**Estimating Boundary Layer Depth at the South Pole Using Only Standard Meteorological Data to use in the Interpretation of Nitric Acid Concentrations**

W.D. Neff1, D.D. Davis2

1 Cooperative Institute for Research in the Environmental Sciences, University of Colorado, Boulder Colorado

2School of Earth and Atmospheric Science, Georgia Institute of Technology, Atlanta, GA 30332, USA

The Investigation of Sulfur Chemistry in the Antarctic Troposphere (ISCAT) field programs in the austral summers of 1998 and again in 2000 ([Davis et al. 2004](#_ENREF_1); [Davis et al. 2001](#_ENREF_2)) discovered unusually high nitric oxide (NO) concentrations at the South Pole. These early analyses concluded that the high NO levels were associated with shallow stable boundary layers, concomitant with light winds, and colder temperatures. Davis et al. also argued that the high levels of NO at the South Pole, compared to other polar sites, were partly due to the long fetches for air parcels in the katabatic flow from the Antarctic high plateau and the lack of a diurnal cycle in sunlight allowing continuous photolysis of snow nitrate. This led to a major field program in 2003 to examine this new phenomenon, the Antarctic Tropospheric Chemistry Investigation (ANTCI), which involved ground-based measurements at the South Pole as well as light aircraft probing over more extensive areas of the Antarctic Plateau in 2003 ([Davis et al. 2008](#_ENREF_3))and again in 2005 and 2006 ([Slusher et al. 2010](#_ENREF_7)).

To directly address boundary layer effects on NO concentrations, the 2003 ANTCI field program deployed a sodar to measure boundary layer depth using the scattering of acoustic waves from the thermal structure of the boundary layer. These direct measurements confirmed the relationship between NOX levels and boundary layer depth ([Neff et al. 2008](#_ENREF_4)) posed earlier ([Davis et al. 2004](#_ENREF_1)). A final set of ground-based NO observations at the South Pole were obtained within the sunlit period from January 2006 until mid-January 2007. The latter data set was unique in that it covered the full summer cycle of insolation, photochemistry and meteorology at the South Pole. However, no direct boundary layer depth (BLD) measurements were made during this study. Thus, one of the major goals here was also to ascertain if the BLD for 2006 (as well as for the time periods of 1998 and 2000) could be estimated from rountinely available meteorological variables and show the same relationship between BLD and NO concentrations as was found in 2003.

In the current analysis we first examined the dependence of nitric acid concentrations on a number of meteorological factors individually, using linear regression. These included wind speed and direction, temperature, difference in temperature at 2 and 20 m on a tower, bulk inversion strength from daily rawinsonde profiles, cloud fraction, solar zenith angle, and direct solar radiation. This analysis over the four seasons of NO data collection revealed the most important variables controlling NO although their relative values varied from season to season. This variability presumably depends on other processes that control the photolysis rates for nitrate at the snow surface. Next, we used the BLD data from 2003 to identify variables with the highest regression coefficients followed by multiple linear regression to find the optimum combination of variables. This resulted in a regression equation using wind speed and direction, temperature and ∆Ttower that, when applied, resulted in capturing almost 70% of the variance. We then used sodar data collected in 1993 at the South Pole ([Neff 1994](#_ENREF_5)) and applied the 2003 regression equation to those data with a similar result. To further test the regression result we then carried out MLR for the 1993 data and applied the results to 2003. These results are sumarized in the figure below. The table also shows the difference in means and standard deviations for each comparison. The key result is that the only significant differences are in the means but not in the standard deviations. The difference in standard deviations for fiting 1993 sodar data lies in the coarser resolution of the sodar that year.

Finally Figure 2 shows power-law fits to NO versus BLDMLR for each of four seasons. The major differences lie in the shallow BLD regimes. For example in 2000, the polar vortex broke up early: with the attendant increase in stratospheric ozone, the actinic flux to the surface was reduced in turn lowering the photolysis of snow nitrate to NO. In addition, winds aloft (300 hPa) were rarely from the southeast to south, a wind wind direction favoring clear skies and light winds ([Neff 1999](#_ENREF_6); [Stone; Kahl 1991](#_ENREF_8)). In 2003, circulation anomalies in late November led to high surface nitrate, increasing the flux of NO into the boundary layer while meteorological conditions favored shallow boundary layers.



**Figure 1.** Upper: Observed BLD in 2003 compared with estimates derived from the MLR equations obtained from 2003 and 1993 sodar data. Lower: Observed BLD in 1993 compared with estimates derived from the MLR equations obtained from 2003 and 1993 sodar data.

**Table: Comparing MLR fits for 2003 and 1993 sodar data (mean/standard deviation)**

|  |  |  |
| --- | --- | --- |
|  | 2003 MLR | 1993 MLR |
| 2003 data | **2.4/26.4** | 5.4/37.3 |
| 1993 data | 7.4/28.2 | **1.8/34.9** |



**Figure 2**. Power law fit to all four seasons of NO and BLDMLR

**References**

Davis, D., and Coauthors, 2004: South Pole NOx chemistry: an assessment of factors controlling variability and absolute levels. *Atmospheric Environment*, **38,** 5375-5388.

Davis, D., and Coauthors, 2001: Unexpected high levels of NO observed at South Pole. *Geophysical Research Letters*, **28,** 3625-3628.

Davis, D. D., and Coauthors, 2008: A reassessment of Antarctic plateau reactive nitrogen based on ANTO 2003 airborne and ground based measurements. *Atmospheric Environment*, **42,** 2831-2848.

Neff, W., D. Helmig, A. Grachev, and D. Davis, 2008: A study of boundary layer behavior associated with high NO concentrations at the South Pole using a minisodar, tethered balloons and sonic anemometer. *Atmospheric Environment*, **42,** 2762-2779.

Neff, W. D., 1994: Studies of the variability in the troposphere and atmospheric boundary layer over the South Pole: 1993 Experiment design and preliminary results. *Ant. Journ. U.S.*, **28,** 302-304.

Neff, W. D., 1999: Decadal time scale trends and variability in the tropospheric circulation over the South Pole. *Journal of Geophysical Research-Atmospheres*, **104,** 27217-27251.

Slusher, D., and Coauthors, 2010: Atmospheric chemistry results from the ANTCI 2005 Antarctic plateau airborne study. *Journal of Geophysical Research: Atmospheres (1984–2012)*, **115**.

Stone, R. S., and J. D. Kahl, 1991: Variations in boundary layer properties associated with clouds and transient weather disturbances at the South Pole during winter. *J. Geophys. Res.*, **96,** 5127-5144.