Boundary Layer Depth Effects on Surface Chemistry: Insights from Comparing South Pole Antarctic and Summit Greenland

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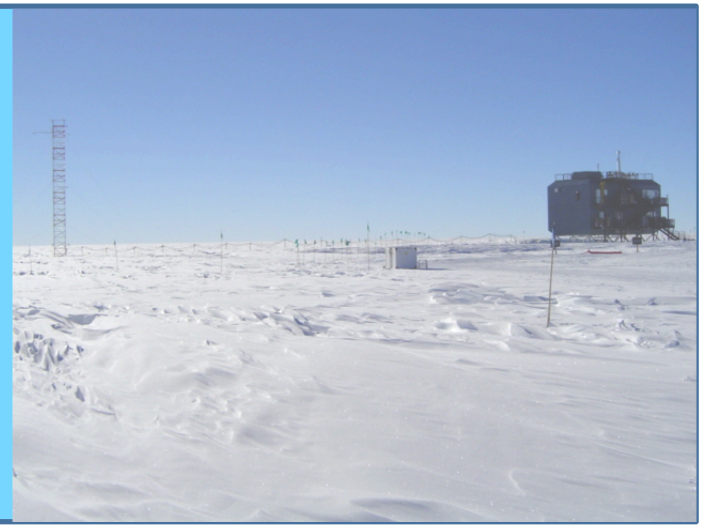
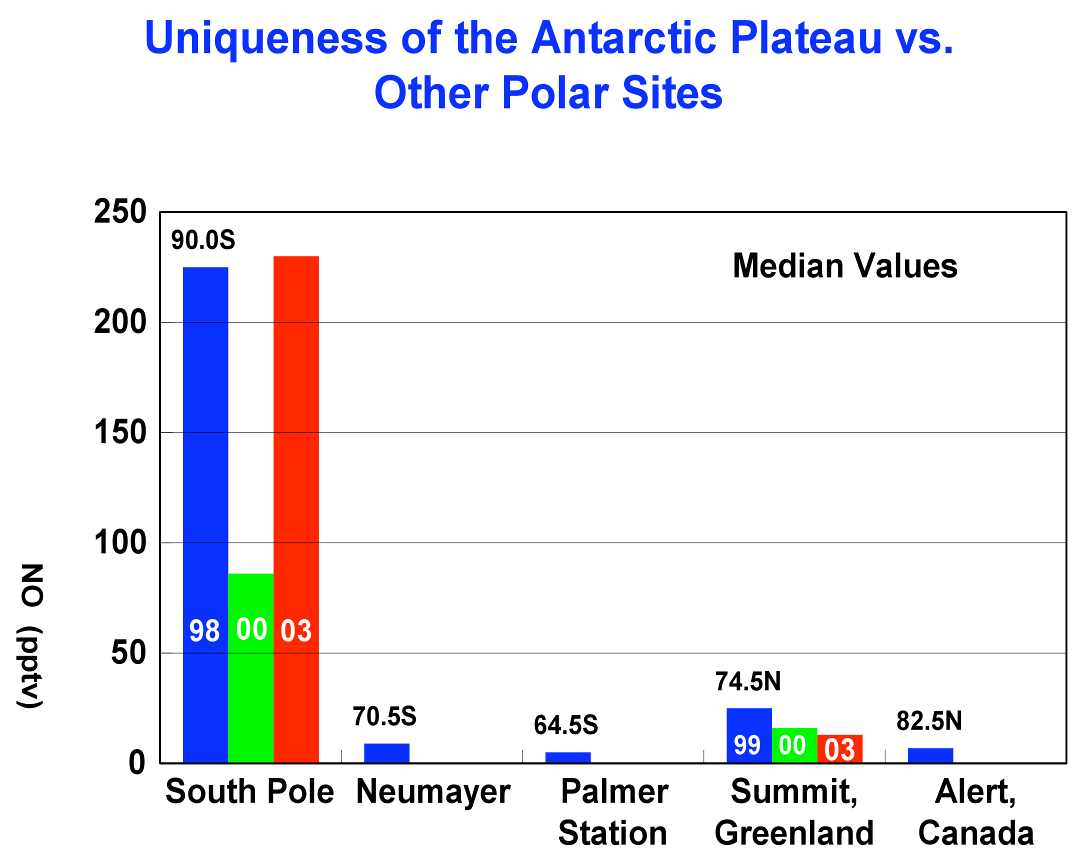


The results of the ANTCI, SCATE and ISCATE field experiments at the South Pole showed unusually high levels of NO compared to other polar sites



--D.D. Davis

The results of Davis et al. 2004 suggested that the high levels of NO originated from non-linear chemistry in shallow boundary layers

