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Aerosol observations over the ice caps

A. W. Hogan
Atmospheric Sciences Research Center
State University of New York at Albany
Scotia, New York 12302

D. Nelson
Global Monitoring for Climatic Change
National Oceanic and Atmospheric Administration
Boulder, Colorado 80302

Greenland and Antarctica present unique cases for aerosol studies. While these are "continental" situations, the absence of vegetation and fossil fuel combustion, and the presence of continuous ice cover, result in an absence of surface sources. The only source of particulate matter over the ice caps appears to be meteorological transport from other maritime or continental regions, and chemical or photochemical reaction of gases to form particles.

Fenn and Weickmann (1958) studied aerosols over Greenland and in many instances found that the concentration was below the detection threshold of a Pollak counter. Pollak and Metnieks (1959) changed the illumination of the counter to provide a converging light beam, and were able to recalibrate the instrument to respond to aerosol levels that approach particle-free gas.

Megaw (1973) and Flyger *et al.* (1973) recently renewed interest in the study of Greenland aerosols by hypothesizing that the "background" or "end point" of Northern Hemisphere aerosol occurs over the Greenland Ice Cap. I accompanied one of these expeditions (Hogan *et al.*, 1975) and made aerosol observations at sea level and atop the ice cap near the center of the land mass.

The aerosol at sea level was similar to maritime aerosol, but a small diurnal variation was detected. The concentrations observed on the vegetated southern tip of Greenland were similar to rural aerosols in North America and Africa. These observations are included only for interest and are not typical of ice-cap observations.

The aerosol measured at Dye II, atop the Greenland Ice Cap at an elevation of over 3,000 meters, was generally of low concentration. The range of concentration was from 100 to 250 particles per cubic centimeter on clear days. At the station, slightly higher readings were generally observed from a platform 20 meters above the ice, although there is a possibility of local contamination. The highest values occurred in subsiding air with a cold front west of the station.

Extremely low values accompanied and followed a period of riming, light snow (graupel), and precipitating fog. Flow at this time was from the Davis Strait. The concentration fell to 30 particles per cubic centimeter or less during this period, and slowly returned to about 100 particles per cubic centimeter in 36 hours.

The low concentration observed is similar to that found near maritime cumulus. It would appear that the fog and liquid water cloud that accompanied this storm system were efficient aerosol collectors, thereby reducing the concentration of aerosol to a value approaching the number of liquid cloud drops. The aerosol concentration then remained at a low value because only gas reactions were available as an aerosol source in the new high-pressure system building over Greenland.

Voskresenskii (1968) first reported on antarctic aerosols. He found that typical maritime concentrations existed at the coast with northerly winds. The concentrations accompanying strong katabatic winds from the continent ranged from 60 to 400 particles per cubic centimeter. Hogan (1975) found concentrations of more than 500 particles per cubic centimeter in a strong katabatic wind at Siple Station, under conditions of subsidence over the Polar Plateau.

Experiments at Amundsen-Scott South Pole Station detected concentrations of 50 to 125 particles per cubic centimeter at the surface during the austral summer. During subsidence conditions the concentration rises considerably, sometimes to as high as 1,500 particles per cubic centimeter as shown in figure 1. These additional particles are very small and are near the threshold of detection. These particles apparently form somewhere above the strong surface inversion usually present over the Polar Plateau; they cannot be transported in because coagulation would greatly decrease the number concentration of particles of this size within a few hours. These particles come down with the subsiding air and are transported along the surface by katabatic winds. This is in agreement since the

largest concentration and the smallest size occur at the Pole (midway across the continent), and the lower concentration and the slightly larger size occur at Siple (toward the coast).

Nelson continued aerosol observations through the austral winter. The aerosol concentration rapidly approaches the threshold of detection (i.e., 10 to 20 particles per cubic centimeter) following sunset, and remains at this level through the polar night. The concentration rises rapidly as the sun strikes the atmosphere prior to astronomical sunrise, and remains at this higher level (figure 2) for about a month, returning to lower levels in late summer.

Initially this increase in aerosol concentration might be attributed to photochemical conversion in the presence of sunlight; however, the polar atmosphere appears to undergo mixing in the lower layers at this time, as evidenced by a decrease in air temperature at 650 to 500 millibars. This prevents drawing the unique conclusion that the

