Variations in Tropospheric Ozone in the Arctic (with an emphasis on Barrow and Summit)

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in Boulder
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at Barrow
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NOAA Earth System Research Laboratory
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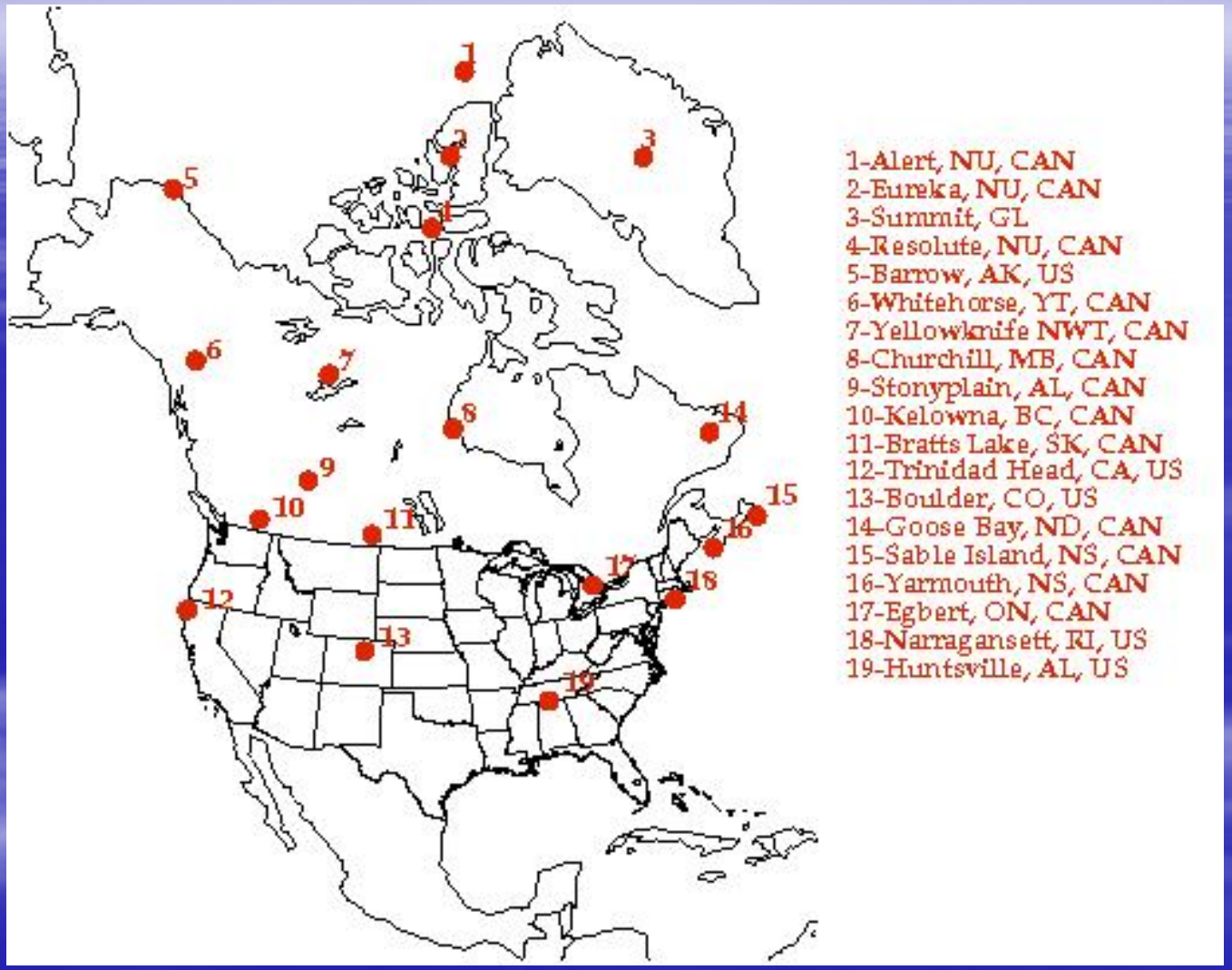
Jacquie Witte – NASA GSFC

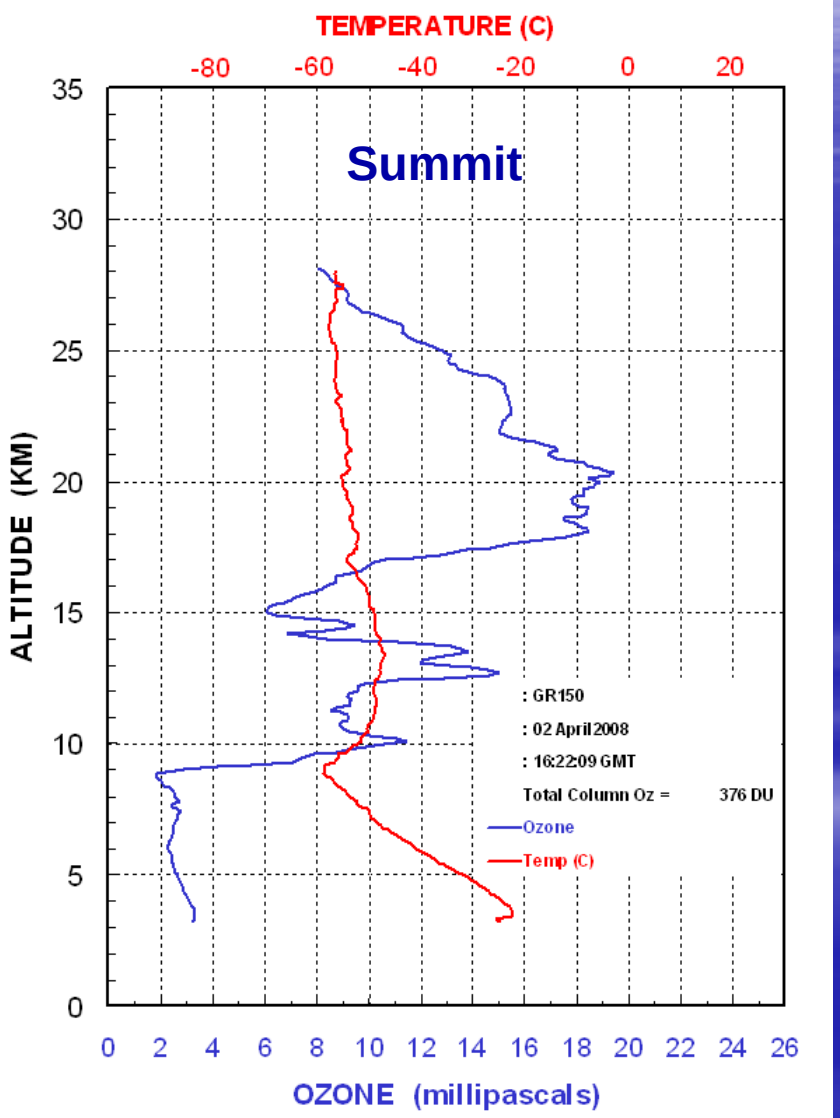
Global Monitoring Annual Conference
May 14, 2009
Boulder, Colorado

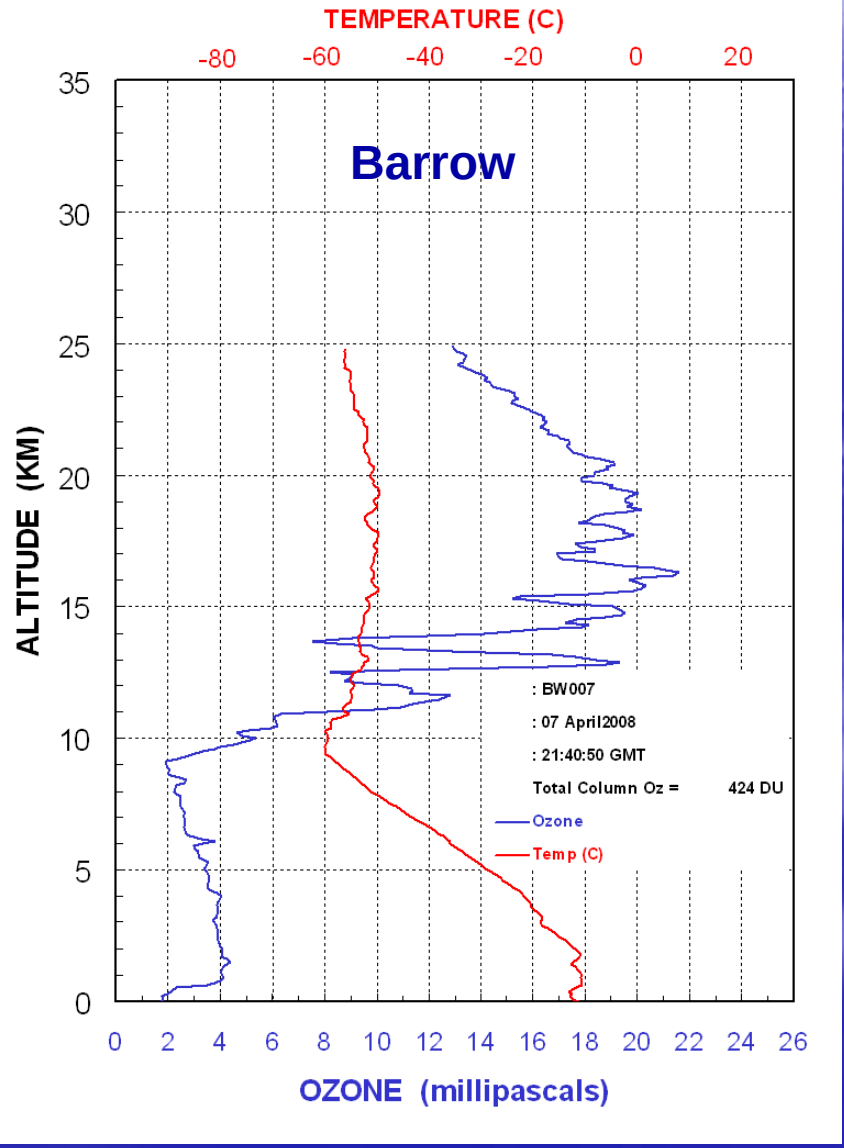
Locations making ozone profile measurements during ARCIONS (ARCTAS Intensive Ozone Network Study) 2008



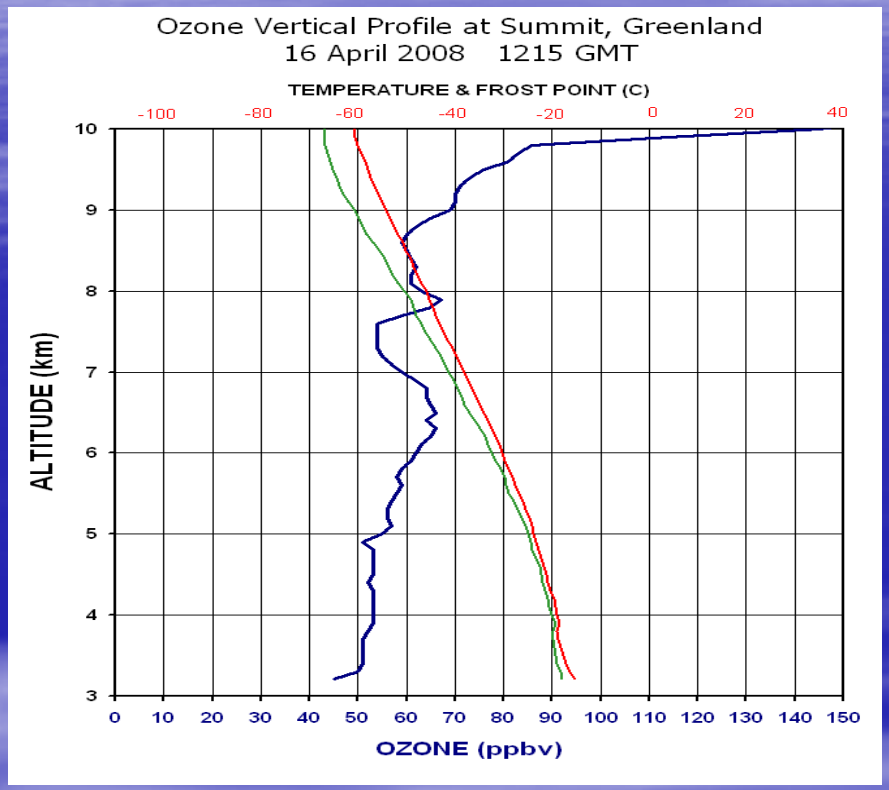
Acknowledgements: Funding provided by NASA, Environment Canada, NOAA/ESRL/GMD. Logistic support from CH2M Hill (CPS), many station operators doing the balloon soundings.