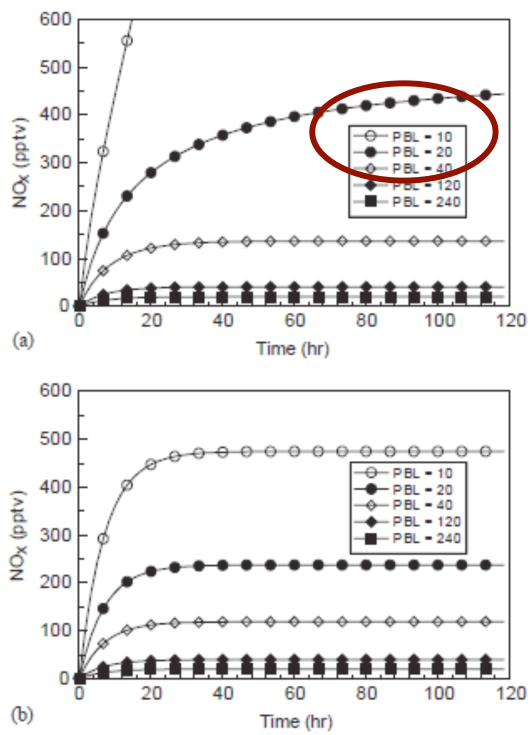
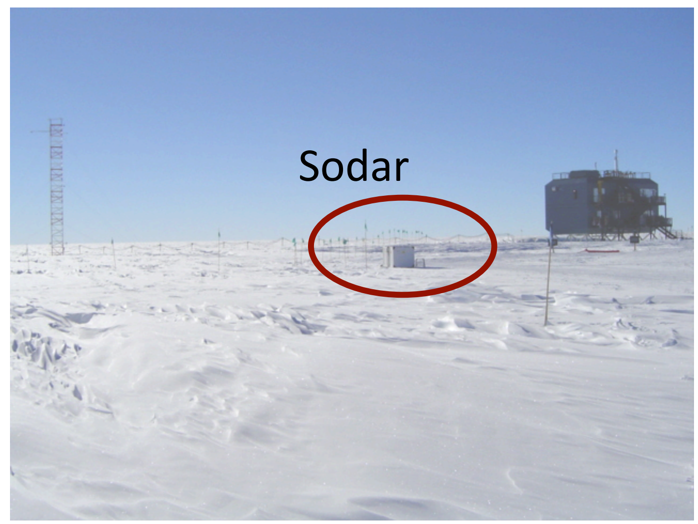
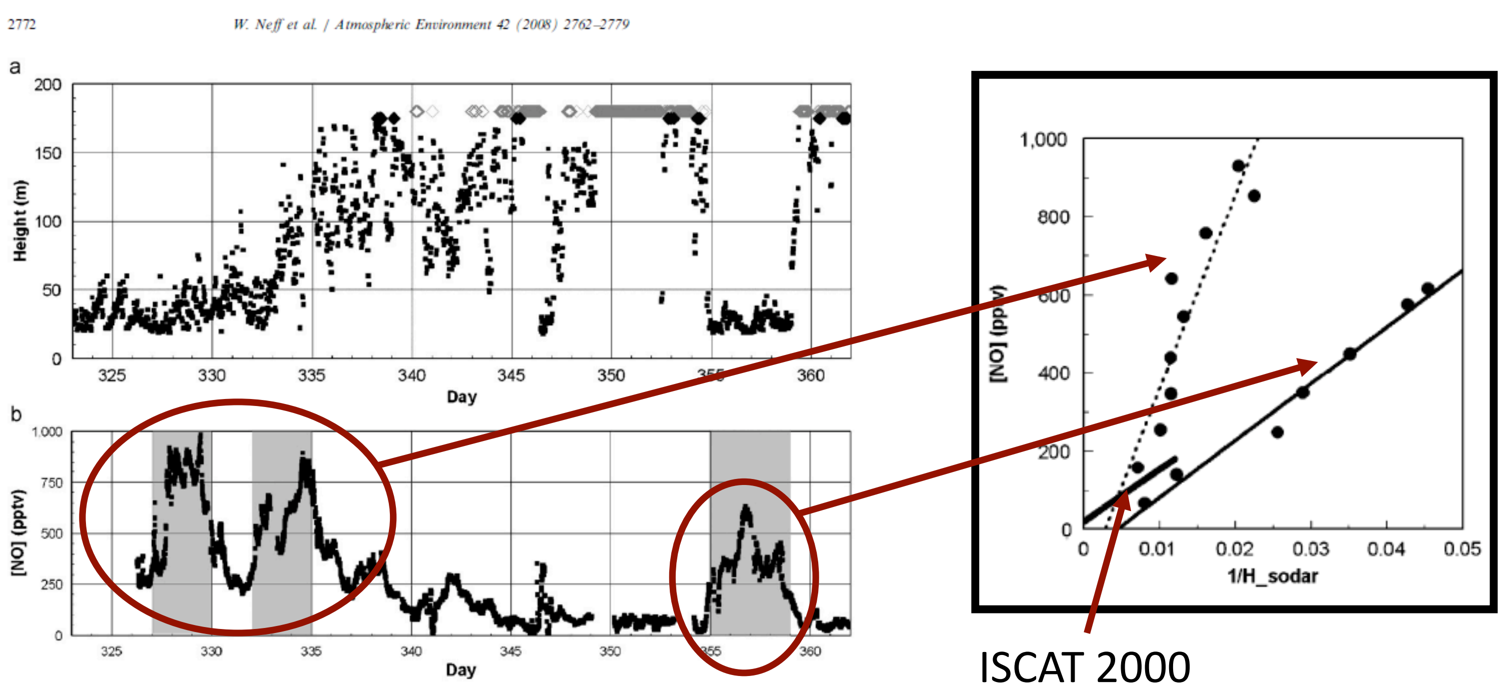


Fig. 10. Model simulated accumulation (pptv) of NO_x in a moving parcel of air above a SP snow surface as a function NO_x lifetime and mixing depth. Panel (a): variable NO_x lifetime as shown in Fig. 8 and (b) constant NO_x lifetime at 7 h. Note, the NO_x lifetime is estimated from: $([NO_x])/(k[OH][NO_2]+(k[HO_2][NO_2]-k[HO_2NO_2]))$, where the "$k$" terms are the corresponding reaction coefficients or thermal decomposition constant.



The results of ANTCI 2003 confirmed the dependence of high NO levels on boundary layer depth.