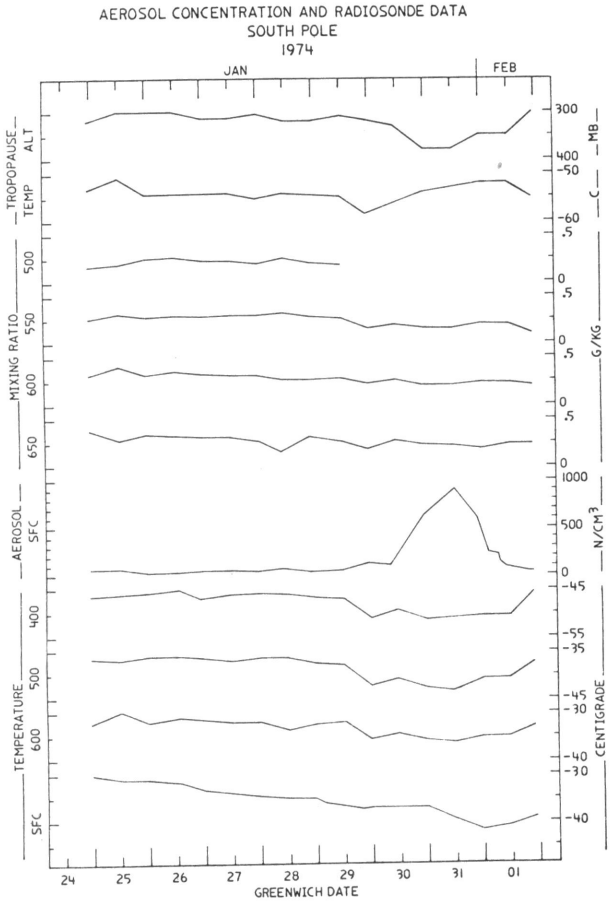

Figure 1. Chronology of aerosol observations at the South Pole. A lowered tropopause and strong subsidence increased the concentration twentyfold during 30-31 January 1974. (Reprinted with permission from *Journal of Applied Meteorology*, June 1975.)

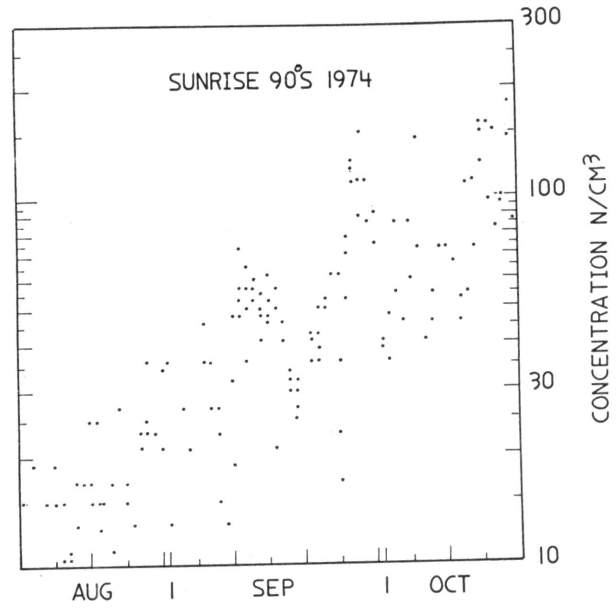

Figure 2. Chronology of aerosol observations during the period around sunrise 1974. The austral winter concentrations of zirconium, less than 30 particles per cubic centimeter, were no longer found after sunrise.

return of sunlight converts resident vapors to particles, resulting in an increased spring concentration.

Conditions for vapor-to-particle conversion appear to be present on the polar plateau as shown by experiments with two vapors at −37°C. Terpene vapors (from citrus rind) immediately produced an immeasurably large aerosol concentration when added to surface air. Vapors from a strong oxidant (iodine crystals) produced the same results after thorough flushing of the instrument to remove all traces of terpenes.

Rasmussen (personal communication) measured aerosol concentrations aloft from an airplane in January 1975, and found concentrations of two to four times that found at the surface. Similar results were reported by Hoffman and Rosen (personal communication), who found about one particle per cubic centimeter that was large enough to scatter light aloft. This is about 1,000 times the concentration of particles this size that I found near the surface.

Those sparse data indicate that the ice caps are sinks for atmospheric aerosol. The sink only acts in the region *below* the strong near-surface inversion, and aerosol probably passes unmodified above the inversion when mixing is not present. The extremely low concentrations measured at most times over the ice caps are *not* characteristic of all polar air, but rather are characteristic only of that region below the surface inversion.

A brief description of the antarctic aerosol system is summarized as follows:

(1) A strong inversion forms near the surface during the polar night. Particles trapped beneath this inversion are removed by thermophoretic forces and turbulent diffusion, and are collected on the ice surface. Aerosols of maritime and stratospheric origin pass essentially unmodified over Antarctica above this inversion.

(2) The katabatic wind is accompanied by breaks in this inversion. Air from aloft is transported to the surface through these breaks and flows coastward with the katabatic wind. The aerosol observed in katabatic wind represents a mixture of aerosol-rich upper air and aerosol-depleted lower air.

(3) This transport continues after sunrise, and some photochemical aerosol is produced by sunlight. These quantities are small, but because of low concentration of resident aerosol these small individuals can survive for a few days without being collected by those larger particles.

(4) Although the surface inversion persists during summer, some mixing occurs due to the strong subsidence, gravity waves, and other phenomena. A decrease in the 650- to 500-millibar temperature results from this mixing and may accompany increased aerosol concentration at the surface.

The antarctic ice sheet and its accompanying low inversion are an aerosol sink. The capacity of this sink is limited by the mixing of higher level air through the inversion.

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Microparticle research at the Institute of Polar Studies

LONNIE G. THOMPSON
Institute of Polar Studies
The Ohio State University
Columbus, Ohio 43210

Examination of microparticles in glaciological samples was greatly enhanced during the past year by the establishment of a clean room and the upgrading of equipment in the Institute of Polar Studies microparticle laboratory. The new facility is a class 100 clean room, as certified by the manufacturer, Weber Technical Products.

The laboratory is used only to determine micro-

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Microparticle laboratory at the Institute of Polar Studies, The Ohio State University.