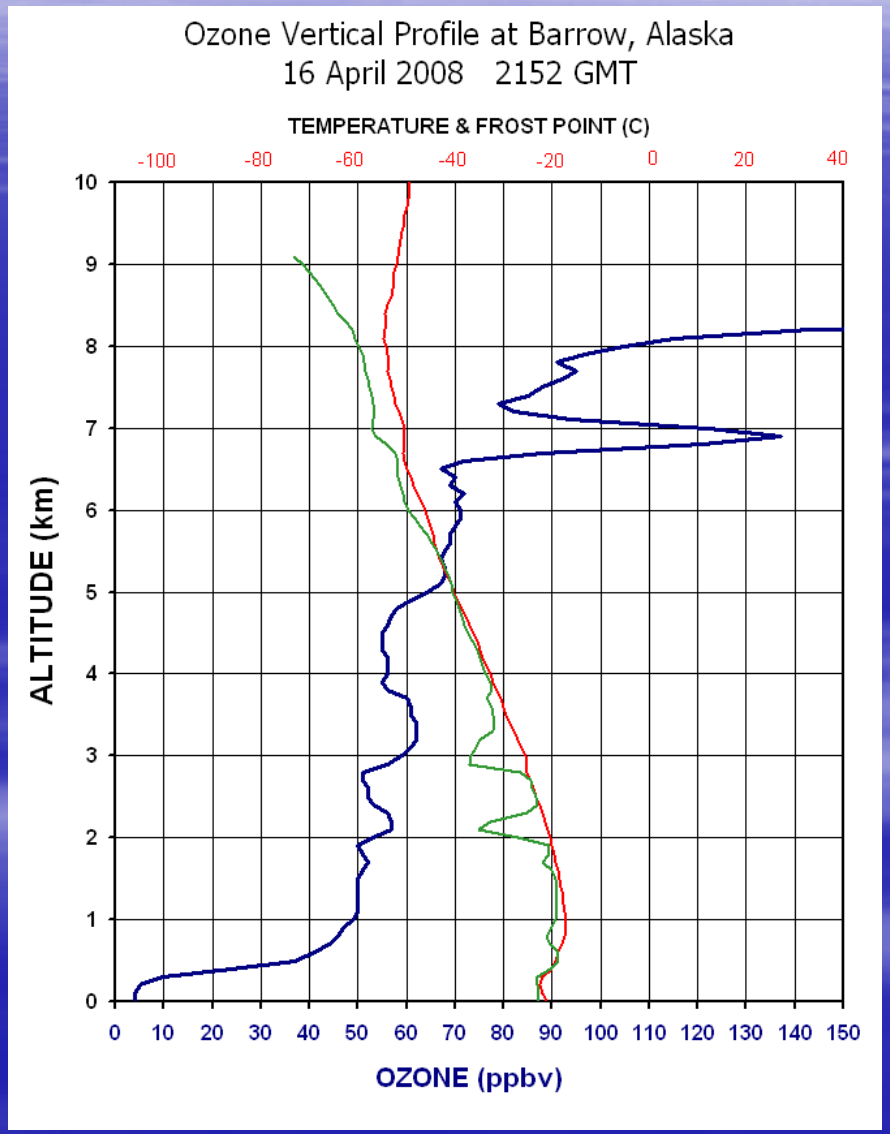
Examples of April profiles from Summit, Greenland (left) and Barrow, Alaska (right)



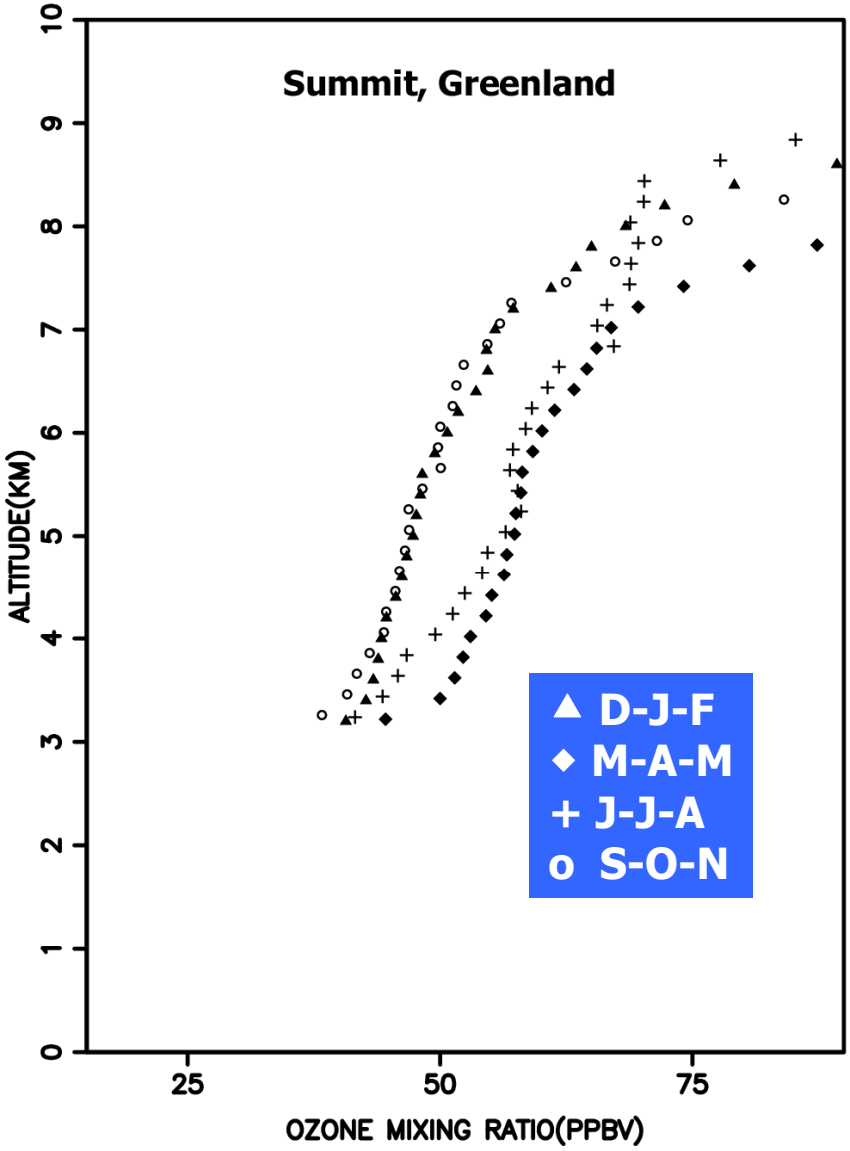


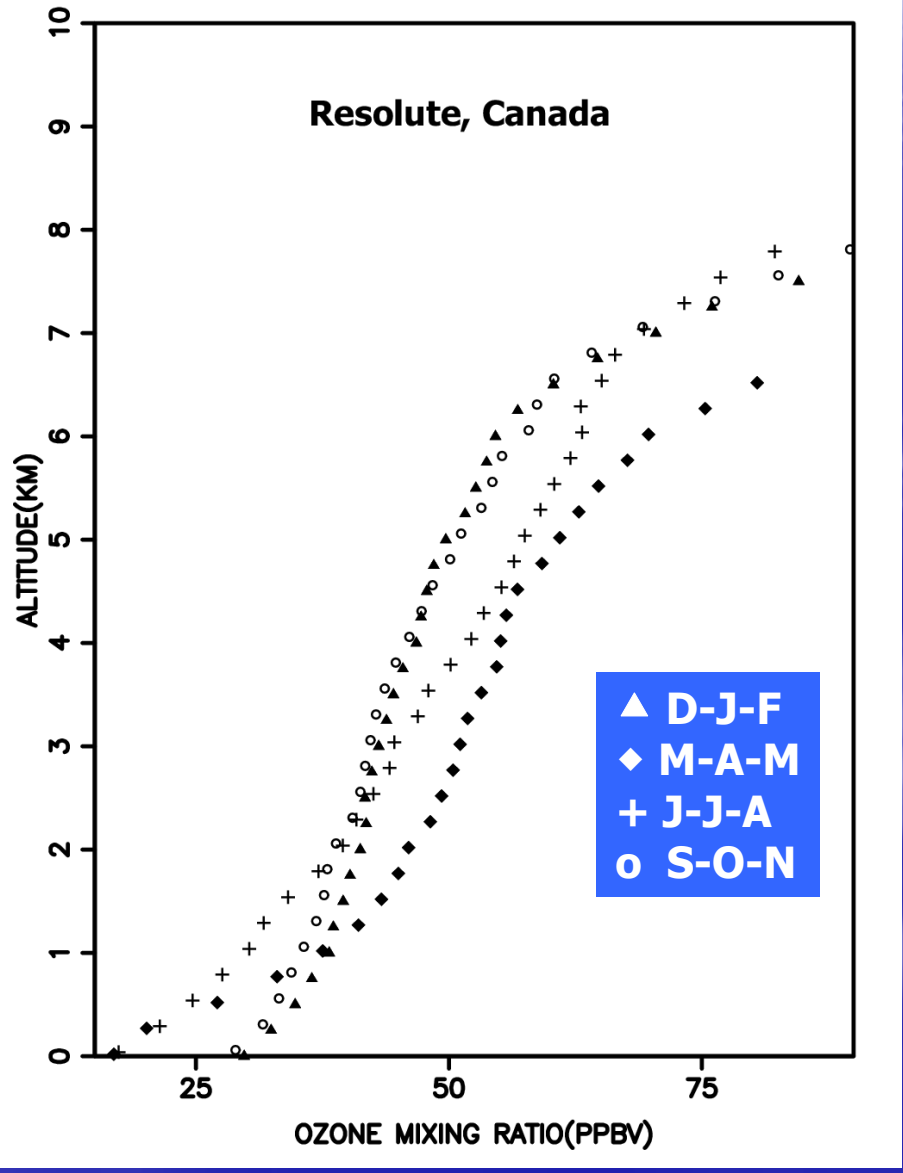
Tropospheric profiles from Summit, Greenland (left) and Barrow, Alaska (right) on 16 April 2008