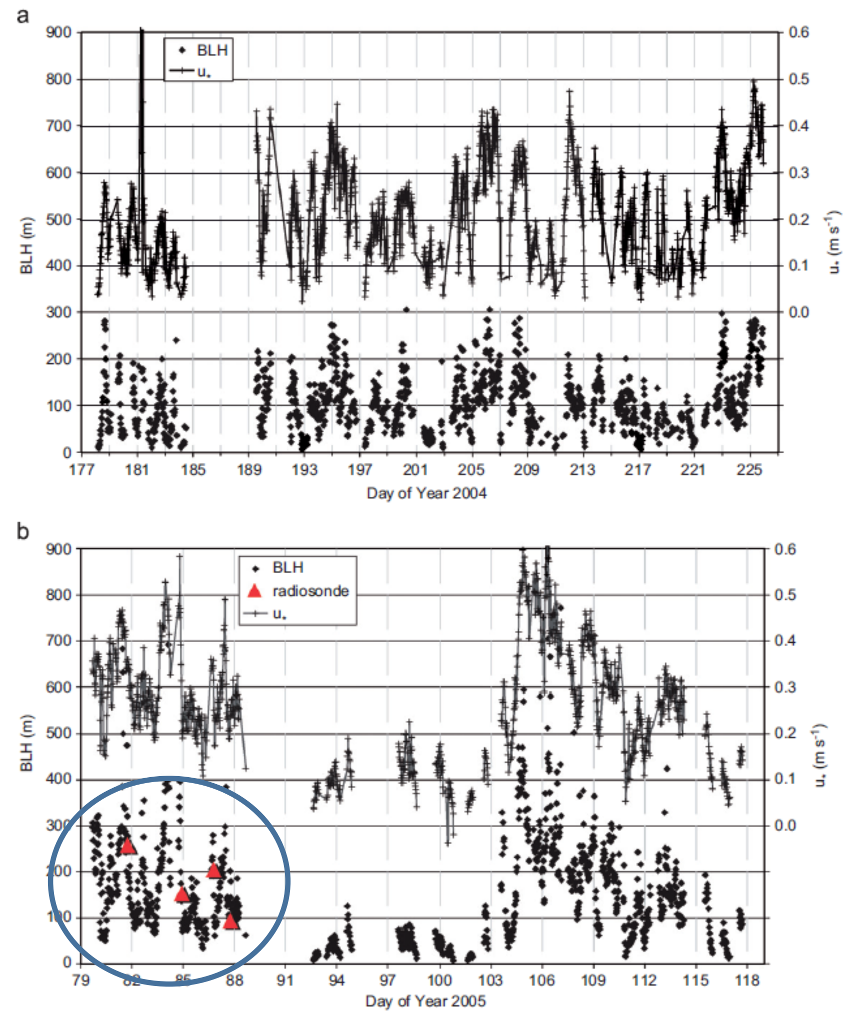


This raised the question of whether similar shallow boundary layers occurred at Summit Station on the high Greenland ice sheet.

First results using inference of boundary layer depth using a diagnostic equation approach (2004-2005):

Boundary-layer dynamics and its influence on atmospheric chemistry at Summit, Greenland

Lana Cohen[a], Detlev Helmig[a,*], William D. Neff[b], Andrey A. Grachev[c], Christopher W. Fairall[b]

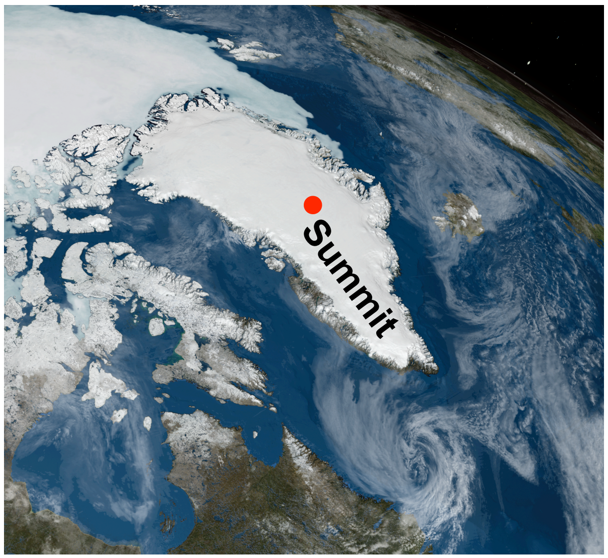


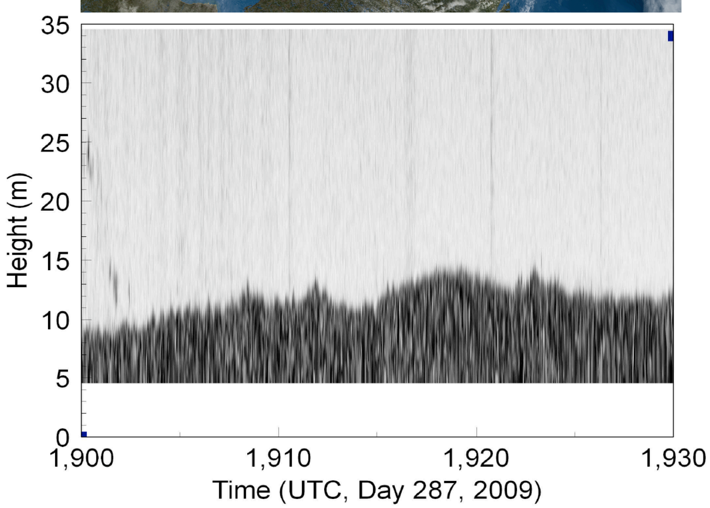
Results:

