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VERTICAL STRUCTURE OF ARCTIC HAZE OBSERVED BY LIDAR

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In the study of the Arctic Haze phenomenon, understanding the vertical structure of the haze aerosol is crucial in defining mechanisms of haze transport. Questions have also arisen concerning the representativeness of surface observations of Arctic Haze. Due to the strongly stratified nature of the Arctic troposphere, the mechnanisms which transport aerosol to the surface from the transport altitudes of the lower troposphere are not obvious. In order to examine these questions, a Mie scattering lidar was installed at Alert, NWT, Canada, from September, 1984 to March, 1985. Lidar observes atmospheric aerosols and hydrometeors as they appear in nature, unmodified by sampling effects. As such the results obtained are more realistic of the light scattering characteristics of the in situ aerosol than are those obtained by integrating nephelometers, for example, which heat the aerosol and dry it before measurement. With this lidar, a pulse (694.3 nm at 0.5 Joules output energy) was transmitted vertically through an evacuated tube in the roof of a building at Alert. The receiver consisted of a 20cm diameter Fresnel telescope, neutral density and polarizing filters, an RCA C31000A PMT, Analog Modules LA-90-P logarithmic amplifier and a LeCroy TR8827 32 MHz digitizer. Data were recorded on a Compaq Plus portable PC.

Lidar pulses were fired on two minute intervals for the operational periods of one week per month. The lidar equation was solved for the backscattering coefficient of the aerosol assuming no two-way transmission losses in the signal (an excellent assumption for much of the clear air situations encountered in the Arctic). After output power normalization and range scaling of the return signal, color displays of the time-height lidar profiles of the Rayleigh ratio were prepared. The Rayleigh ratio is the ratio of the backscattered power (backscatter coefficient of the aerosol) to the backscattered power expected from a clear air (Rayleigh) atmosphere at STP. Minimum vertical resolution of the lidar was 4.6 m with a range of 2400 m.

The lidar results have shown that intercomparison between lidar-obtained visibilities and observer visibilities (Figure 1) are in much better agreement than for other optical or aerosol monitors. Visibility was calculated from the lidar Rayleigh backscattering ratio using two distinct backscattering-to-extinction ratios. For Rayleigh ratios greater than 10, it was assumed that ice crystals were adding appreciably to the scattering and Volkovitskii's (1980) results for β_π / α of 0.05 $\pm$ 30% were used. For Mie scattering aerosols the β_π / α ratio was assumed to be 0.03. Using the same stratification given by the Rayleigh ratio, a minus-one power law correction for wavelength (obtained from in situ particle size measurements) was applied for the Mie scatterers and no wavelength correction (Volkovitskii et al., 1980) was used for ice crystal scattering. Visibility at 500 nm was calculated using Koschmeider's relationship assuming the extinction coefficient is equal to the scattering coefficient. The results in Figure 1 show that ice crystal scattering effects are responsible for a portion of the low visibility events. Ice crystal scattering would not be seen by in situ sensors such as an integrating nephelometer.

Three new effects have been identified in the lidar profiles which contribute to the vertical transport of haze:

(1) Isentropic forcing and inversion breakup followed by intense surface mixing. It has been postulated for several years now that haze layers will follow isentropic (equal potential temperature) surfaces from their source regions to the Arctic. A problem with this theory is that air masses cool substantially moving into and within the Arctic. We have obtained evidence that isentropic forcing of the height of haze layers does occur and controls the altitude at which the layers travel. Breakdown in the radiative inversion structure also provides "events" at the surface which are properly viewed as vertical rather than horizontal transport signatures.

(2) Subsidence due to foehns near Greenland. A large scale haze feature (1000 km in horizontal extent and 200 m thick) was observed in February, 1985, in a foehn off Greenland. The layer subsided from 3.5 km altitude to about 0.8 km and then rose again. At the end of the event, snow occurred and the layer was lost in precipitation. This identifies foehns as a mechanism for downward transport of upper tropospheric air to the inversion top.

(3) Ice crystal nucleation and precipitation with subsequent sublimation at the top of the inversion. A third mechanism which appears to move nuclei to the inversion level is clear air ice crystal precipitation. At Arctic temperatures and humidities the atmosphere is often ice saturated. During the fall months, ice crystal precipitation is not as common as it is in spring, indicating that haze may be serving as a source of nuclei for forming ice crystals. An example of clear air ice crystal precipitation from 2.4 km altitude will be shown and after the event an intensification of the backscatter from the top of the inversion is seen. This indicates that this process may be responsible for the vertical structure of Arctic Haze.