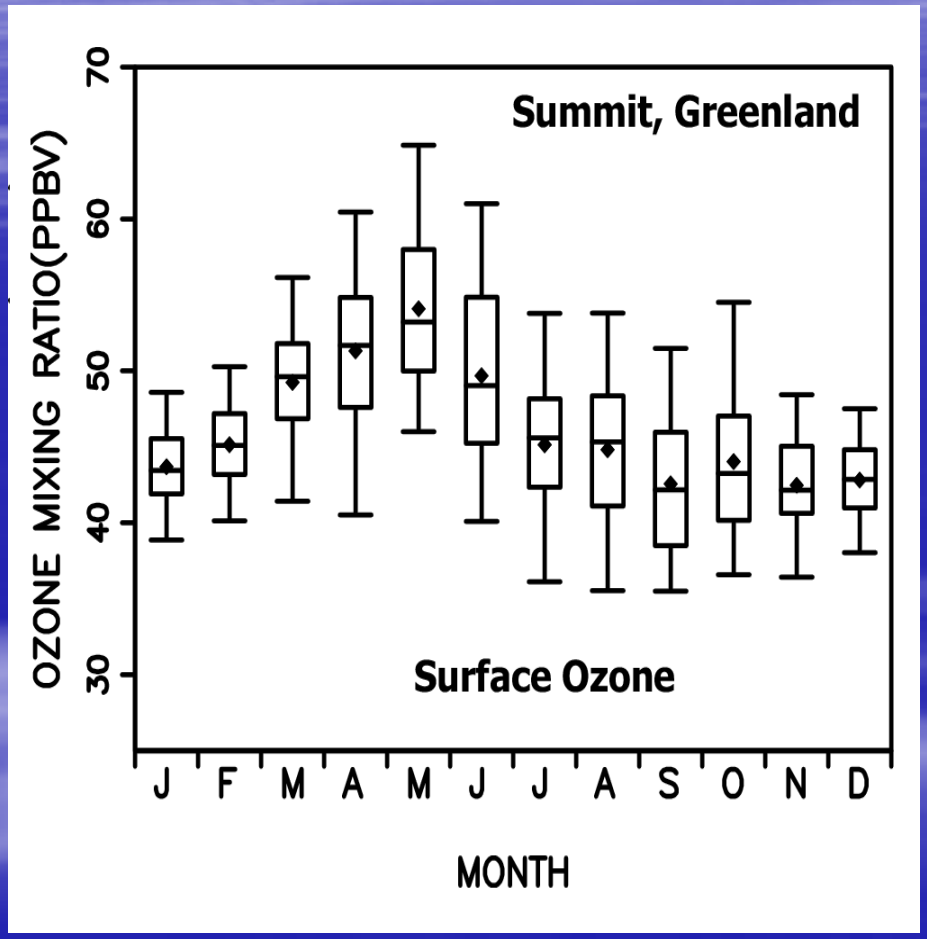


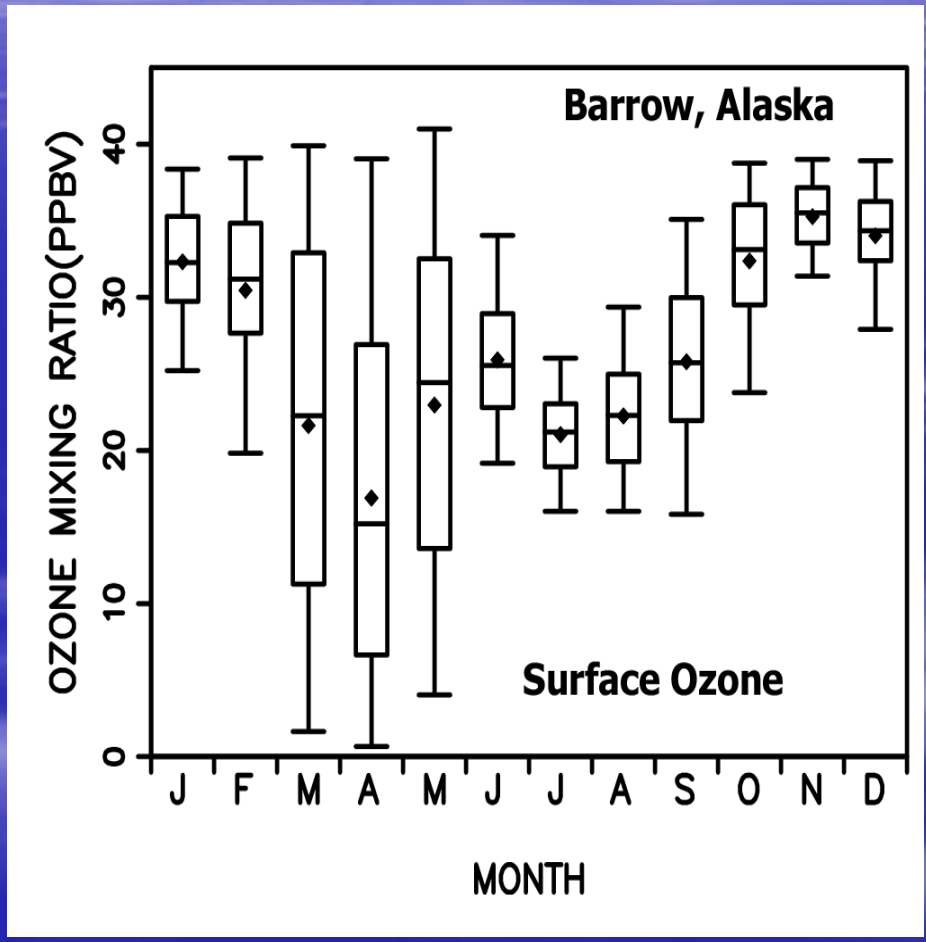
Average Seasonal Profiles at Summit (left) and Resolute, Canada (75N)



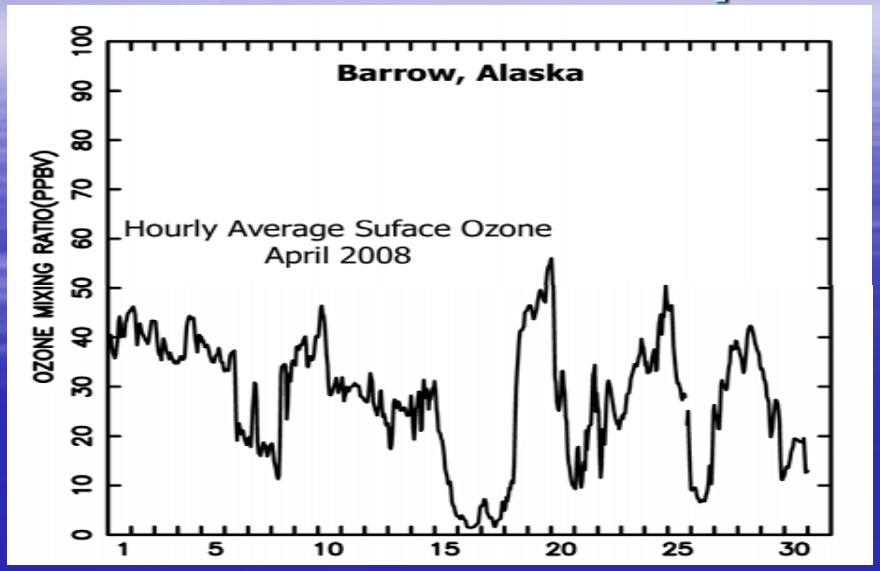


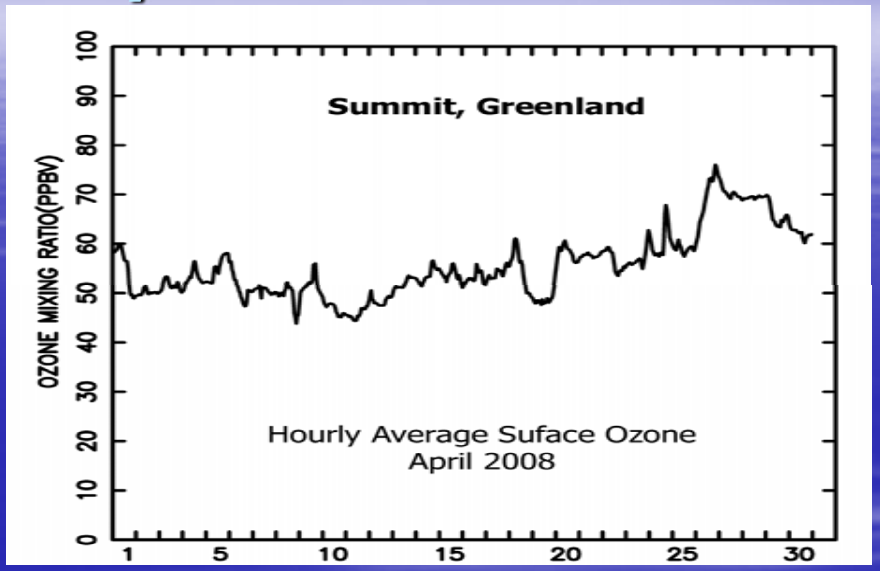
Surface Ozone Seasonal Variation at Summit (72N) and Barrow (70N)

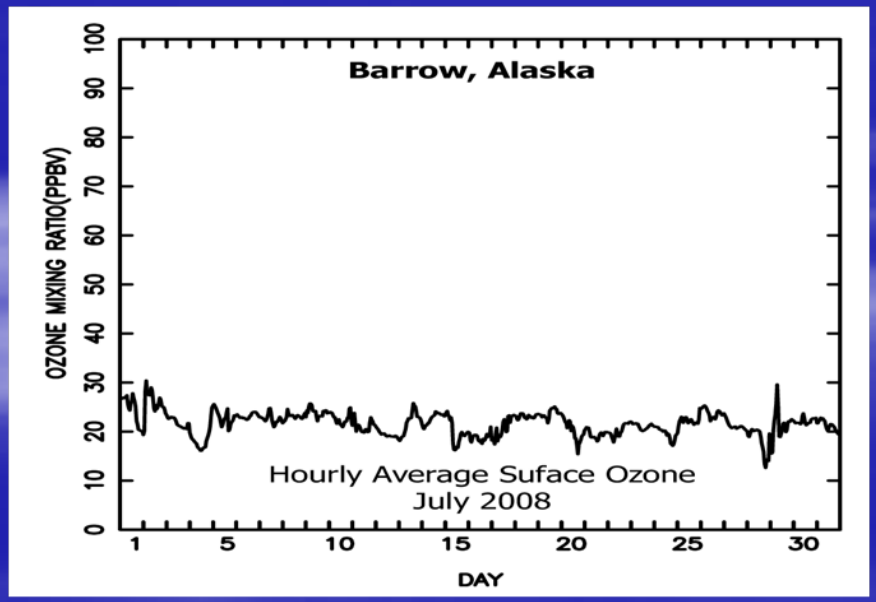


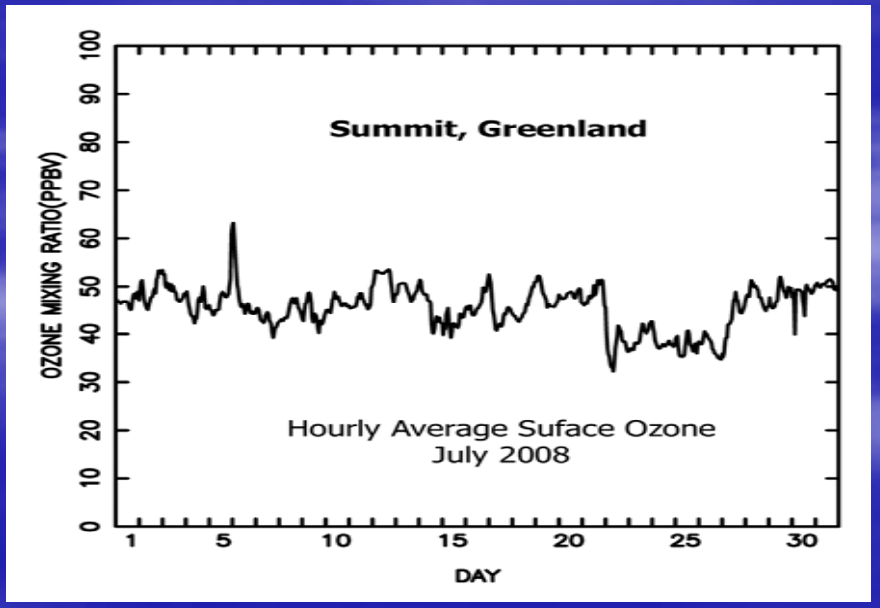


Hourly Average Surface Ozone at Barrow and Summit for April and July 2008



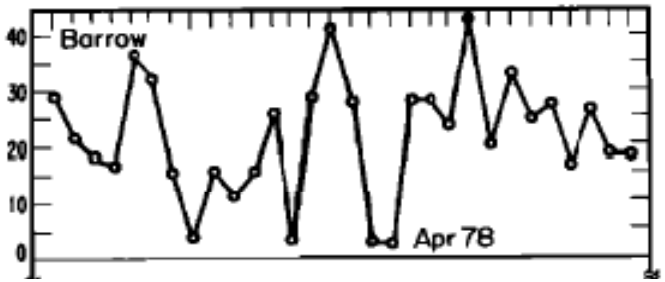






Surface Ozone Depletion at Barrow

The most stunning day-to-day changes in surface ozone occur at Barrow during the spring. It is not unusual for daily ozone values to fluctuate from near zero to 30 or 40 nbar. The near zero values may persist up to a couple of days. It is not clear where air so depleted of ozone originates.