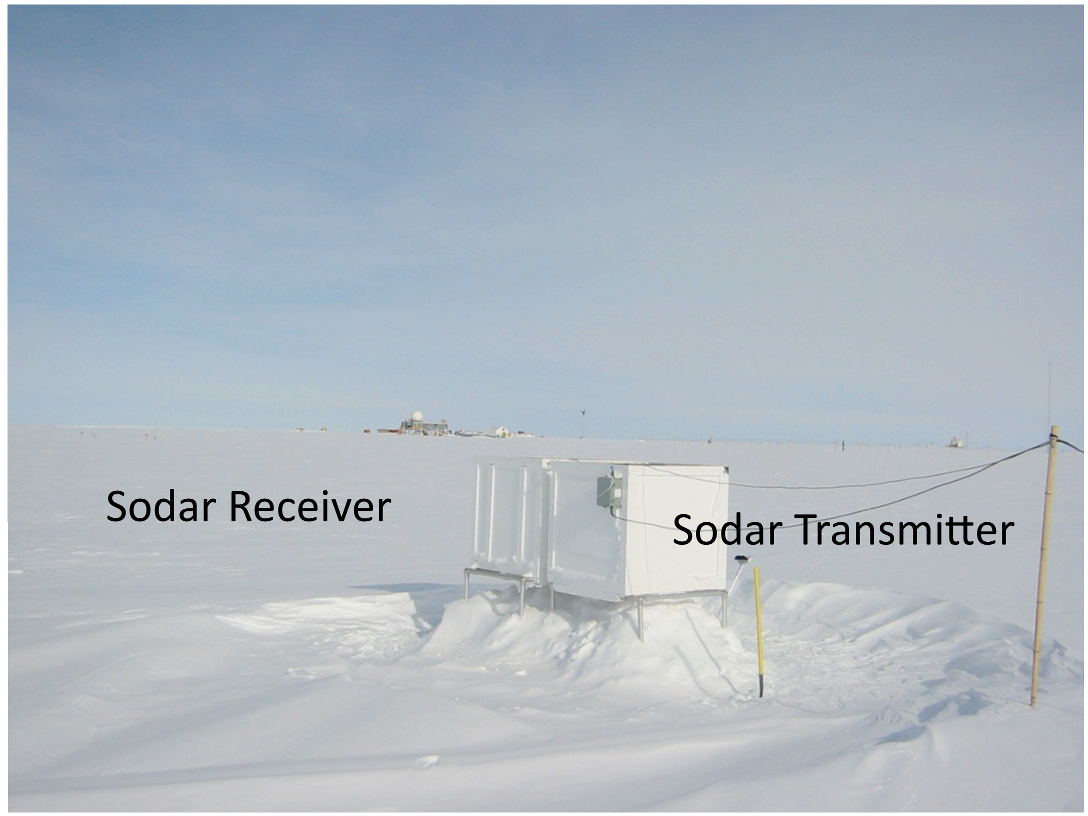
- Fairly deep boundary layers
- Agreed well with limited radiosonde profiles.

No direct measurements with sodar and limited comparison

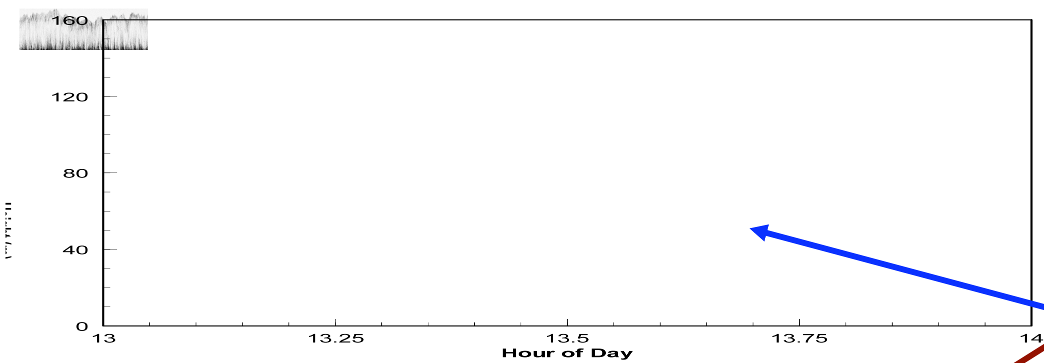
A sodar was deployed in the summer of 2008 and has been running until the present time





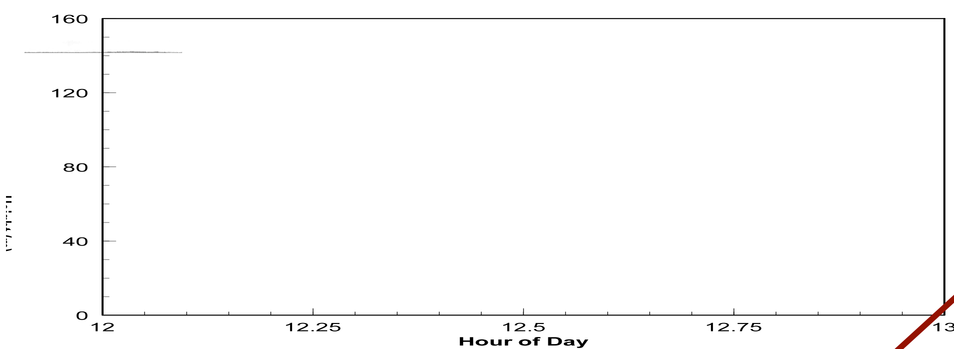


A sodar was deployed in the summer of 2008 and has been running until the present time as part of two other experiments: range of phenomena: Convection



