C31E-0472

Seasonal Variations of Nitrogen Oxides in snowpack air at Summit, Greenland.

C. Toro[1], R.E. Honrath[1†], L.J. Kramer[1], D.Helmig[2], B.A. Van Dam[2], B. Seok[2], J. Hueber[2], L. Ganzeveld[3], P.V. Doskey[1]

[1]Atmospheric Sciences Program, Michigan Technological University
catoro@mtu.edu

[2]Institute of Arctic and Alpine Research, University of Colorado
detlev.helmig@colorado.edu

[3]Department of Earth and Environmental Sciences, Wageningen University
Laurens.Ganzeveld@wur.nl

1. Overview

Our research focuses on snowpack chemistry and air-snow exchange of nitrogen oxides and ozone. The goal of our project is to make advances in the understanding of mechanisms involving these species, in order to improve the ability of current global chemistry-climate models to simulate the impact of snowpack processes upon the overlying atmosphere.

In this poster, we present a set of continuous measurements of NO_x and O_3 in the interstitial air at Summit, Greenland (72.6 N, 28.5 W, 3205 m asl) during Spring of 2009 showing the onset of the photochemical activity.

2. Measurements

GeoSummit Flux Facility

The GEOSummit Flux Facility was designed for air-snow exchange studies. Conduits for sampling tubes and cables run from the 10 m tower to a heated, insulated facility that is located under the snow (downwind from the tower during clean sector flow), and which is accessed through the entryway visible on the right of the photo.

The 10-m tower showed in Figure 1 is equipped to measure:

-***Eddy correlation fluxes*** (O_3 and heat) at 2 heights

-***Ambient air gradients*** of NOx, O_3, temperature and wind speed

-***Broadband solar irradiance and spectral actinic flux*** of downwelling and upwelling radiation (downwelling for J-values calculations)

-***Meteorological conditions*** with sonic and cup anemometers, and aspirated thermocouples

Instruments located in the enclosure at the top of the tower measure long-range transport of NOx, PAN and NMHCs as part of a parallel project (contact Dr. Louisa Kramer, lkramer@mtu.edu).

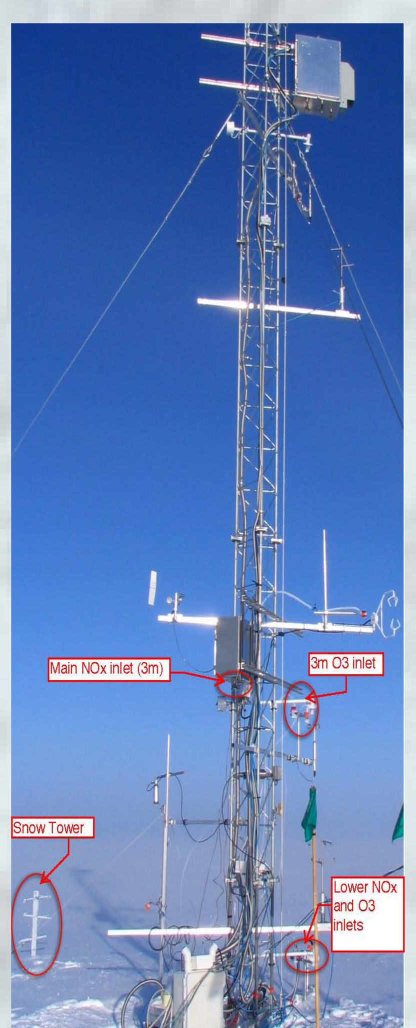

Figure 1. GEOSummit Flux Tower

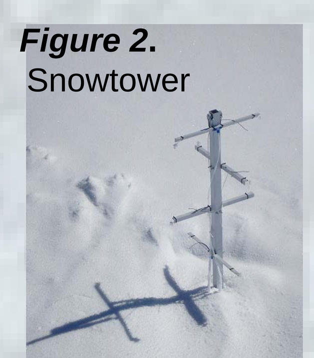

Figure 2. Snowtower

Snowtower has 8 levels , each with two inlets. Total flow ~2 lpm is split between both inlets in order to have a minimum disturbance of the interstitial air.

For the period analyzed in this poster, the depths of each level are +10, -20, -50, -80, -110, -140, -170 and -200 cm.