Reference:

O. A. Volkovitskii, L. N. Pavlova, and A. G. Petrushin, Meteorologiya i Gidrologiya, 3, 114-121, 1980.

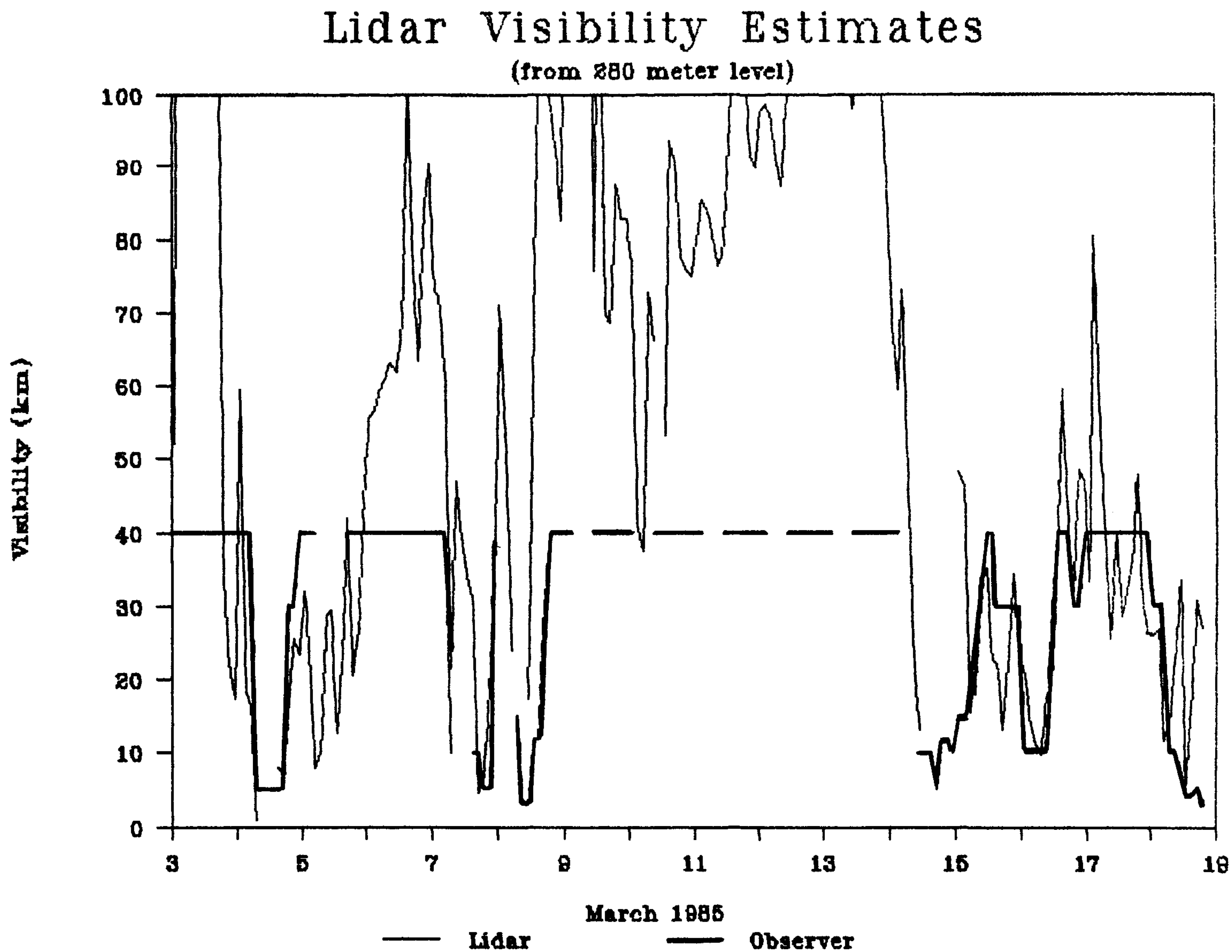

Figure 1. A comparison of lidar estimated visibility (fine line) in a layer from 280-420 m above the surface with the visibility estimated by observers (bold line).