



Editorial

An introduction to the ALERT 2000 and SUMMIT 2000 Arctic research studies

The Arctic troposphere has been described as a unique chemical reactor, in which reactions that may have a significant impact on the global atmosphere occur. Its uniqueness is the result of a combination of several factors. It experiences a prolonged period of darkness, removing the usual energy source for atmospheric chemical cleansing (solar radiation), followed by a corresponding period of continuous light, when photochemistry is very active. Cold conditions frequently result in a very stable surface layer, although moderately unstable conditions often occur during summer. It is largely underlain by snow and ice, or by the Arctic Ocean, boundaries that provide surfaces or aerosols for active heterogeneous chemistry. Finally, while there are virtually no anthropogenic pollution sources within the Arctic itself, it is impacted by emissions from many of the world's largest industrial regions, resulting in surprisingly high pollution levels, especially during winter and spring, when "Arctic Haze" predominates.

By virtue of its geography and prevailing transport patterns, the glacial ice of Greenland contains a record of past atmospheric composition, and recent human impacts. Thus, a major motivation for studies of the Arctic troposphere was the desire to understand the relationship between atmospheric composition, snow composition, and the composition of glacial ice (the so-called "transfer function"), and to use the glacial ice core record to gain inferential information regarding the climate of the past, including perturbations due to anthropogenic activity. Hence, for instance, the relationship between H_2O_2 and HCHO in the atmosphere and the firn in Greenland has been extensively studied. However, oxides of nitrogen were observed to exhibit surprisingly large exchange rates with the snowpack, inspiring a series of studies of nitrogen speciation and air–snow exchange.

An intriguing discovery that provided a great impetus for Arctic atmospheric chemistry research was the finding in the 1980s of ozone depletion in the atmospheric boundary layer near the time of polar sunrise. It is now clear that this is the result of a gas-phase bromine atom chain reaction. The presence of the BrO molecule and the release of molecular bromine due to hetero-

geneous processing of sea-salts in aerosols and in snow have since been observed. In addition, extremely rapid destruction of ozone in snowpack interstitial air has recently been reported. An equally surprising recent discovery was that gaseous elementary mercury (Hg) appeared to undergo depletion in concert with ozone raising the specter of a potential major contamination of the Arctic biosphere. However, attempts to develop a coherent mechanistic explanation for these depletion processes failed on the basis of purely gas-phase chemistry, and heterogeneous processes involving snow and aerosol particles had to be invoked.

The importance of photochemistry within the snowpack was demonstrated by analyses of snowpack interstitial air, made at Alert and at Summit in 1998. Snowpack photochemistry was identified as a likely cause of large interstitial-air and ambient HCHO concentrations, and was shown to result in NO_x concentrations in interstitial-air up to an order of magnitude larger than ambient levels, consistent with the presence of an unexpected diurnal cycle in ambient-air NO_x .

These recent results led to the ALERT 2000 and SUMMIT 2000 campaigns, conducted at Alert, Nunavut, Canada, and at Summit, Greenland. These studies had the aim of investigating in more detail air–snow interactions and photochemistry both within and above the snowpack surface. The participating groups and their study objectives are presented in Tables 1 and 2. Papers collected in this special issue of Atmospheric Environment report a wealth of new information about the chemistry of the lower Arctic troposphere, highlighting in particular the important role of interactions between the atmosphere and photochemical and physical processes occurring within the underlying snowpack. Key topics can be summarized as follows:

ALERT 2000:

- confirmation of the production of Br_2 and BrCl;
- air–snow exchange processes and snowpack production/destruction of Br_2 , O_3 , nitrogen oxides, VOCs, and Hg determined from sampling snow interstitial and surface air as well as from snow chambers;

Table 1
Study objectives and corresponding principal investigators (PIs)