3. Results

Figure 3 shows the temporal evolution of NO_2 and NO gas-phase production in the interstitial air due to nitrate photolysis [1,2]. Also is showed the evolution of ozone profiles in the snowpack. NO_2 and NO data are expressed as **enhancements above ambient concentrations (2 m). Ozone data is presented as mixing ratios.** Inlet depths remains constant during this period.

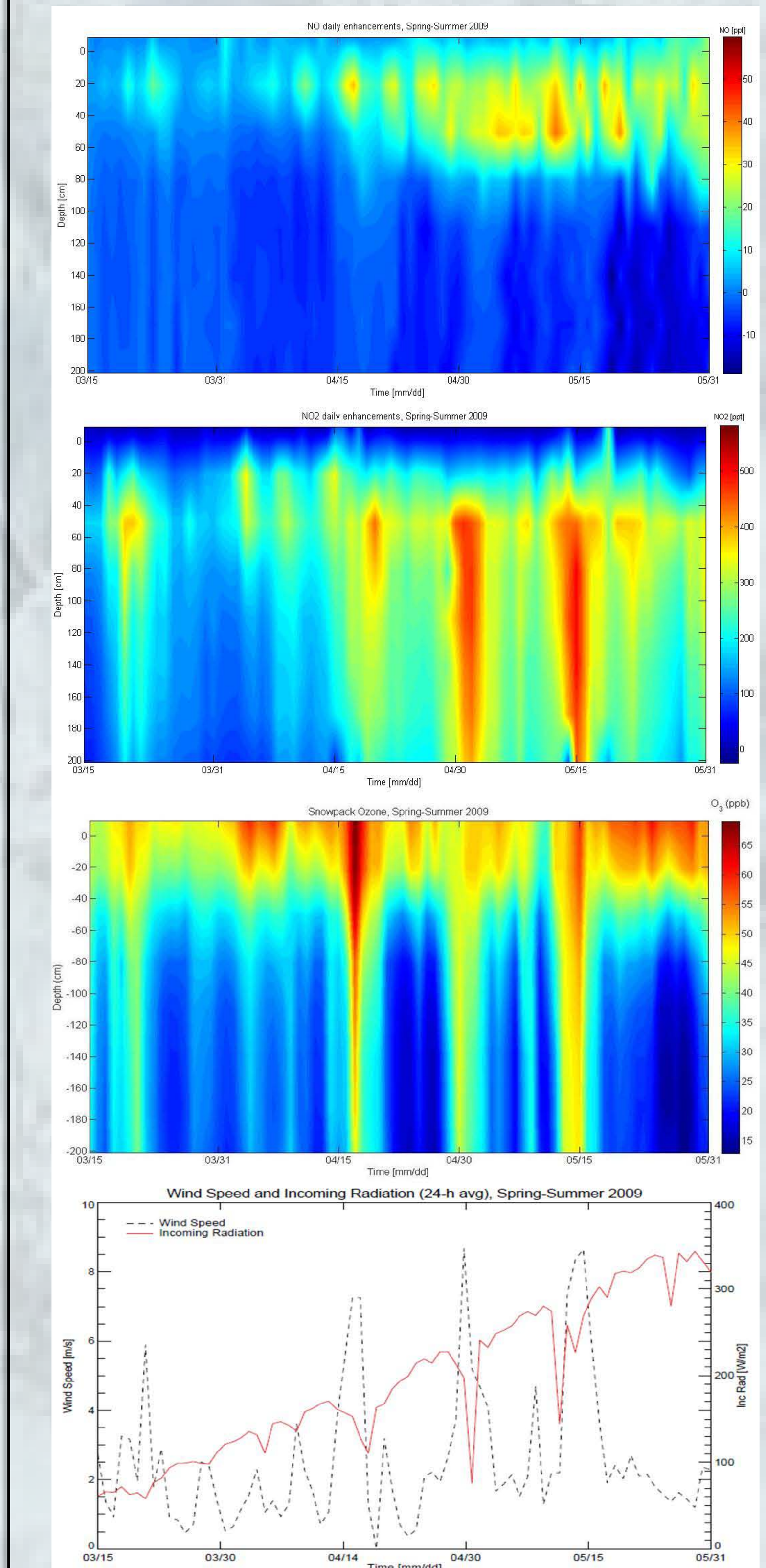

Figure 3. Seasonal variations of NO_2, NO and O_3 since early spring until beginning of summer. Wind speed and Incoming radiation are also plotted for the same period. All data is 24-h average.