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Surface Ozone Measurements in Clean Air

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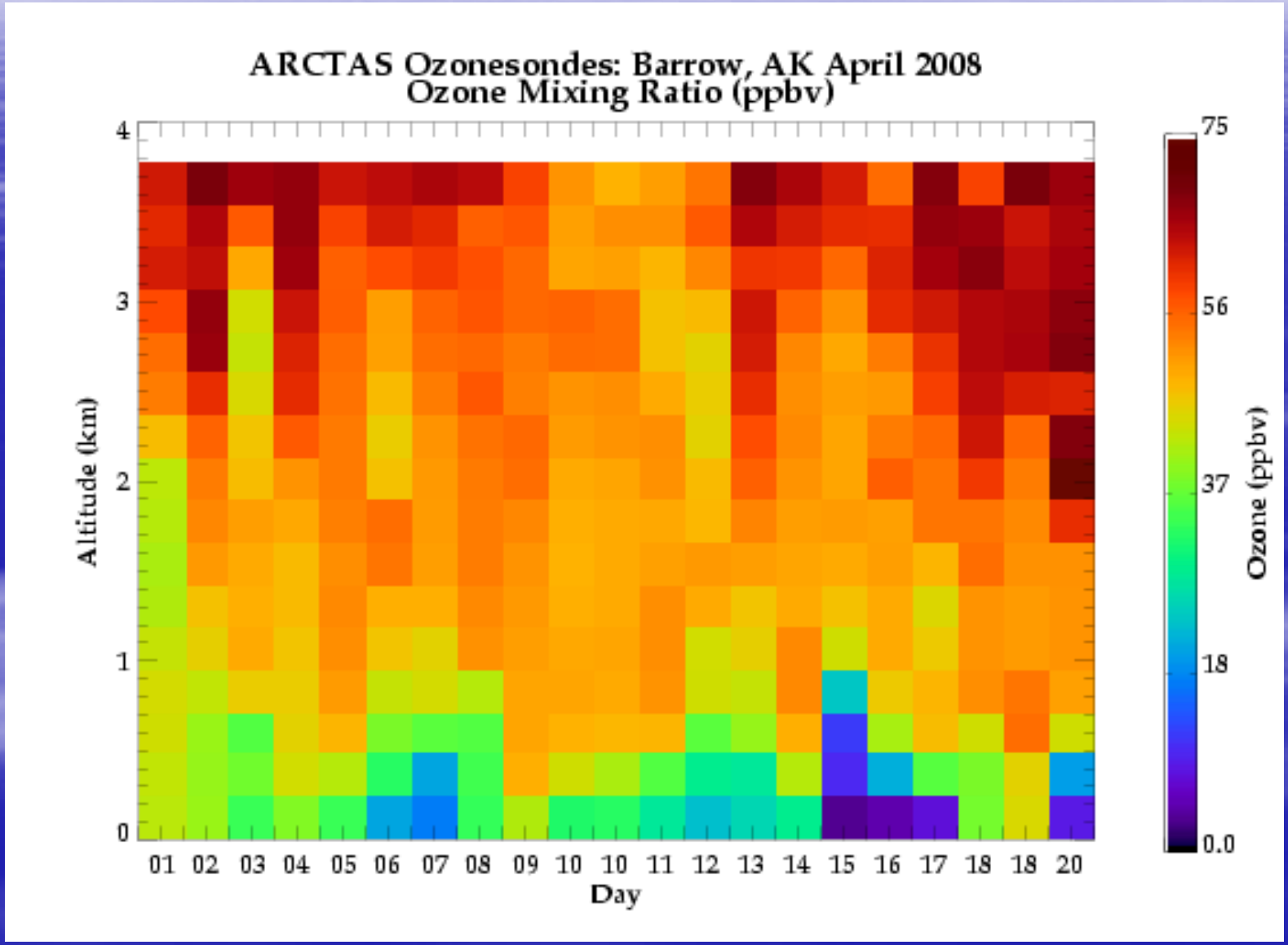
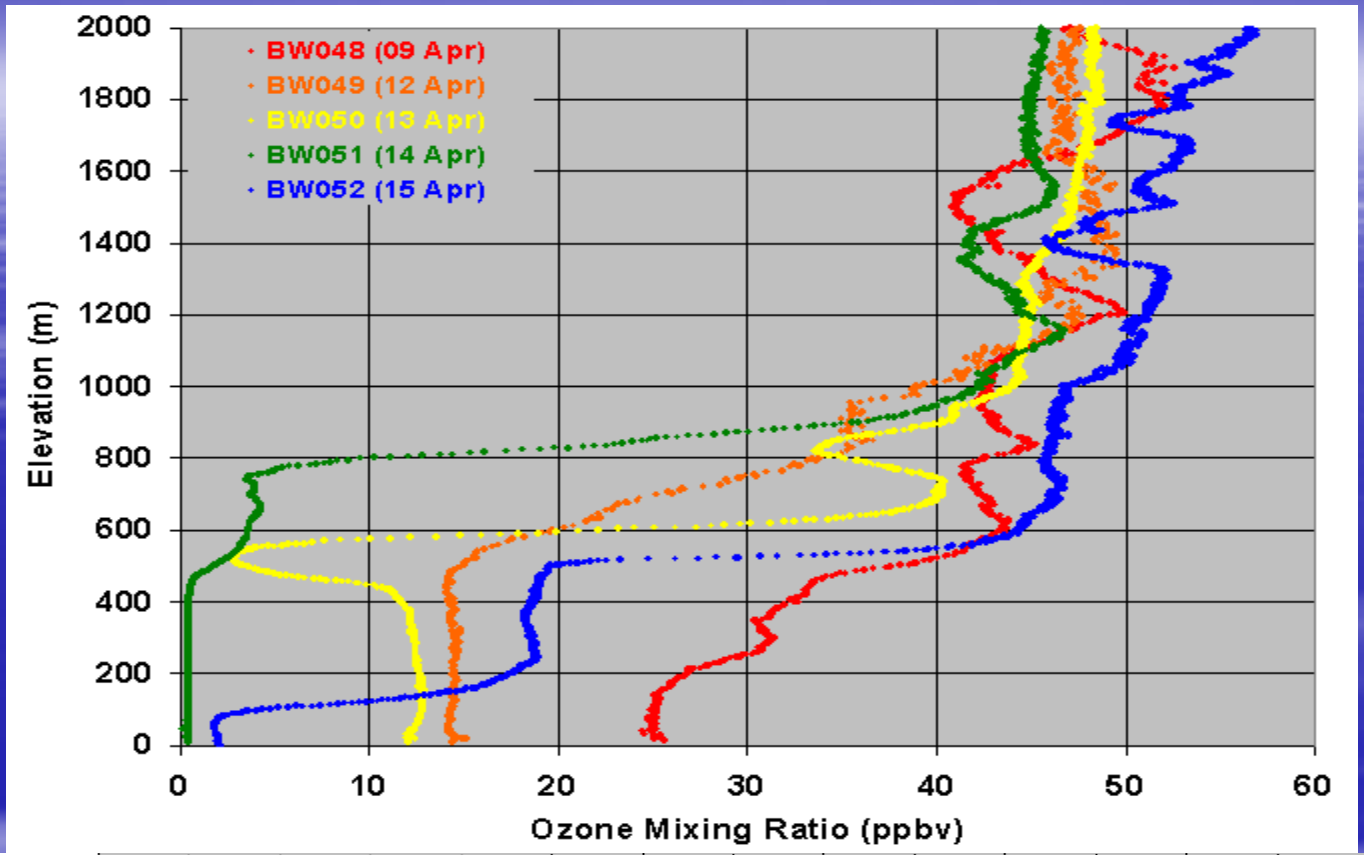
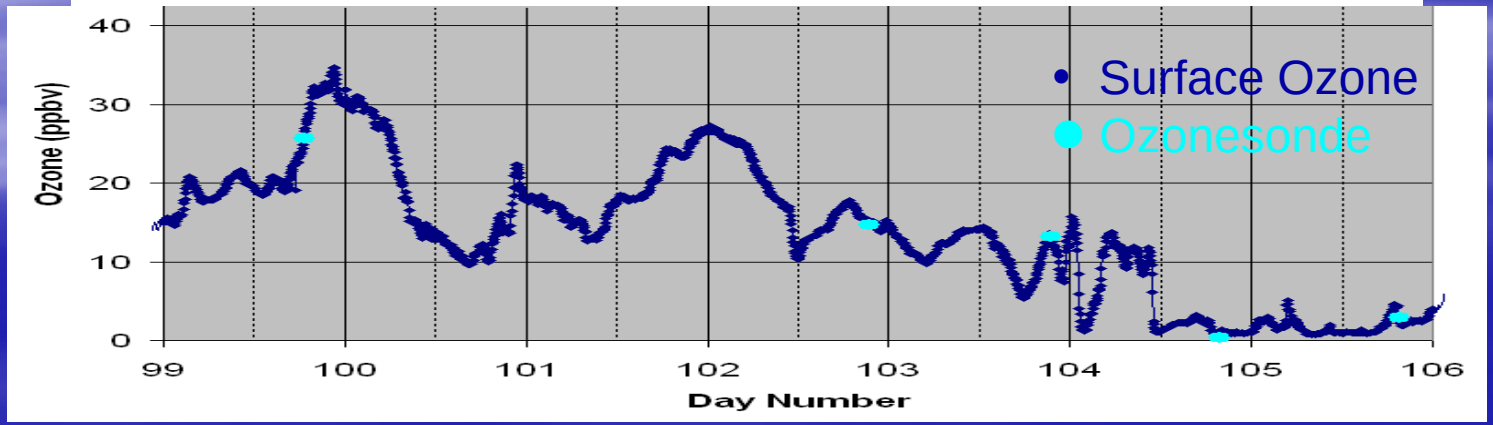
Surface ozone measurements at the four baseline U.S. geophysical monitoring for climatic change observatories provide a glimpse of tropospheric ozone behavior at locations generally isolated from local anthropogenic contamination. Variations on time scales from hours to years are considered. Observations in tropical and polar regions suggest weak coupling between tropospheric and stratospheric ozone in these regions. At subtropical and mid-latitude stations, on the other hand, there appears to be stronger coupling between tropospheric and stratospheric ozone. A small diurnal variation in surface ozone at Samoa may indicate photochemical influence on the ozone budget there. Some of the year-to-year differences in surface ozone at the four stations indicate possible global influences on the tropospheric ozone budget. No significant long-term trends are apparent in the data, however.

