PM_{10} Source Apportionment at McMurdo Station, Antarctica

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INTRODUCTION

Antarctica is perhaps the last pristine area on Earth, and the National Science Foundation (NSF) wants to keep it that way. NSF operates three permanent research stations in Antarctica: McMurdo, South Pole, and Palmer (Figure 1). McMurdo, at the southern tip of Ross Island, is the largest such facility, with an austral summer population of over 1,000 scientists and support personnel. McMurdo serves as a base for all U.S. research activities in Antarctica. NSF seeks to minimize the impacts of these activities on the Antarctic environment.

In much of Antarctica, the atmosphere is extremely clean. Air pollutant concentrations can be up to six orders of magnitude lower than those found in urban areas of the United States. However, McMurdo is a small town with smoke stacks, unpaved roads, and motor vehicles (Figure 2). The U.S. Antarctic program is subject to the terms of the international Antarctic Treaty and the U.S. Antarctic Conservation Act of 1978, which require minimizing man-made pollution of land, water, and air.

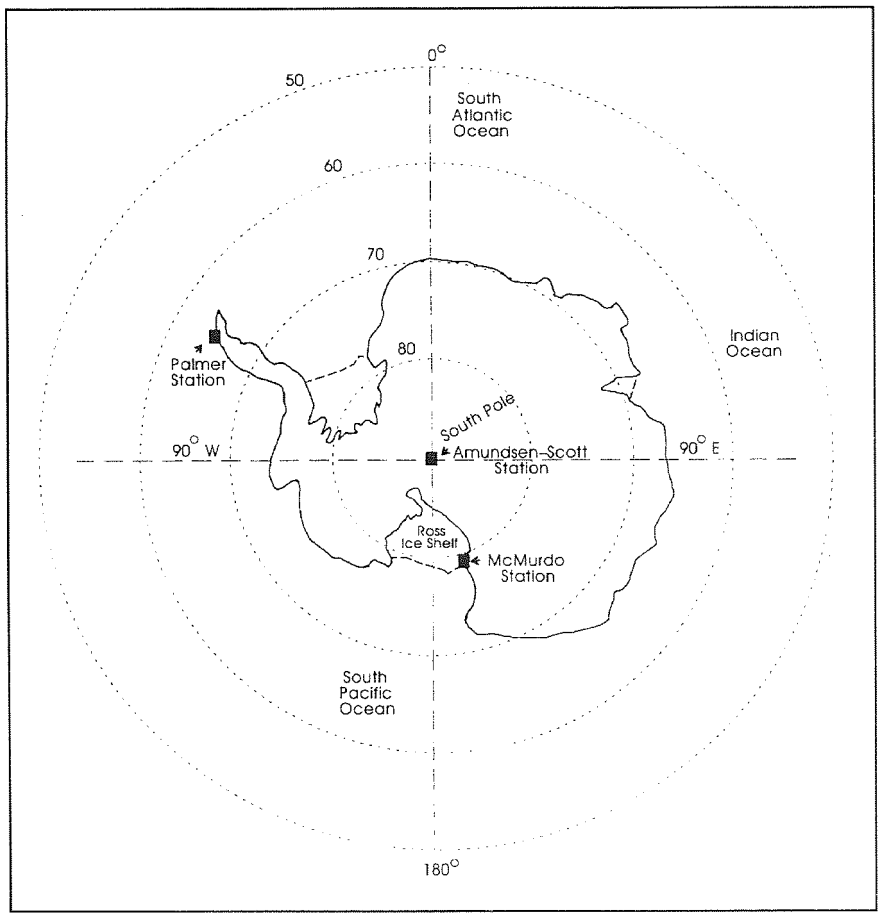

Figure 1. Map of Antarctica showing locations of NSF research stations (McMurdo, South Pole, and Palmer).