Temporal Evolution and Spatial Distribution for NO

Early spring:

•Low activity. Values observed are ~10 ppt above ambient

After April 15:

•NO concentrations are in the order of 20-30 ppt above ambient.

•NO observed mainly at the upper layers where NO_2 photolysis can occur.

Temporal Evolution and Spatial Distribution for NO_2

Early spring:

•NO_2 levels ~200 ppt at the surface layers of the snow (20-40 cm depth).

•Photochemical activity increases with greater incoming radiation.

•Lowest NO_2 levels within the first 20 cm, most likely due to snowpack ventilation.

After April 15:

•Maximum values observed at deeper levels (~50cm), upper layers with low values probably due to ventilation effect [2] and NO production by photolysis

•Vertical distribution that reaches the deepest levels with some episodes of high values (~500 ppt) at 200 cm of depth. These periods are coincident with high wind speed events (Figure 3), that cleans the atmosphere above the snowpack emphasizing the difference between the interstitial air and ambient concentrations. In addition, wind pumping mechanism can also affect the mixing in side of the snowpack.

Temporal Evolution and Spatial Distribution for O_3

•During all the period analyzed, ozone concentrations decline significantly with depth (high levels observed mainly at the first 20 cm of the snowpack).

•Only few episodes of ozone intrusion at deeper levels of the snowpack are observed. These episodes are correlated with the high wind speed events during the season. In this figure, ozone is presented as actual concentrations, thus the high levels observed deep into the snowpack must be direct effect of disturbances of the snowpack due to wind pumping [3].

Vertical flux of NOx

•The comparison of ambient mixing ratios at different levels above the snow shows the influence of the snowpack over the overlying atmosphere. NO present a clear diurnal cycle as a result of NO_2 photolysis in the upper layers of the snowpack [4]. Peak in NO_2 emissions can be observed later in the day when sunlight is not enough to produce NO_2 decomposition.

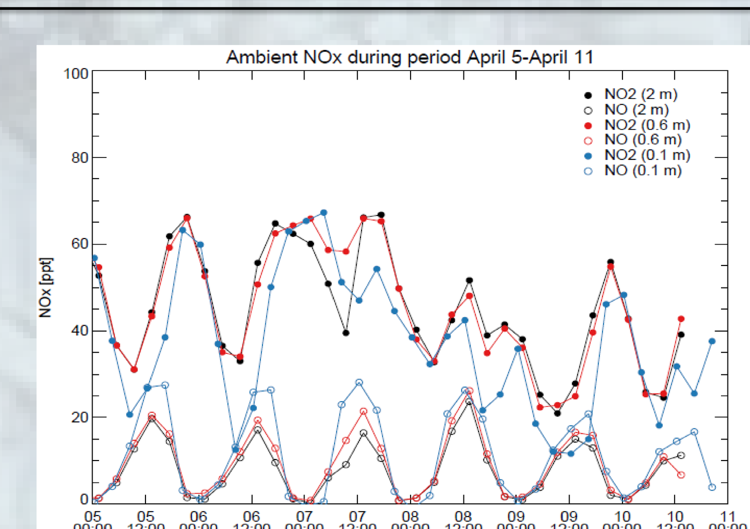

Figure 7. Ambient mixing ratios of NO_x at 2 m and 0.6 m. (4-hr avg) during April 5 to April 11. Low wind conditions (~2 m/s). All times are local solar time.

Acknowledgements.
This work is funded by National Science Foundation grants ARC0713992 and ARC0713943. Michael Dziobak provided essential instrumentation and field support. We especially thank the Summit Science Technicians and support staff and the Flux Facility design and construction team for their assistance.

Diurnal Cycles

• NO_2 (a) and NO (b) show clear diurnal cycles associated with photochemical production. Upper-levels of the snowpack correlated with the maximum incoming radiation (Figure 6, middle plots). Maximum NO_2 values are offset with respect to radiation at deeper levels, therefore these high values are most likely the result of vertical transport (bottom plots).

• Negative values observed for NO at lower levels ((b), bottom plot) are due stable conditions above the snowpack (that allows to accumulate gases above it), and nearly zero NO concentrations at these depths, thus the resultant enhancements are negative.

•At the level above the snow is possible to observe a NO diurnal cycle even with the strong wind conditions, showing NO flux out of the snow.