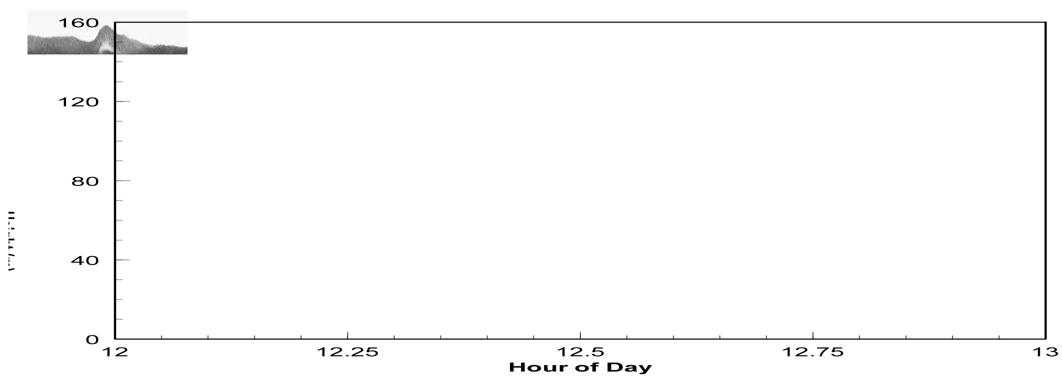
Example: Convective conditions with a capping inversion. Near surface echoes arise *from rising warm air parcels*. Elevated echo layer generated at the interface with the laminar flow over the convective layer.

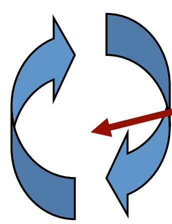
A sodar was deployed in the summer of 2008 and has been running until the present time as part of two other experiments: range of phenomena: Shallow boundary layers



Example: Very shallow boundary layer (<10 m) occurring under light wind, stable conditions.

A sodar was deployed in the summer of 2008 and has been running until the present time as part of two other experiments: range of phenomena: Disturbances





Example: Solitary wave propagating on the inversion. *Note the inner core of the circulation.*

Results from diagnostic scaling:

Two equations were evaluated:

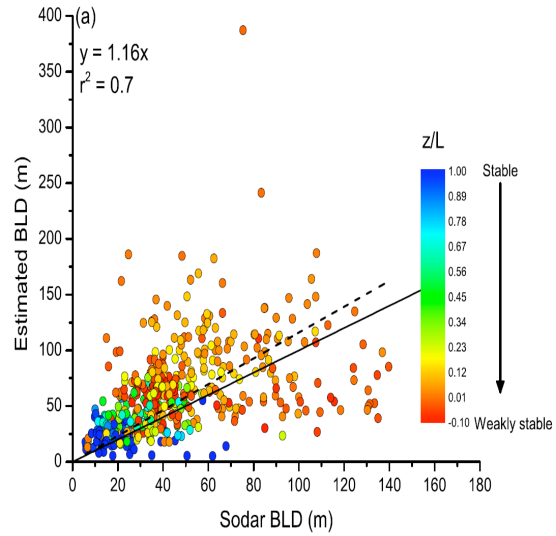
1) Pollard (1973): $H = 1.2u_*(fN_b)^{-1/2}$

2) Zilitinkevich and Baklanov (2002) is described by: $H = C_s^2\left(u_*L/|f|\right)^{1/2}$

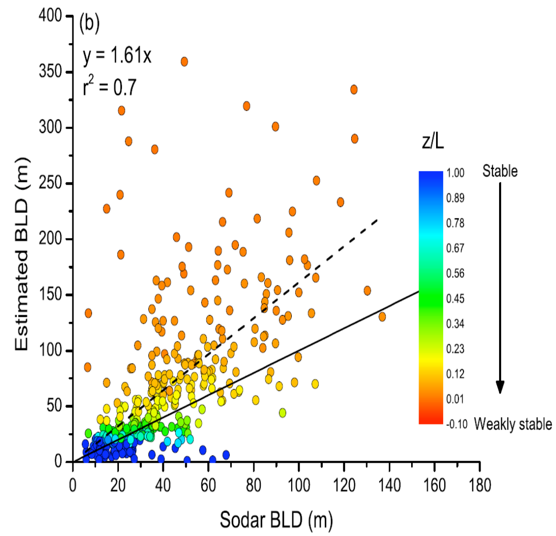
Evaluation of boundary layer depth estimates at Summit Station, Greenland

B. Van Dam[1], D. Helmig[1,*], W. Neff[2], L. Kramer[3]

(1)



(2)