It is unlikely that any U.S. air quality standards are violated in Antarctica. However, PM_{10} (atmospheric particles with diameters less than 10 μm) and sulfur dioxide are regulated pollutants in the United States and are of general interest because of their role in global climate and biogeochemical cycles. McMurdo is a significant source of these materials in Antarctica. Therefore, the NSF sponsored a study by the Desert Research Institute (DRI) to identify and quantify the sources of PM_{10} in McMurdo. Information on particle chemistry and sulfur dioxide concentrations obtained during this study will be useful for assessing impacts of future activity and will improve our understanding of the atmospheric geochemistry of this remote area.

Approach

Receptor modeling has been widely used in the United States to help states and localities develop strategies to reduce concentrations of ambient PM_{10}. The contributions of various source types to PM_{10} are

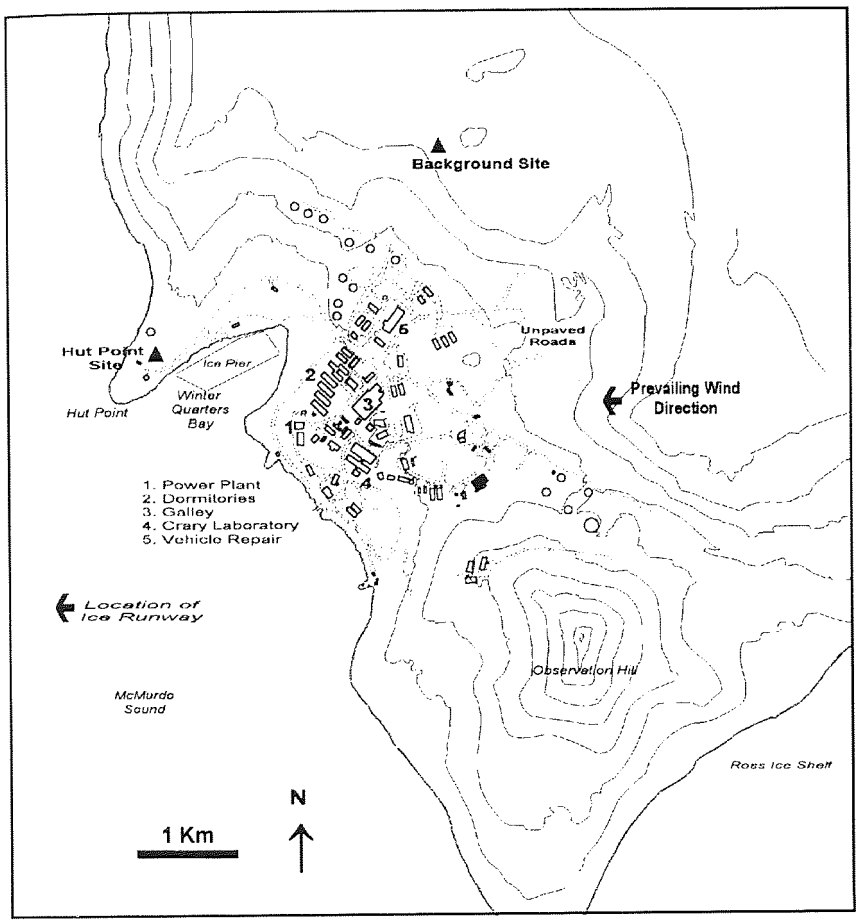

Figure 2. McMurdo Station, located on the southern tip of Russ Island. Major PM_{10} sources and unpaved roads are identified by number and dotted lines, respectively.

determined by comparing the detailed chemical compositions of their emissions to that of the ambient PM_{10} aerosol. This comparison is done using the Chemical Mass Balance Model (CMB), developed at DRI with support from the U.S. Environmental Protection Agency (EPA). The DRI/EPA CMB version 7.0 is a statistical model based on a multiple linear regression technique. The independent variables are the source profiles, or fractional abundances of chemical species like ions, carbon, and elements in the source emissions. The dependent variable is the ambient concentration profile of the same chemical constituents. The regression coefficients are the estimates of source contributions to PM_{10}.