Ozone Vertical Profile Cross-section from Ozonesondes at Barrow in April 2008

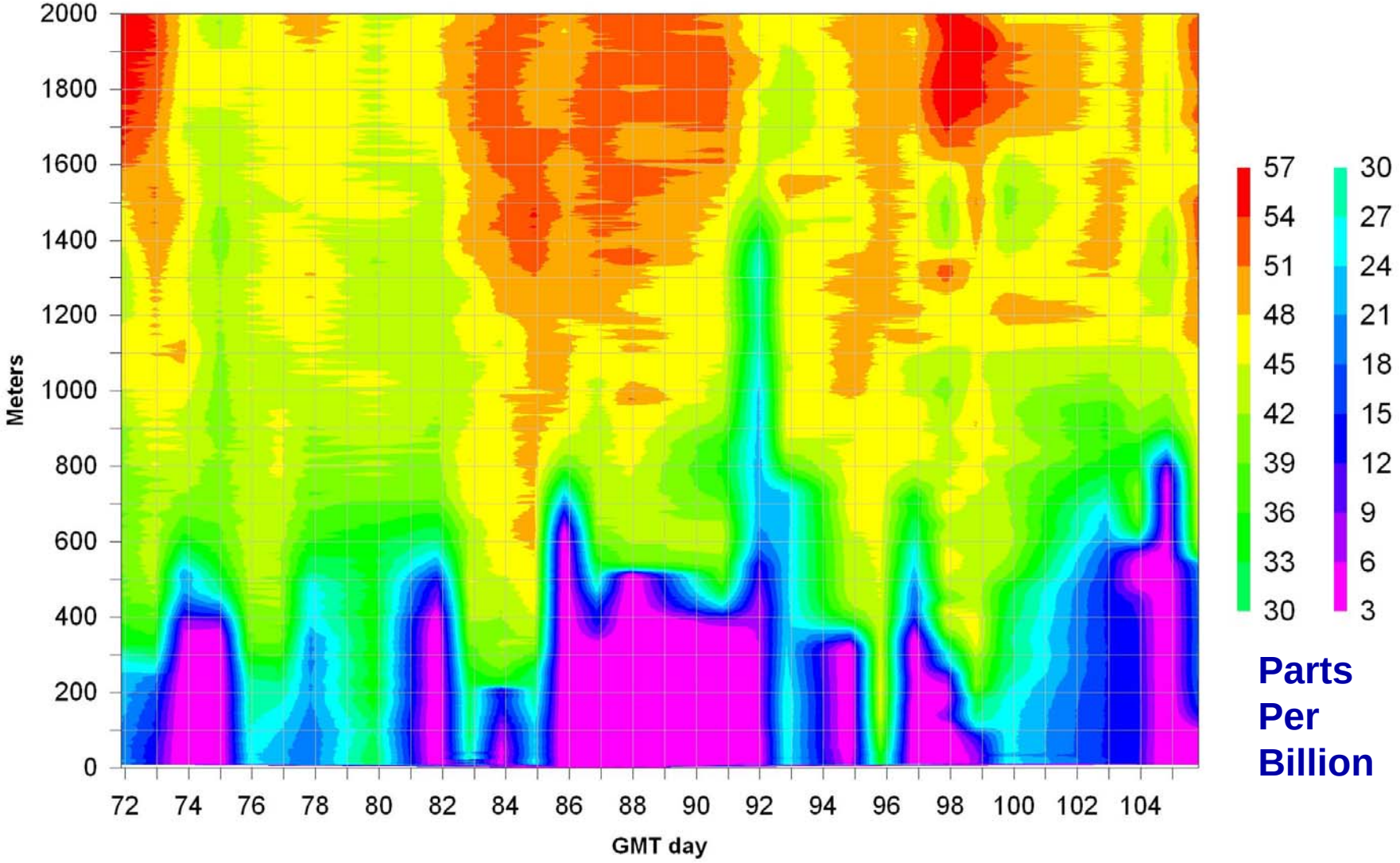


Ozone Profiles at Barrow During April 9-15, 2009





Ozone (ppb) Cross-section at Barrow, AK During March 13, 2009 (Day 72) - April 16, 2009 (Day 106)



Surface Ozone Depletion (connecting to halogen chemistry)

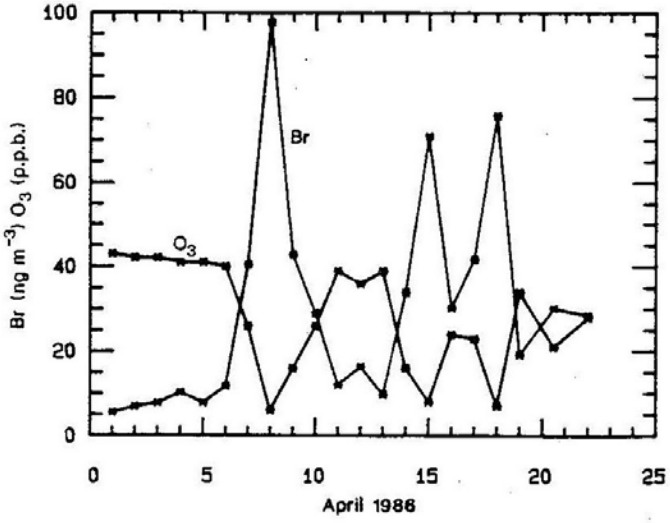


Fig. 1 A comparison of daily mean ground level O_3 and filterable Br(f-Br) concentrations at Alert, Canada, in April 1986 (from Barrie *et al.*[2]), illustrating the strong inverse correlation between the two parameters.

Barrie, L., J. Bottenheim, R. Schnell, P. Crutzen & R. Rasmussen (1988), Ozone destruction and photochemical reactions at polar sunrise in the lower Arctic atmosphere, *Nature*, 334,138-141.

Wofsy, S., M. McElroy, and Y. Yung (1975), The chemistry of atmospheric bromine, *GRL*, 2, 215-218.

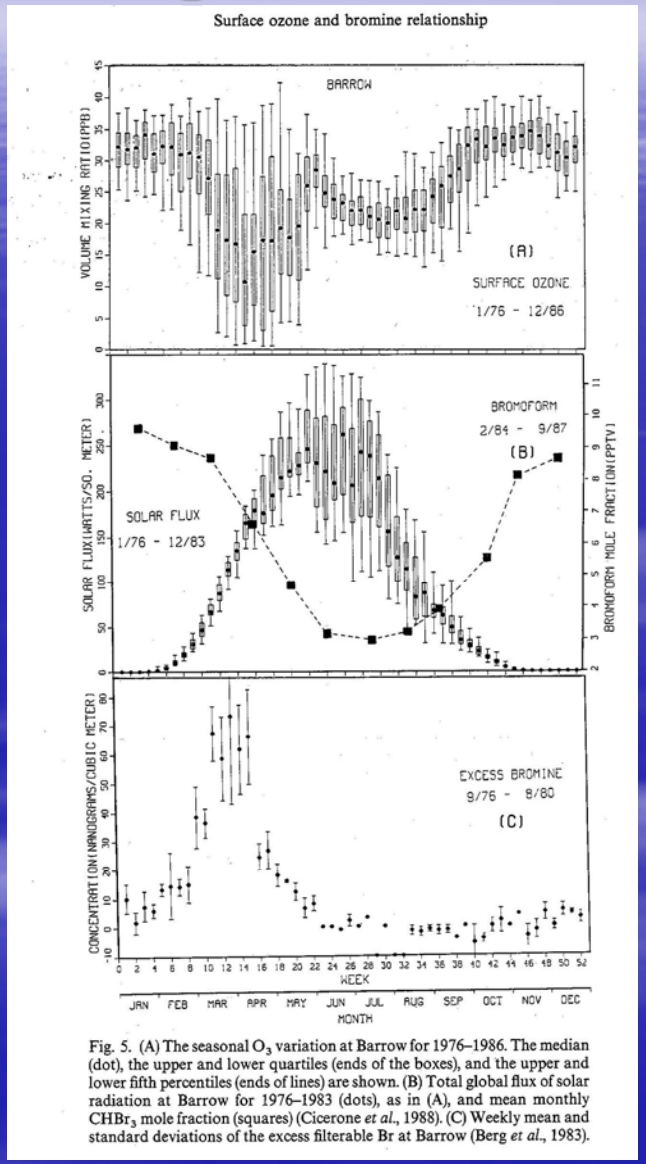
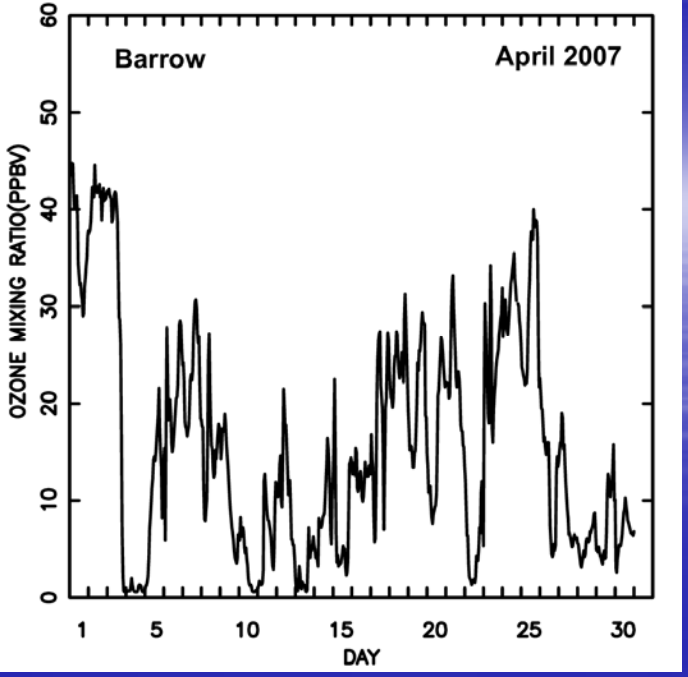
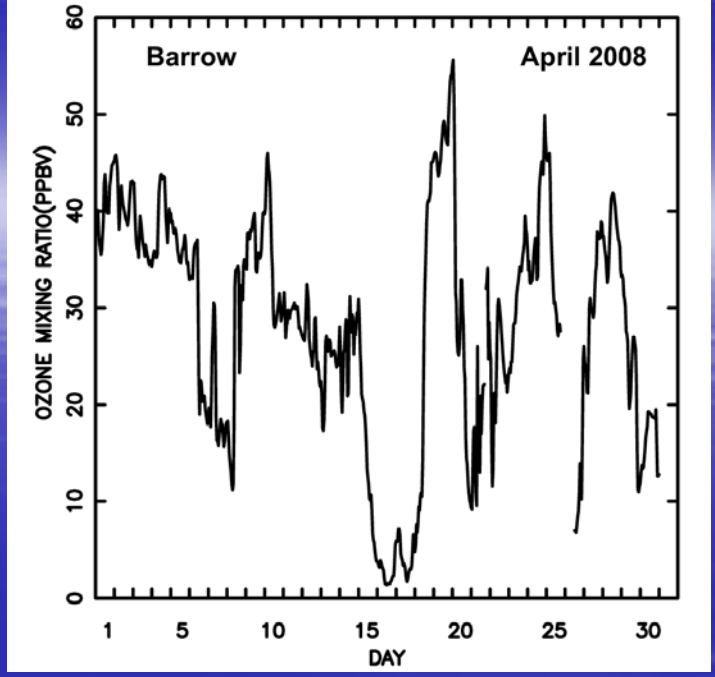


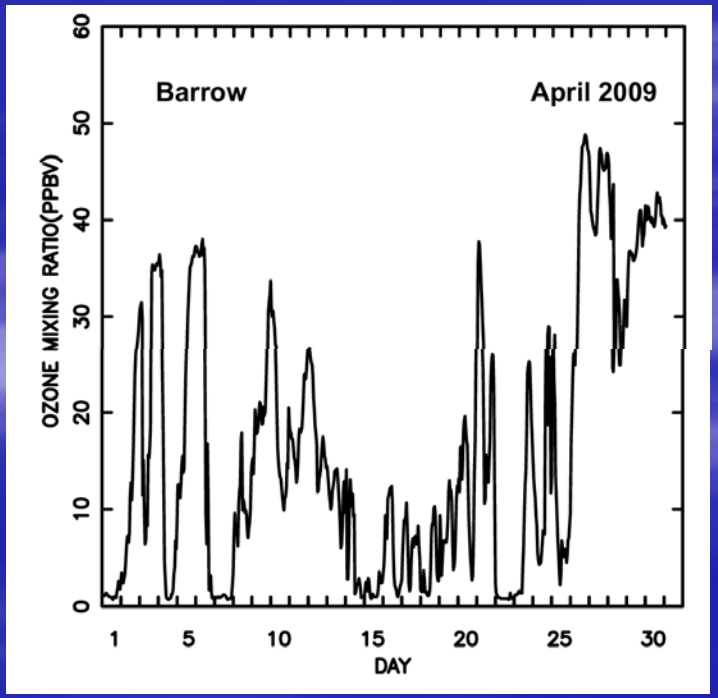
Fig. 5. (A) The seasonal O_3 variation at Barrow for 1976–1986. The median (dot), the upper and lower quartiles (ends of the boxes), and the upper and lower fifth percentiles (ends of lines) are shown. (B) Total global flux of solar radiation at Barrow for 1976–1983 (dots), as in (A), and mean monthly $CHBr_3$ mole fraction (squares) (Cicerone *et al.*, 1988). (C) Weekly mean and standard deviations of the excess filterable Br at Barrow (Berg *et al.*, 1983).