Results van Dam et al: No effect of boundary layer depth on NO/NOX

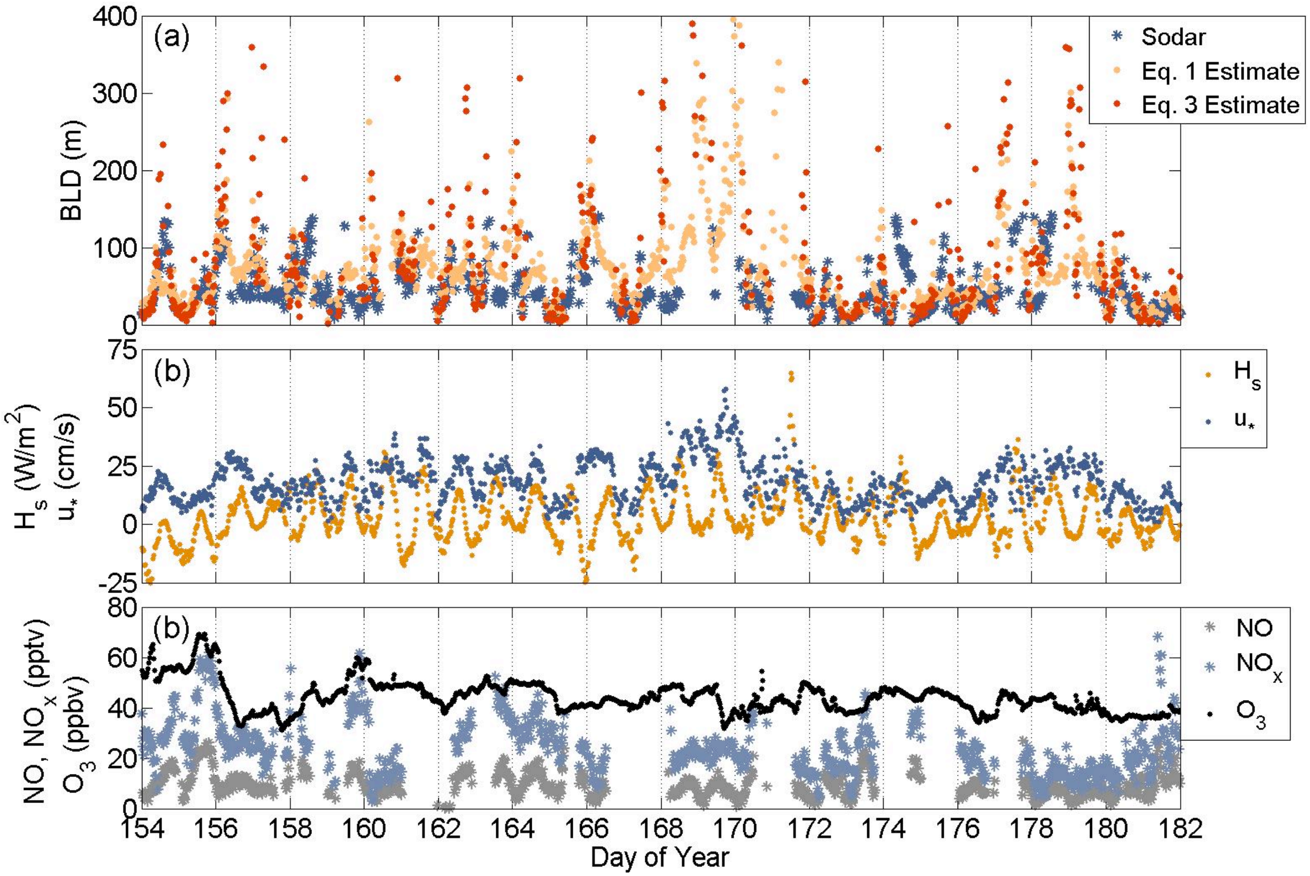


Figure 6: Time series of (a) BLD observations from the sodar and estimates using Eq. (1) and (3), (b) friction velocity and sensible heat flux, and (c) NO, NO_x ($NO+NO_2$) and O_3 measured at 2.5 m on the meteorological tower.

Some discussion:

Low NO despite shallow boundary layers: what is different?

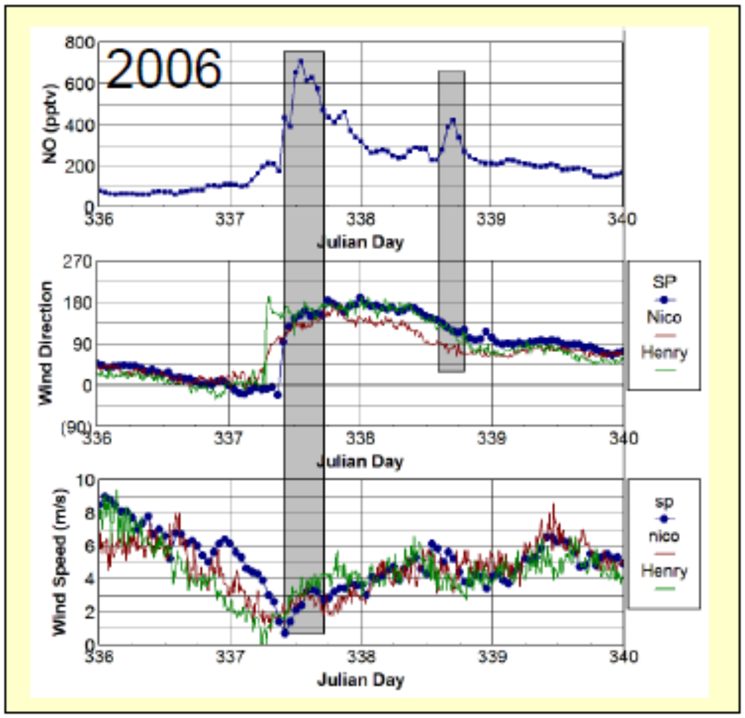
- **Latitude/Diurnal Cycle? Not likely as NO levels at Concordia (75.1°S versus 72.5°N) are as high as at the South Pole. Also Slusher et al 2009 show high NO over much of the ice sheet between South Pole and Vostok.**
- **Ozone Hole and denitrification of the stratosphere? Unlikely as snow nitrate levels are comparable.**
- **Low snow accumulation rates over high Antarctica compared to Greenland? Likely – as suggested by Frey et al. 2013:**

The diurnal variability of atmospheric nitrogen oxides (NO and NO_2) above the Antarctic Plateau driven by atmospheric stability and snow emissions

