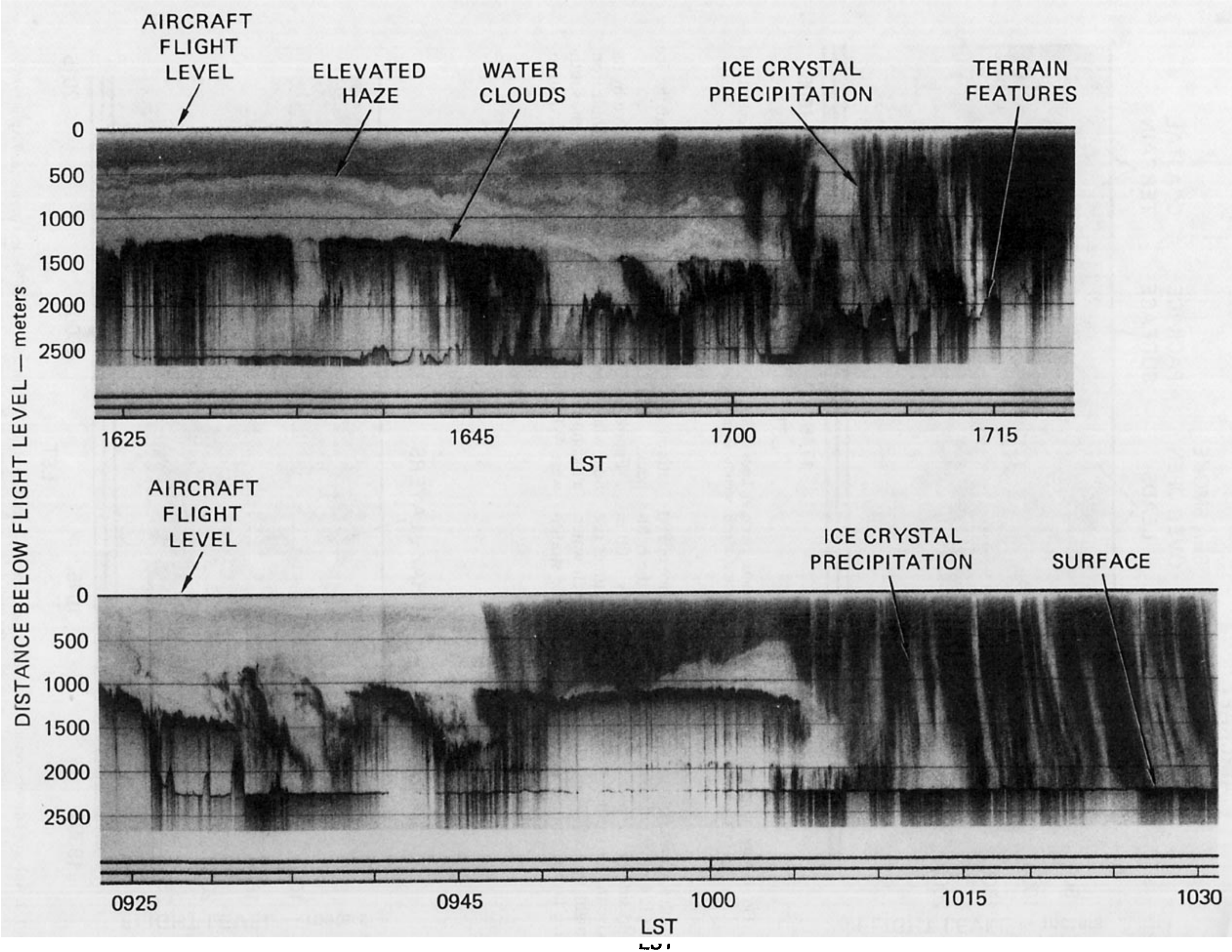

FIG. 3. Airborne lidar observations of atmospheric haze and cloud distributions. Upper panel: Thule to Sondrestrom, Greenland, 17 April 1986. Lower panel: Sondrestrom, Greenland to Frobisher Bay, Baffin Island, 18 April 1986. Note cirrus ice crystal precipitation on the right side of the cross sections extending from flight level to ground level.

spheric features and underlying terrain move closer to the position of the aircraft at the top of the cross section. The increases in "terrain" height (1, 2, and 3 in Fig. 2), therefore, are caused by altitude changes. Similarly, the undulations in the haze layers are caused by altitude variations. The point of interest in these data is the multiple aerosol-layer structure in a 2000- to 2200-m-thick atmospheric layer between the lidar aircraft and the underlying ice pack. Individual aerosol layers are 200- to 300-m thick.

Figure 3 shows the lower atmospheric structure of haze and clouds along the west coast of Greenland from Thule to Sondrestrom (upper frame) and from Sondrestrom across the Davis Strait to Frobisher Bay, Baffin Island (lower frame). These cross sections present examples of the presence of multiple aerosol layers, water clouds, ice crystal clouds, and underlying terrain features. Water clouds at an altitude of 1000 m to 1500 m above the terrain are seen in the first half of the top panel of Fig. 3 and 1000 m to 1500 m above the ice surface of the Davis Strait in the middle of the lower panel of Fig. 3. The composition of these clouds, which are only about 100-m thick, is inferred from the relatively large, lidar backscatter signal and the high attenuation (revealed by the weak surface return signals). The final one-third of the top panel of Fig. 3 and the last two-thirds of the lower panel of Fig. 3 show apparent ice crystal clouds and/or ice crystal precipitation, (e.g., fall streaks) with relatively small optical depths judging from the large atmospheric layer over which strong backscatter signals were detected by the lidar. Also, the onboard aircraft instrumentation indicated the presence of ice crystals. The frequent occurrence of ice crystal clouds and ice crystal precipitation in the area of Alert has been discussed by Hoff (1988).

4. Conclusions

Sample observations made by airborne lidar during AGASP-2 show highlights of meso- and microscale aerosol and cloud features in the lower troposphere over northern Greenland and Baffin Bay. The observations complement those obtained by ground-based lidar at Alert, and described by Hoff (1988), and attest to the utility of airborne lidar in Arctic and Antarctic atmospheric studies.

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