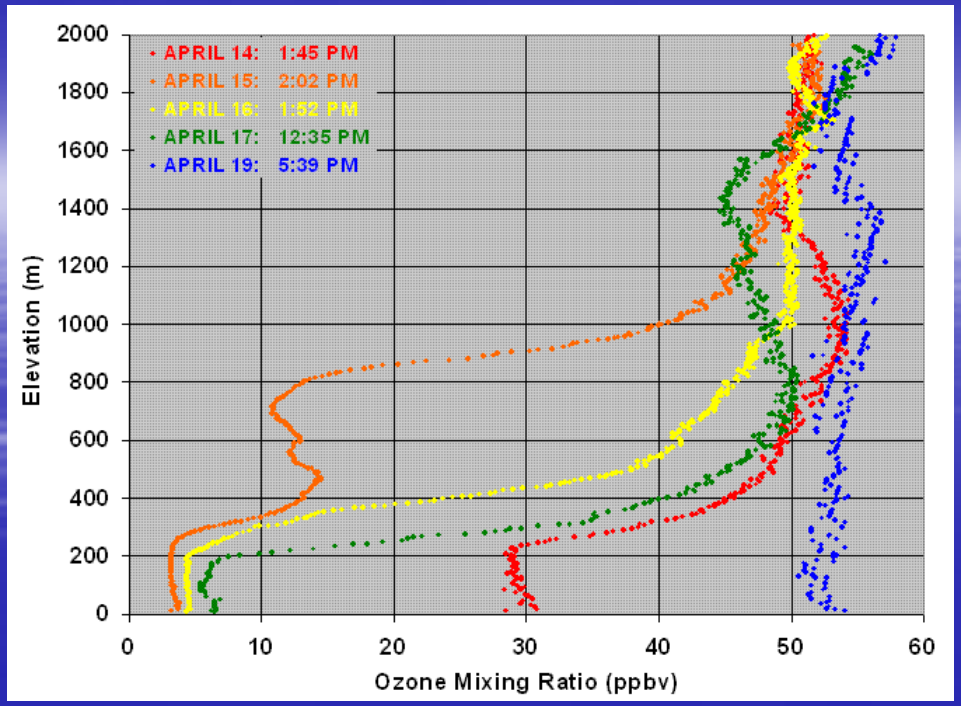
Oltmans, S., R. Schnell, P. Sheridan, P. Tans, et al. (1989), Seasonal surface ozone and filterable bromine relation-ship in the high Arctic, *Atmos. Environ.*, 23, 2341-2441.