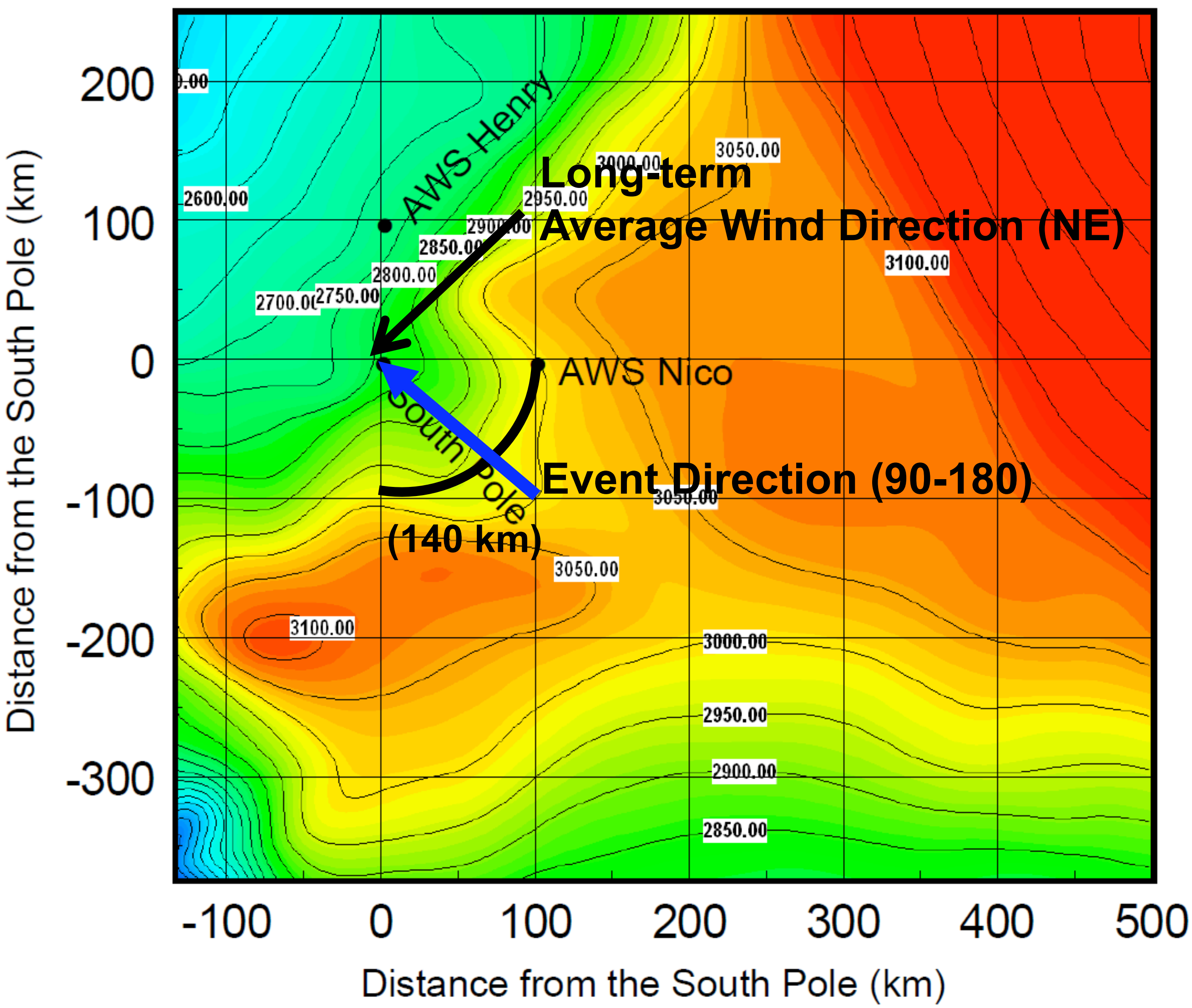
M. M. Frey[1], N. Brough[1], J. L. France[2], P. S. Anderson[1,3], O. Traulle[4], M. D. King[2], A. E. Jones[1], E. W. Wolff[1], and J. Savarino[5]

Some next questions:

- The results of Frey et al 2013 suggest that NO production is local (it follows the insolation cycle at Concordia).
- However, at the South Pole, sudden increase are often found that have a more frontal character:



A topographic issue, 90 deg shift in wind direction with "chemical events":