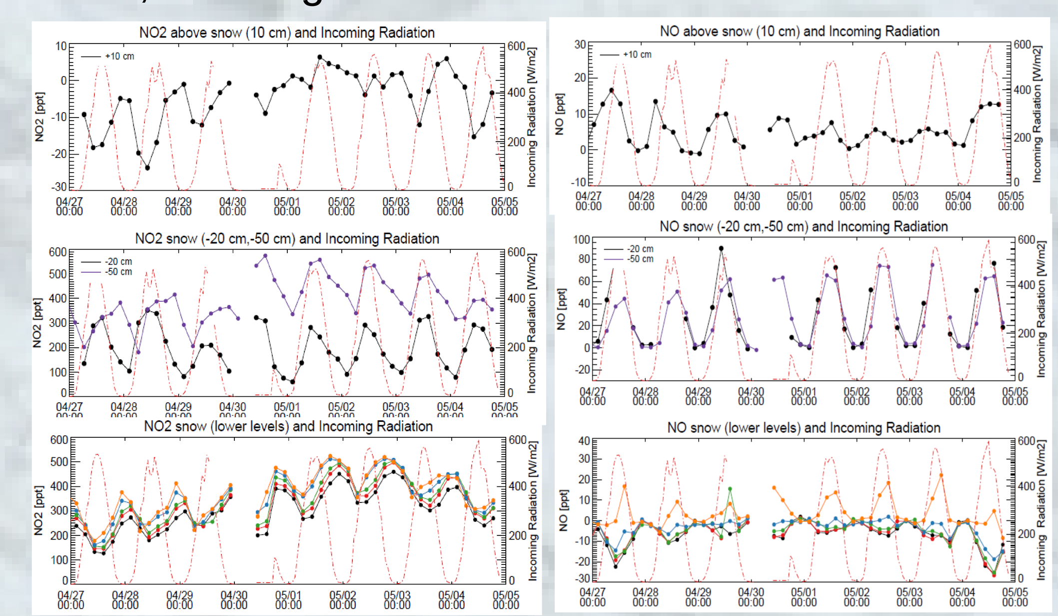

Figure 6. NO_2 and NO time series. Wind speed during this period was between 2-4 m/s (Apr 27-Apr 29, May 3-May 5) and 6-10 m/s (Apr 29-May 3). NOx data is 4-hr average and radiation data is 1-hr average. All times are local solar times. Bottom plots: -80 cm (●),-110 cm (●), -140 cm (●), -170 cm (●) and -200 cm (●).

6. Conclusions

❑ During late spring, maximum values of NOx are observed at ~50 cm depth in the snowpack. In early spring, when incoming radiation is low, maximum values are observed closer to the surface. NOx enhancements ranged between 100 ppt and 500 ppt in agreement with previous measurements at Summit [6, 7].

❑ NO is present mainly at the upper levels and is diffusing out due to ventilation of the snowpack. Ozone is also present at the upper levels, but due to uptake of ambient concentrations into the snowpack.

❑ High wind speeds (~ 8 m/s) can affect the snowpack at deeper levels, increasing the mixing of the interstitial air.

❑ In mid-spring, high values of NO_2 are observed as deep as 2 m into the snowpack, probably due to vertical transport. Ozone does not reaches deep levels, except when high wind speed events affect the snowpack.

7. Future Work

❑ Analysis of gradients above the snow and flux calculations will help us to study emission and deposition of ozone and NOx species at Summit.

❑Our next step will be to study the snowpack over biological active soil, in order to characterize the range of air-snow-soil processes that affect snow-covered areas.

8. References

1. Honrath et al., *Geophys. Res. Lett.*, 26, 695,(1999)
2. Dibb et al., *Atmos. Environ*., 36, 2501, (2002)
3. Domine et al., *Atmos. Chem. Phys*., 8,171,(2008)
4. Helmig et al., *Atmos. Environment*, 41, 5061, (2007)
5. Honrath et al., *Atmos. Environment*, 36, 2629,(2002)
6. Peterson M.C. and Honrath R.E., *Geophys. Res. Lett.,28, 511, (2001).*
7. Jacobi et al., *Atmos. Environment*, 38, 1687, (2004).

† Dr. Richard Honrath
1969-2009

He sadly passed away on April 17, 2009 in a kayaking accident.