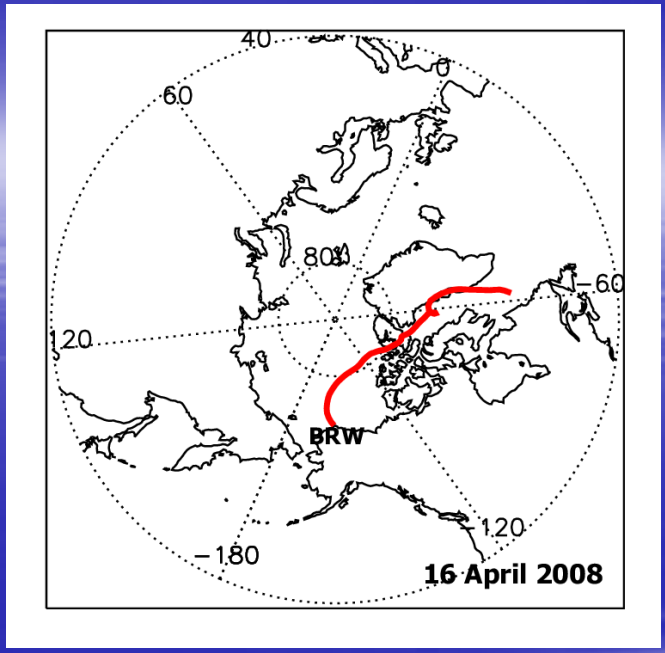


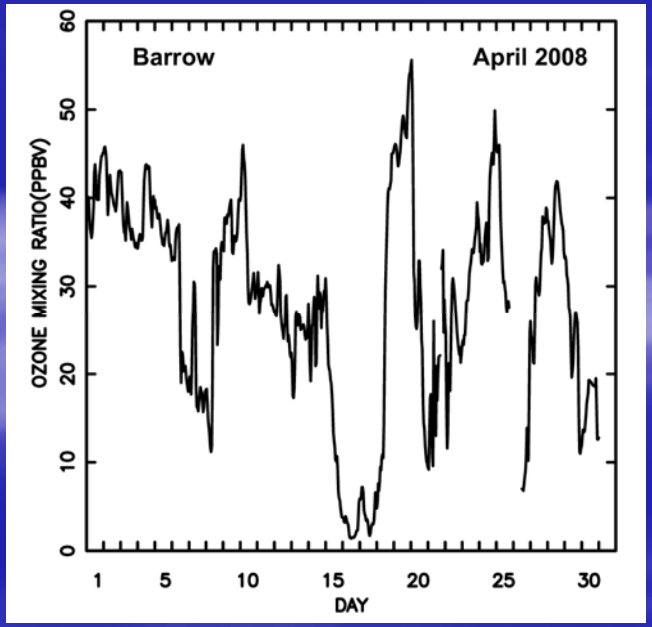


Hourly Average Surface Ozone at Barrow for April 2007, 2008 and 2009

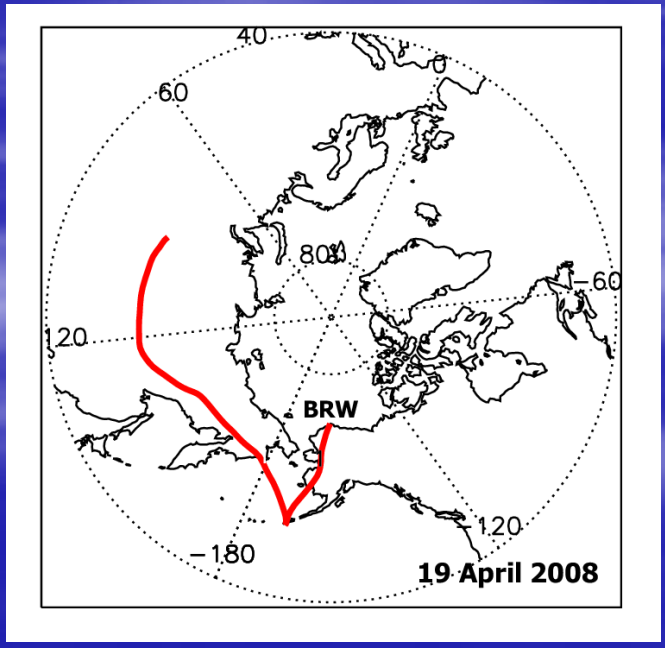




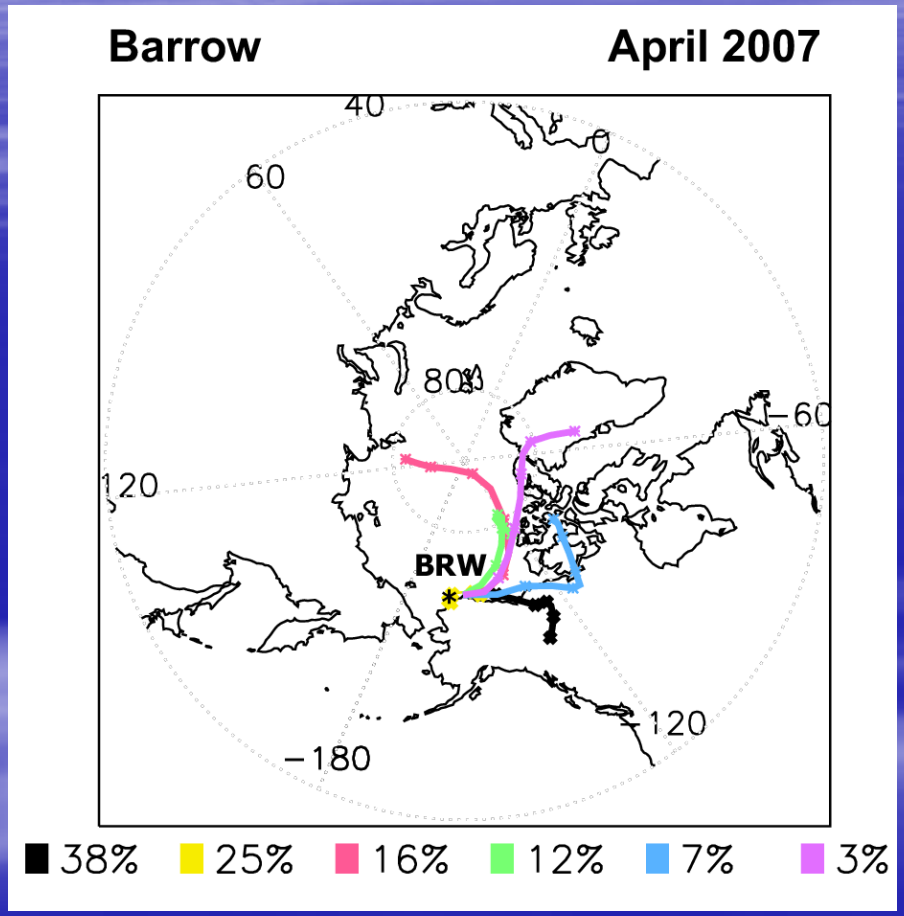


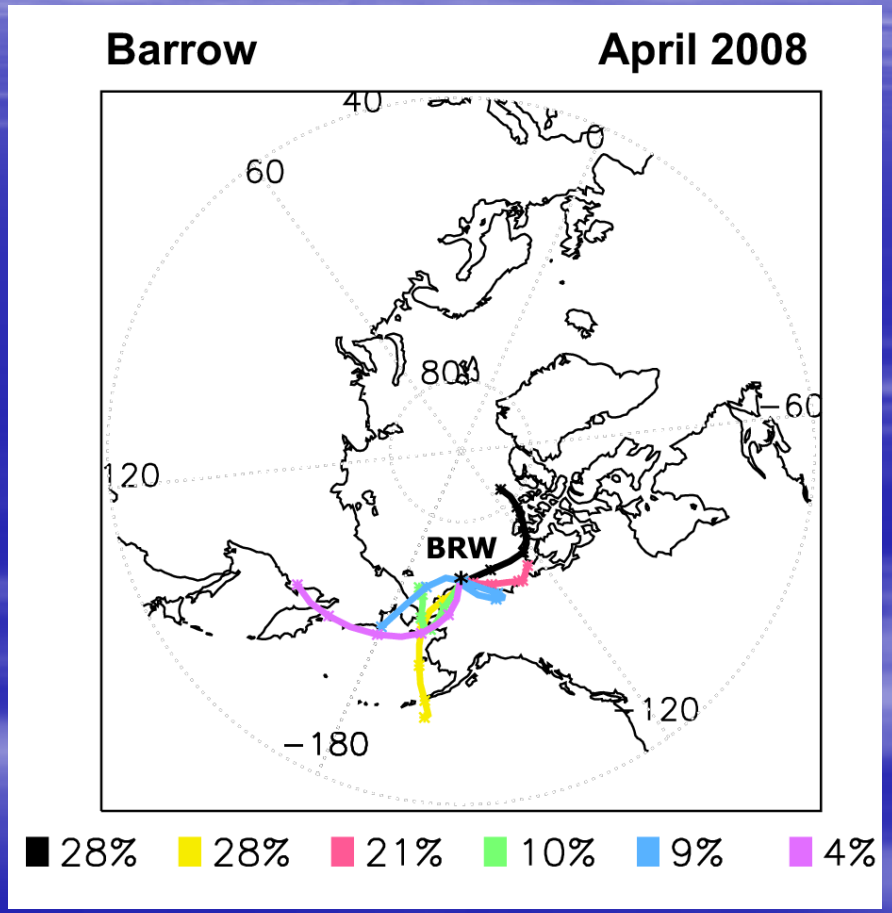


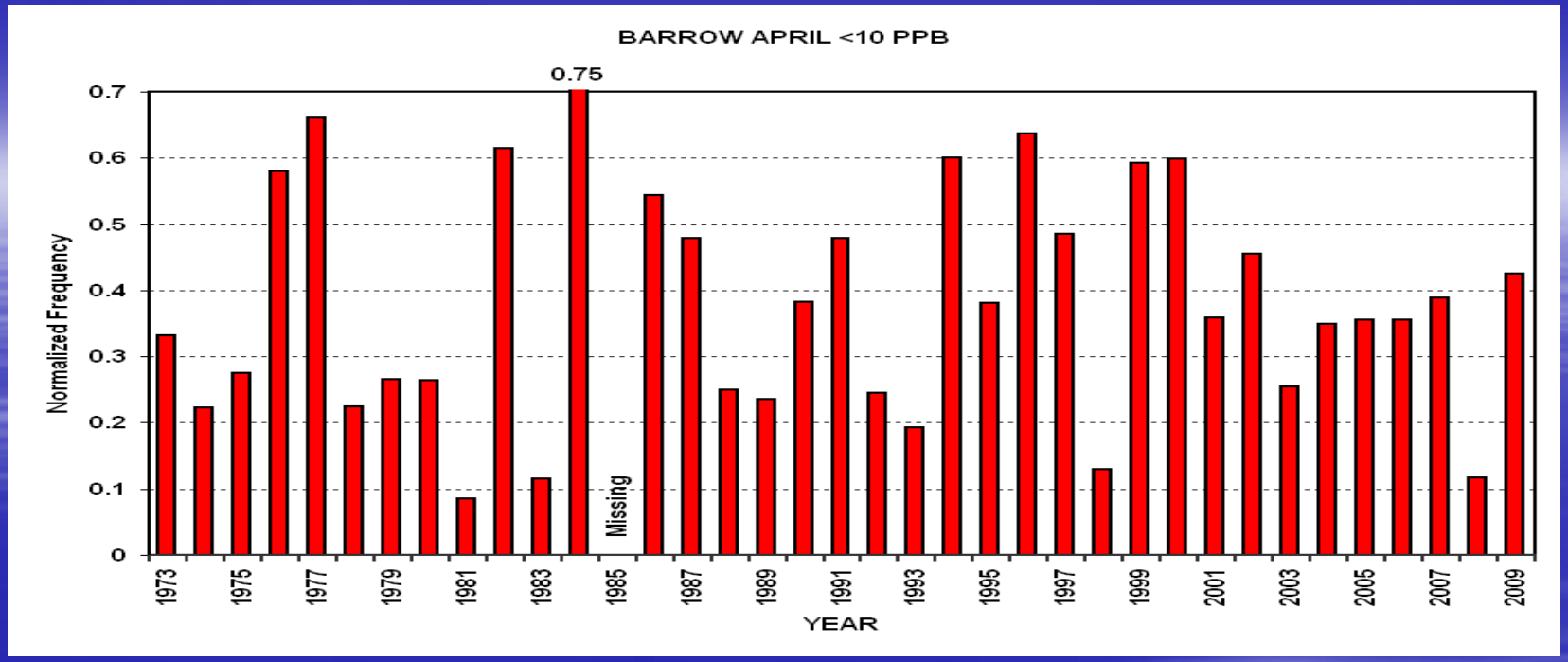
Back Trajectories from Barrow for 16 April 2008 and 19 April 2008

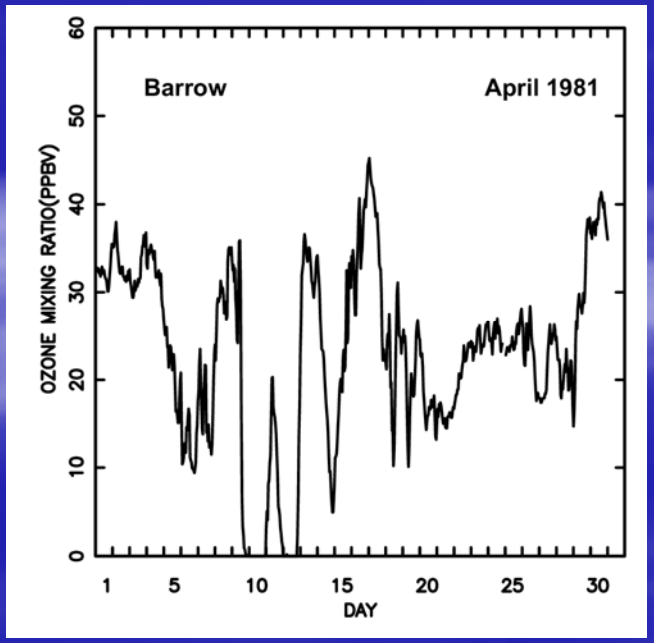


Clustered Back Trajectories from Barrow for April 2007 and April 2008

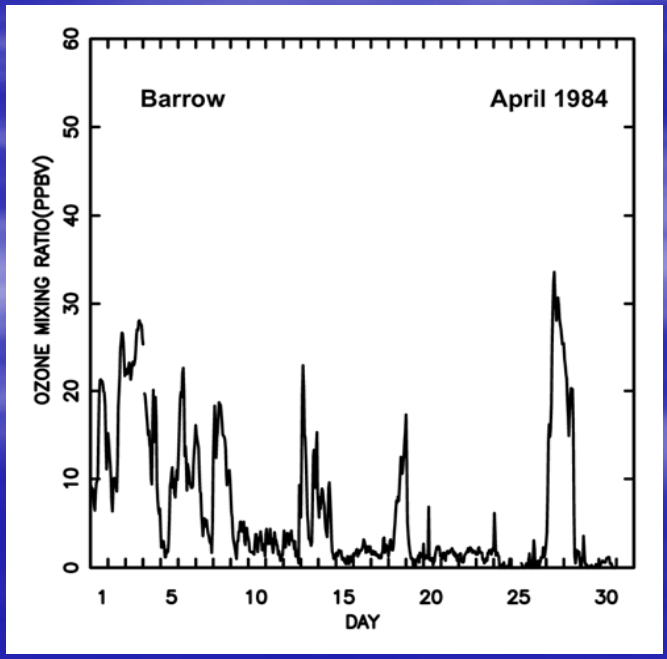




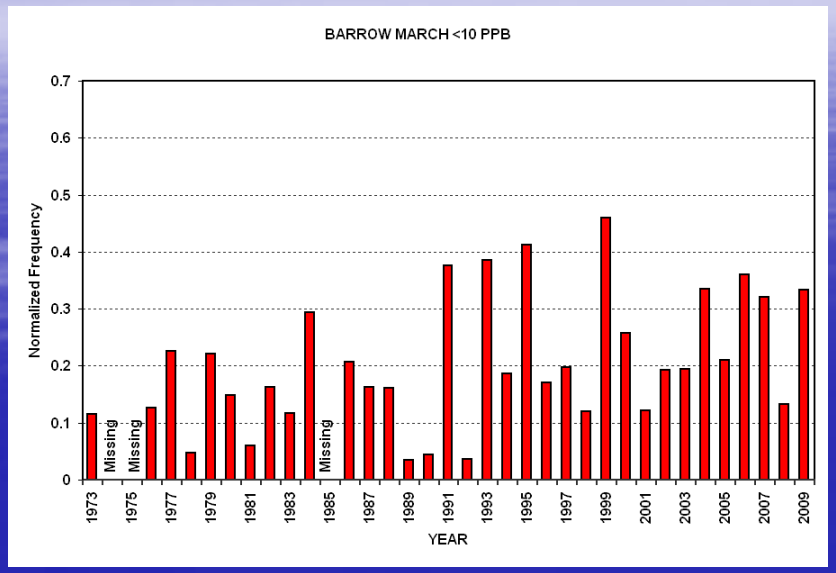


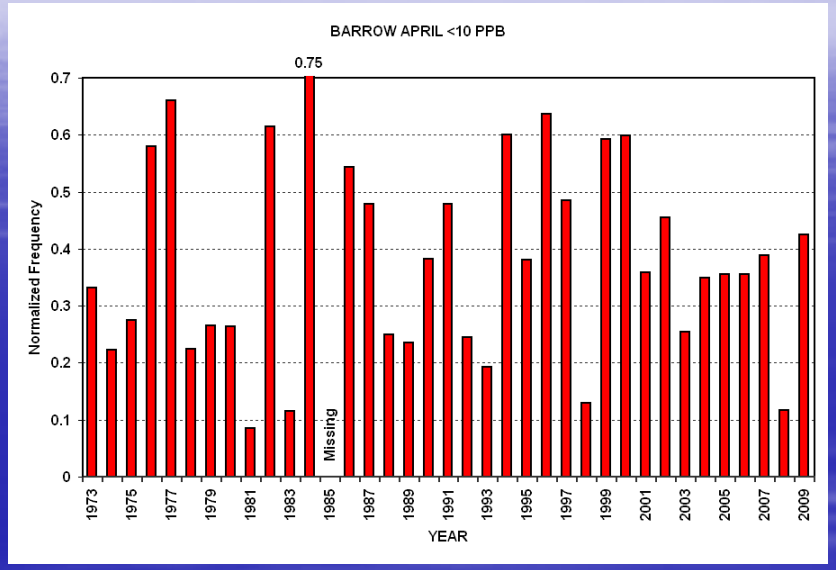


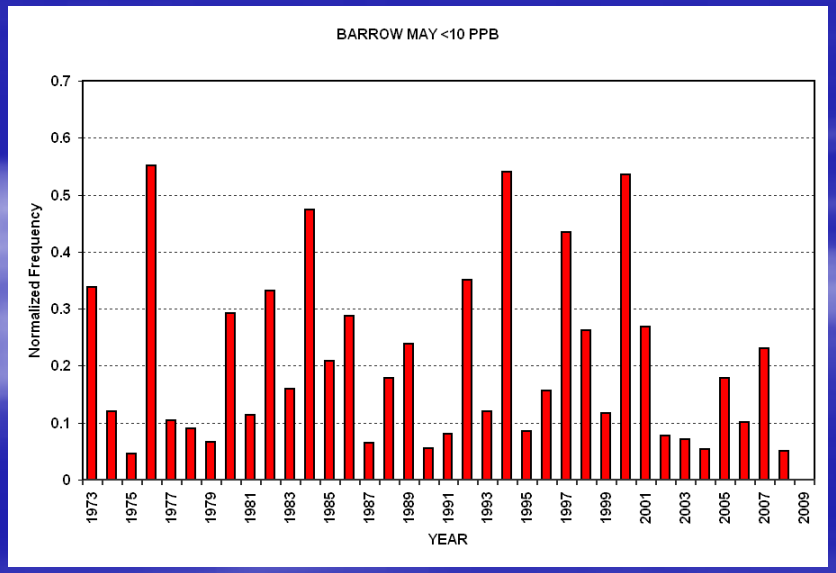
Fraction of Surface Ozone Hourly Averages at Barrow for April ≤ 10 ppb

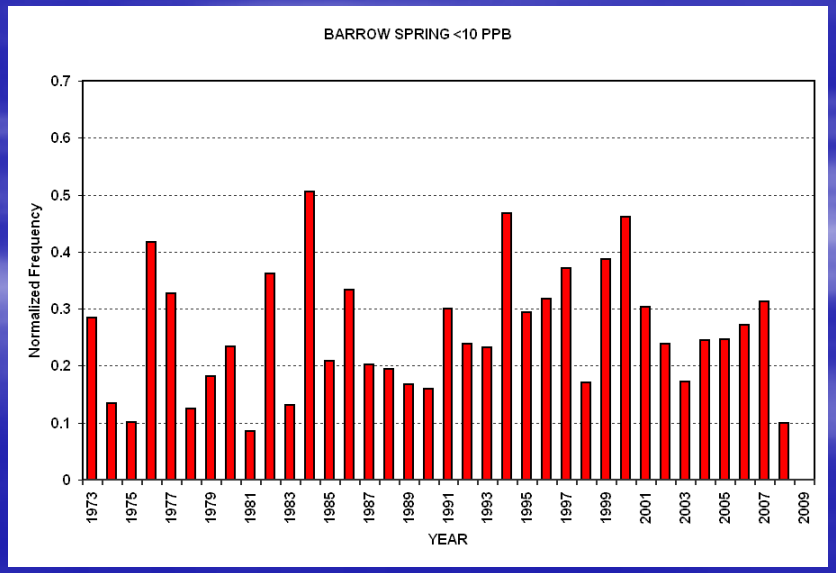


Fraction of Surface Ozone Hourly Averages at Barrow for March, April, and May ≤ 10 ppb