Study topic	PI	Institution
<i>ALERT 2000</i>		
NMHCs, OVOCs, ozone profiles	Jan Bottenheim Project Co PI	Meteorological Service of Canada, Toronto, Ont., Canada
OVOCs	Paul Shepson Project Co PI	Purdue University, West Lafayette, IN, USA
Br ₂ , BrCl	Chester Spicer	Battelle Memorial Institute, Columbus, OH, USA
BrO by DOAS	Barbara Finlayson-Pitts	University of California, Irvine, CA, USA
BrO by LIF	Ulrich Platt	Universität Heidelberg, Heidelberg, Germany
Dicarboxylic acids in snow	Linnea Avallone	University of Colorado, Boulder, CO, USA
Gaseous and particulate mercury	Kimitaka Kawamura	University of Hokkaido, Sapporo, Japan
	William H. Schroeder	Meteorological Service of Canada, Toronto, Ont., Canada
HONO, HO ₂ NO ₂	Xianliang Zhou	Wadsworth Center/NYSDOH, Albany, NY, USA
Major ions in air and snow	Ivo Allegrini	C.N.R.-Istituto sull'Inquinamento Atmosferico, Rome, Italy
Micrometeorology, ozone profiles by tethersonde	Jose Fuentes	University of Virginia, Charlottesville, VA, USA
NO, NO ₂ , NO _y	Richard Honrath	Michigan Technological University, Houghton, MI, USA
	Harald Beine	Michigan Technological University, Houghton, MI, USA, and C.N.R.-Istituto sull'Inquinamento Atmosferico, Rome, Italy
Snow chemistry	ShaoMeng Li	Meteorological Service of Canada, Toronto, Ont., Canada
Snow physics	Mary Albert	Cold Regions Research and Engineering Laboratory, US Army Corps of Engineers, Hanover, NH, USA
Snow physics, carbonyls in snow	Florent Domine	C.N.R.S.-Laboratoire de Glaciologie et Géophysique de l'Environnement, St Martin d'Heres, France
Solar radiation	William Simpson	University of Alaska, Fairbanks, AK, USA
Surface ozone	Kurt Anlauf	Meteorological Service of Canada, Toronto, Ont., Canada
<i>SUMMIT 2000</i>		
HONO, HNO ₃ , monocarboxylic acids, ions in snow	Jack Dibb Project Co PI	University of New Hampshire, Durham, NH, USA
NO, NO ₂ , NO _y , O ₃ (ambient and in snow)	Richard Honrath Project Co PI	Michigan Technological University, Houghton, MI, USA
Actinic flux (measurements and modeling above and in snow)	Matthew Peterson, Sarah Green	Michigan Technological University, Houghton, MI, USA
H ₂ O ₂ , HCHO	Roger Bales	University of Arizona, Tucson, AZ, USA
Micrometeorology	Konrad Steffen	University of Colorado, Boulder, CO, USA
NMHC, halocarbons, RONO ₂	Don Blake, Nicola Blake	University of California, Irvine, CA, USA
Organics in snow	Paul Shepson	Purdue University, West Lafayette, IN, USA
O ₃ profiles, boundary layer meteorology	Detlev Helmig	University of Colorado, Boulder, CO, USA
Photochemistry in frozen and liquid water	Cort Anastasio	University of California, Davis, CA, USA
Snow physics and air flow through the snowpack	Mary Albert	Cold Regions Research and Engineering Laboratory, US Army Corps of Engineers, Hanover, N.H., USA

- estimation of flux rates of a variety of species, e.g. VOCs, NO_x, O₃, and Hg;
- measurements of ambient methanol and ethanol;
- spectrally resolved measurements of the penetration of solar radiation in the snowpack;
- characterization of snowpack physics including surface area, density, and porosity, leading to modeling of ventilation rates; and
- determination of surface boundary layer O₃ profiles and meteorological influences.

SUMMIT 2000:

- characterization of atmospheric turbulence and mixed-layer depth;
- determination of the vertical fluxes of NO_x, HONO, HNO₃, HCHO, and H₂O₂ out of and into the snowpack;
- determination of O₃ gradients through the boundary layer;
- measurement of the composition of snowpack interstitial air and its response to changes in solar insolation, made in both surface firn and enclosed snow chambers;
- measurements and modeling studies of snowpack physical properties and the movement of air through the snowpack;
- Studies of actinic flux levels within the snowpack, using a combination of radiative transfer modeling and measurements of light levels and the nitrate photodissociation rate constant within the snowpack; and
- analysis of the impact that elevated levels of HONO, HCHO, H₂O₂, and NO_x, all apparently resulting

from processes involving the snowpack, have upon atmospheric concentrations of OH and peroxy radicals.

These studies were made possible by generous financial support from the Meteorological Service of Canada, and the US National Science Foundation, as well as targeted support from several organizations mentioned in the relevant papers. In addition, the ALERT 2000 study benefited from extensive in-kind support of the Canadian Department of National Defense, in particular DREA Halifax. We wish to particularly thank Al Gallant (Environment Canada), and Jim Milne and Ron Verrall (DREA) for their support of the ALERT 2000 campaign.

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