In McMurdo, the main fuel used in electric power generation, space heating, and motor vehicles is AN-8, a lightweight diesel oil similar to JP-8 jet fuel (~0.3% sulfur). There are many different kinds of motor vehicles, including small snowmobiles, pickup trucks and vans, large tracked vehicles, graders and transports, and LC-130, C-141, and helicopter aircraft. Some of the light-duty vehicles use unleaded gasoline. The main power plant runs on six large Caterpillar generators. The buildings are heated with steam, hot water, and forced hot air furnaces. All of the roads in McMurdo are unpaved and are completely exposed during the austral summer.

The DRI study began in November 1995, when all major PM_{10} sources were identified and their emissions monitored. Intrepid DRI researchers sampled exhaust directly behind a Hercules LC-130 aircraft running at full throttle, under the spinning blades of a UH-1 helicopter, and from light- and heavy-duty vehicles, power-plant stacks, mess-hall vents, and a variety of heating systems (Figure 3). Material from unpaved roads and storage piles was also collected.

Figure 3. Sampling stream boiler exhaust atop the Crary Laboratory in McMurdo. McMurdo Sound and Mount Discovery can be seen in the background to the west.

Two ambient PM_{10} and SO_2 monitoring sites were established to measure background concentrations and downwind transport of McMurdo emissions. The downwind site is located next to the Discovery Hut, built in 1902 by the British explorer Robert Falcon Scott who died in his quest for the South Pole. The upwind background site is located on a ridge northeast of town.

In the United States, 24-hour duration PM_{10} samples are collected every sixth day according to EPA's standard protocol for the compliance monitoring network. Because background concentrations in Antarctica can be extremely low, sample duration in McMurdo has been extended to 48 hours. Samples were collected continuously throughout the austral summer from November through January.

PM_{10} was collected on Gelman (Ann Arbor, MI) 8"x10" Zefluor filters with 2.0 µm pore size in Graseby GMW (Village of Cleves, OH) IP10 PM_{10} high-volume samplers. These filters will be analyzed for trace elements by instrumental neutron activation analysis. Custom-built DRI samplers with Graseby GMW G254I medium-volume size-selective inlets were used to collect PM_{10} samples on Gelman 47-mm 2.0 µm pore size PTFE Teflon-membrane filters for analysis of mass and elements, and on Pallflex (Putnam, CT) quartz-fiber filters for analysis of ions, and organic and elemental carbon. Sulfur dioxide was sampled on potassium carbonate-impregnated Whatman No. 41 (Madstone, England) 47-mm cellulose-fiber filters located behind the Teflon-membrane filter for analysis as sulfate by IC.

Neutron activation analysis will provide concentrations of pollution-derived elements such as arsenic, antimony, selenium, and indium, which are not determined well by x-ray fluorescence at low concentrations. Black carbon was measured continuously during the first field season using an aethalometer donated to the project by Dr. Tony Hansen of Magee Scientific in Berkeley, CA (Figure 4).

Figure 4. An aethalometer (Magee Scientific, Berkeley, CA), used for continuous black carbon measurements, and a Graseby GMW hivol PM_{10} sampler at Hut Point, McMurdo.

Expected Results

In addition to estimating individual source contributions by CMB and near-field dispersion modeling, the geographical extent of the McMurdo "plume" will be evaluated by applying a mesoscale model based on data obtained from a network of automated weather stations operated in Antarctica by the University of Wisconsin. EPA's ISC-3 dispersion model will be applied to individual ducted emitters to determine their relative contributions to categorical contributions estimated by CMB. The CALMET/CALPUFF mesoscale model will be used to estimate how far and in which directions the McMurdo plume extends.

The first summer's monitoring has been completed and chemical analysis of the source and ambient samples is under way. Initial results will be available by late boreal summer 1996, and a second PM_{10} monitoring program will be conducted during the austral summer of 1996-97. Data analysis and publications will be completed by the end of 1998. This study represents a unique opportunity to apply monitoring and analysis techniques developed over many years by U.S. air quality scientists to global issues of fundamental scientific importance.

Acknowledgment

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