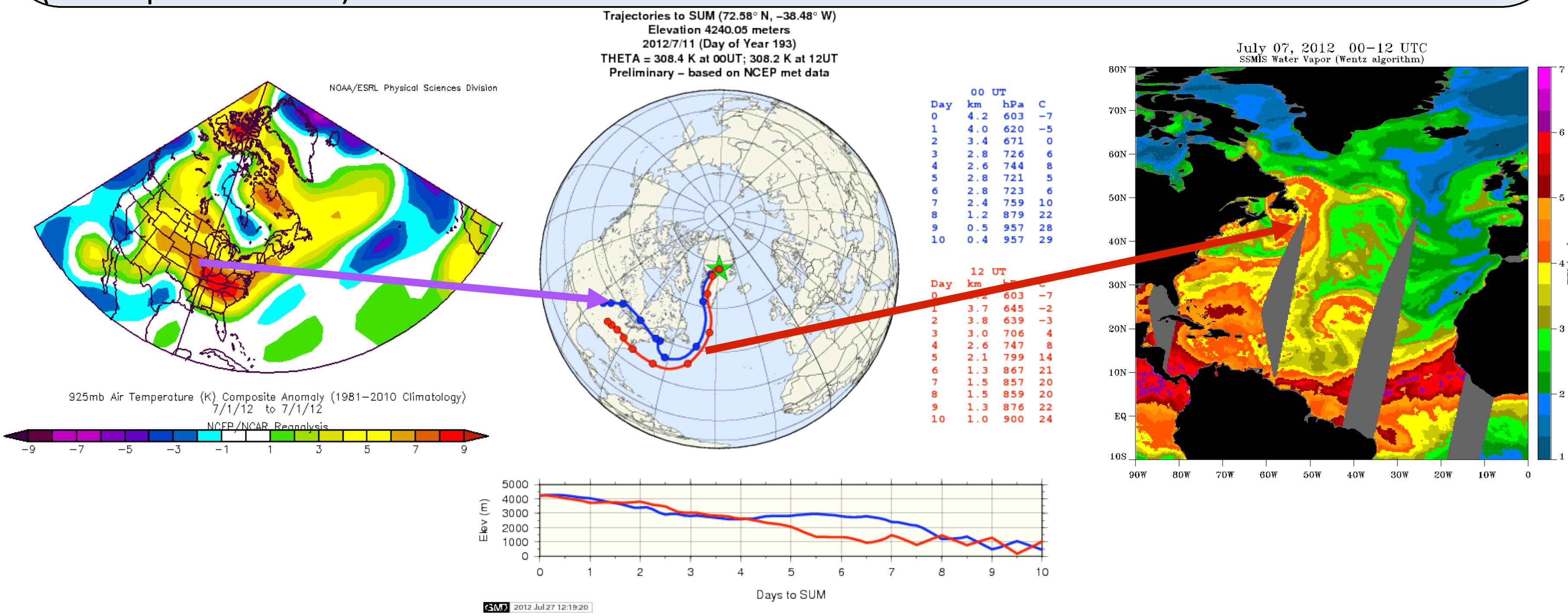


A few more weather stations would be nice…

Some new directions (bipolar):

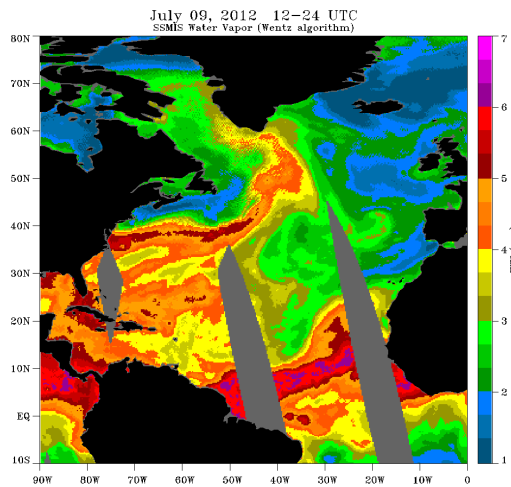
The figures below outline the key ingredients coming together in advance of the 11 July melt episode:

1. Significant temperature anomalies (9°C) in the mid- to eastern U.S. 11 days earlier.
2. Trajectories carrying warm air eastward over the ocean and then north to Greenland arriving on 11 July.
3. A narrow band of moisture coincident with the trajectory to the north to Greenland (Atmospheric River*)

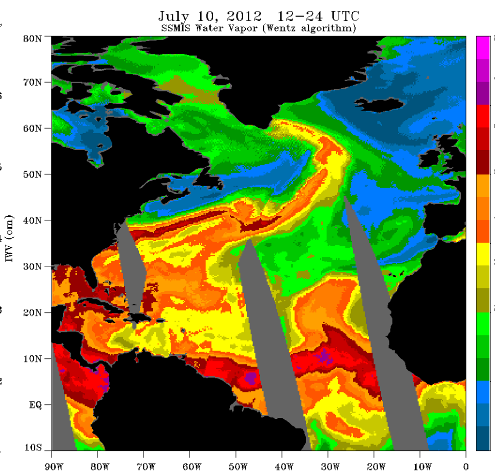


Atmospheric Rivers

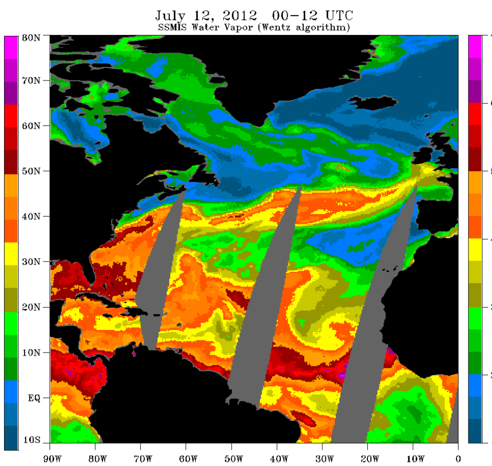
(see Tsukernik et al tomorrow for the Antarctic case)



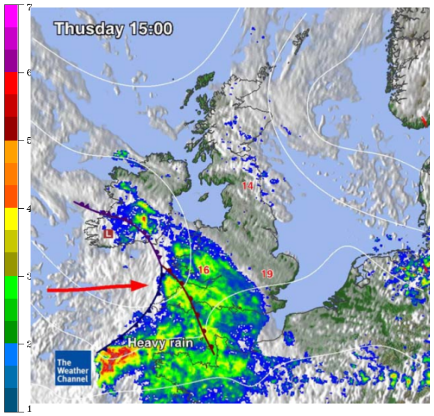
9 July



10 July



12 July



Heavy rain 12 July 1500Z

Melt episodes 2012 versus 1889

Common elements:

1) Trough to the west of Greenland,
2) moist advection over the ocean toward the Labrador Sea,
3) continental temperature anomalies.