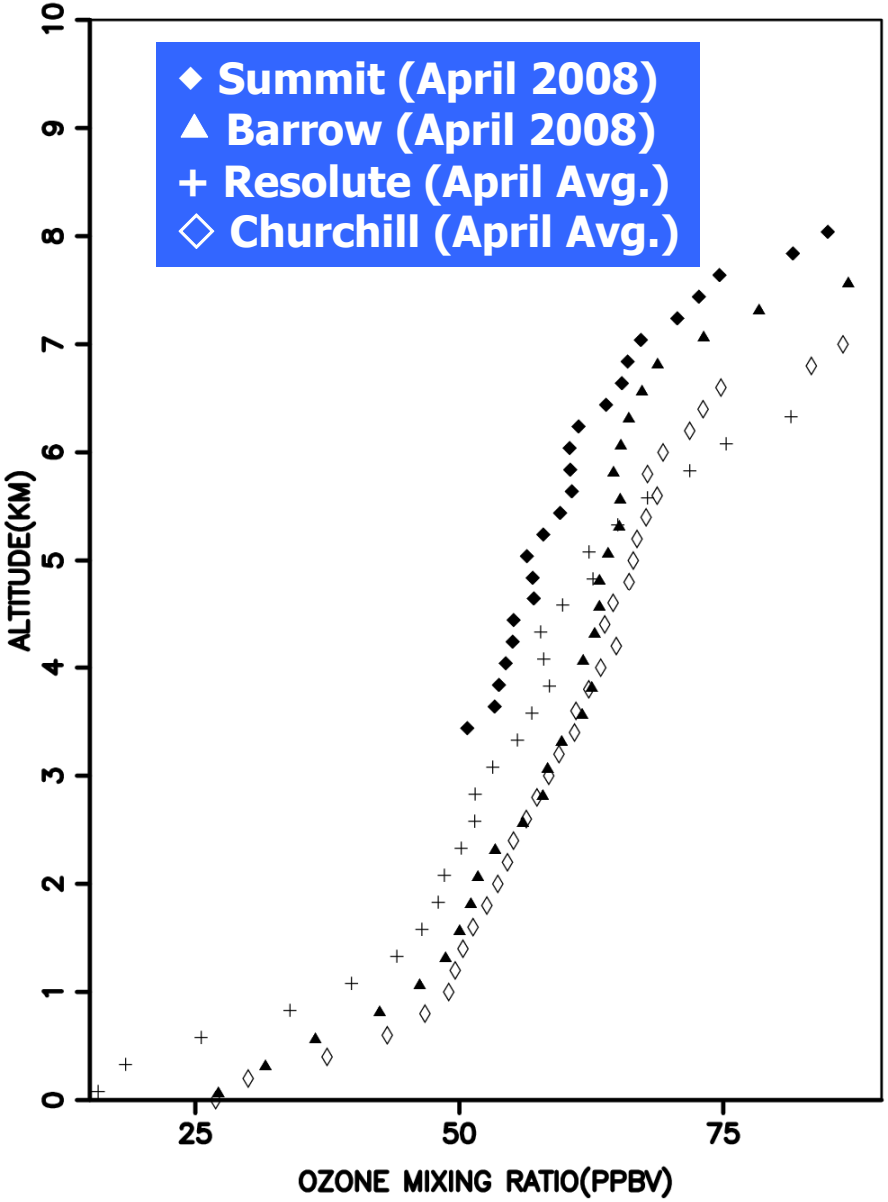






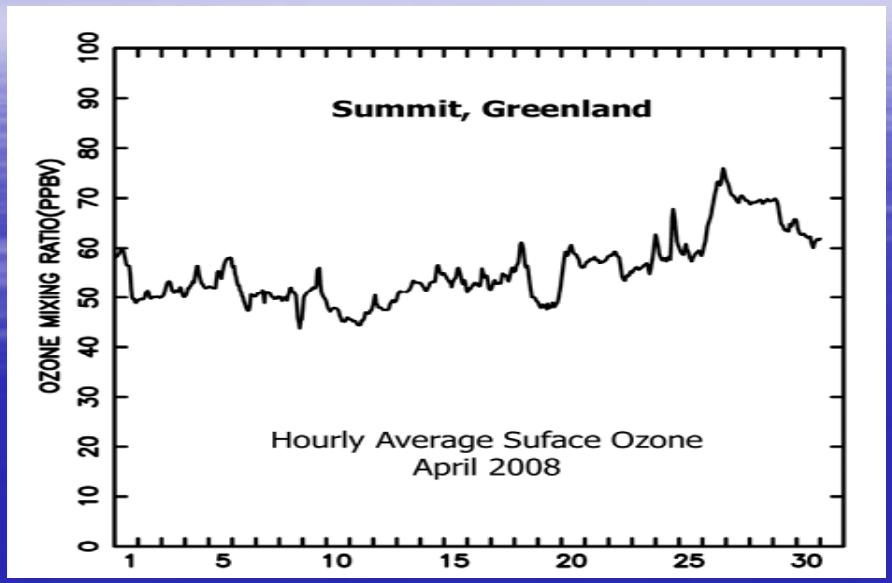
Conclusions

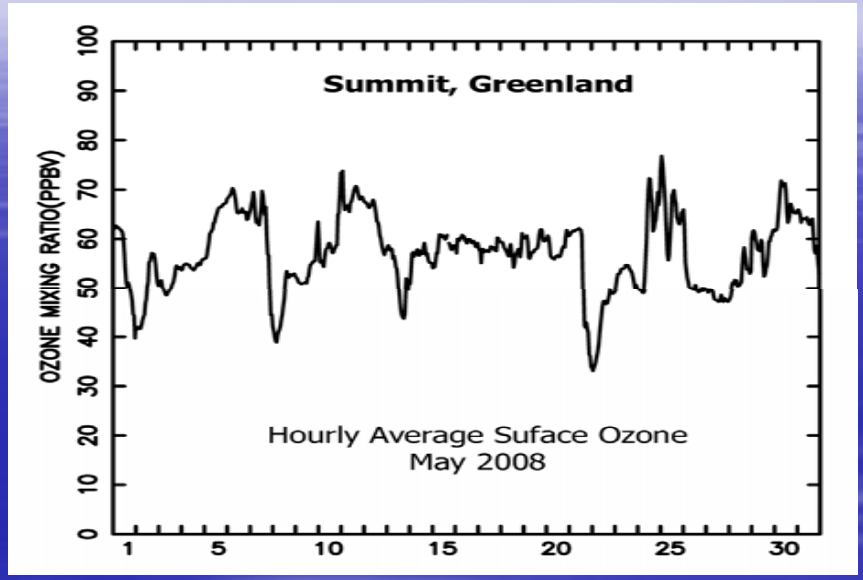
- Because of its altitude and inland location Summit surface ozone behavior is different from Arctic Ocean sites. Summit surface ozone is more similar to free tropospheric behavior at the comparable altitude (~3000 meters).
- The spring boundary layer ozone depletion at Barrow is very dynamic often with very rapid variations in time and particularly with altitude.
- The presence of boundary layer depletion is strongly driven by both the local (boundary layer behavior) and synoptic scale meteorology.
- Year to year variations in the degree of boundary layer ozone depletion appear to be linked to varying circulation patterns, i.e. the presence of air from the Arctic Ocean sector or more southerly flow from the Pacific.

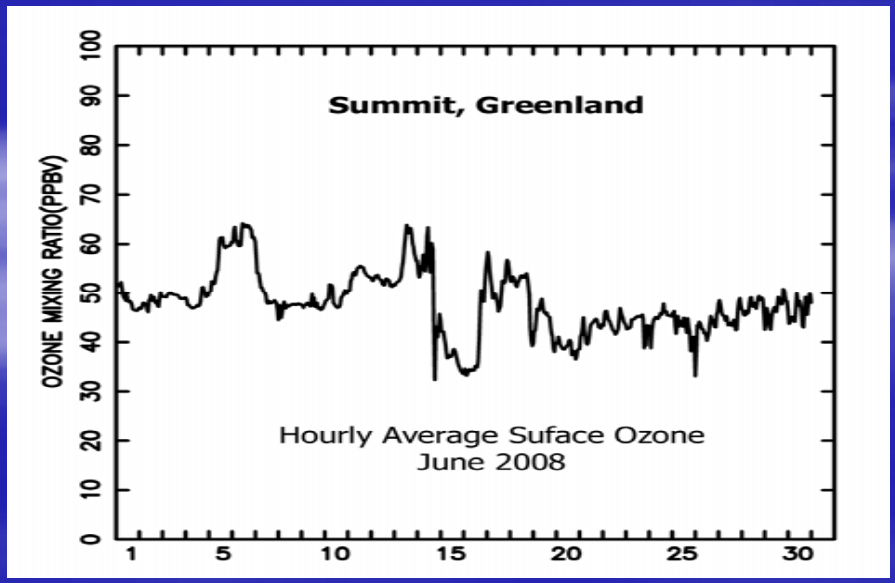


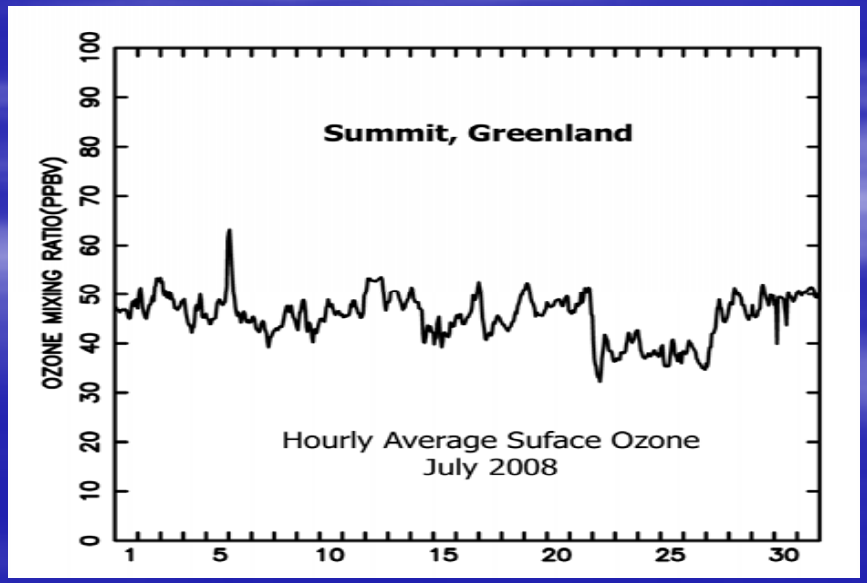
Comparison of the average tropospheric ozone profile for April 2008 at Summit and Barrow with the average April profile at Resolute and Churchill.

Hourly Average Surface Ozone at Summit for April, May, June, and July 2008

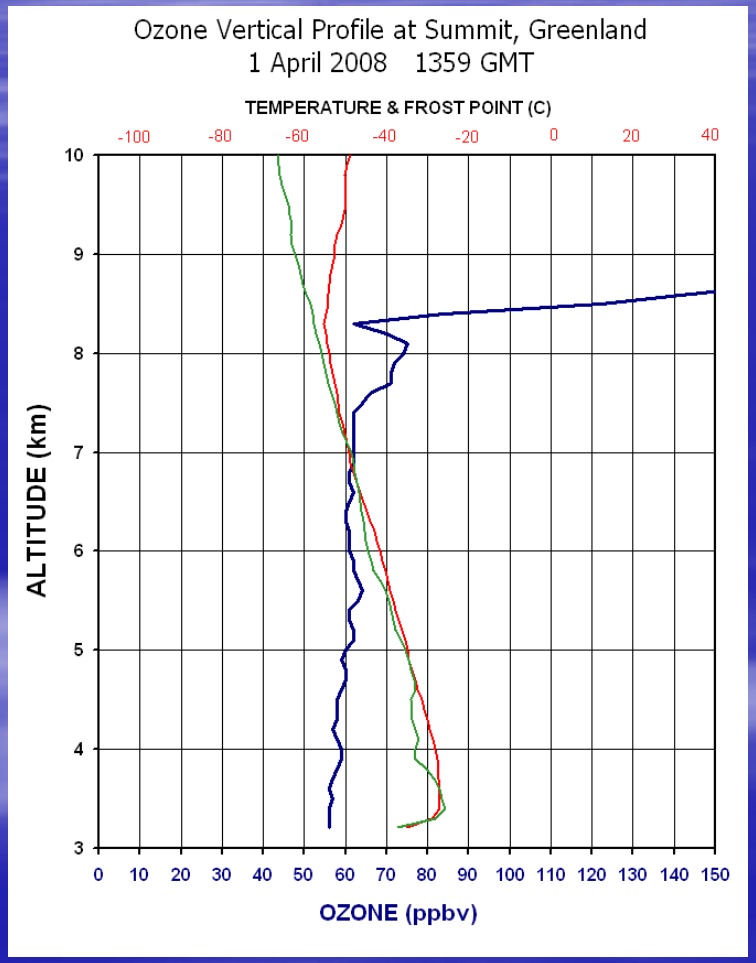


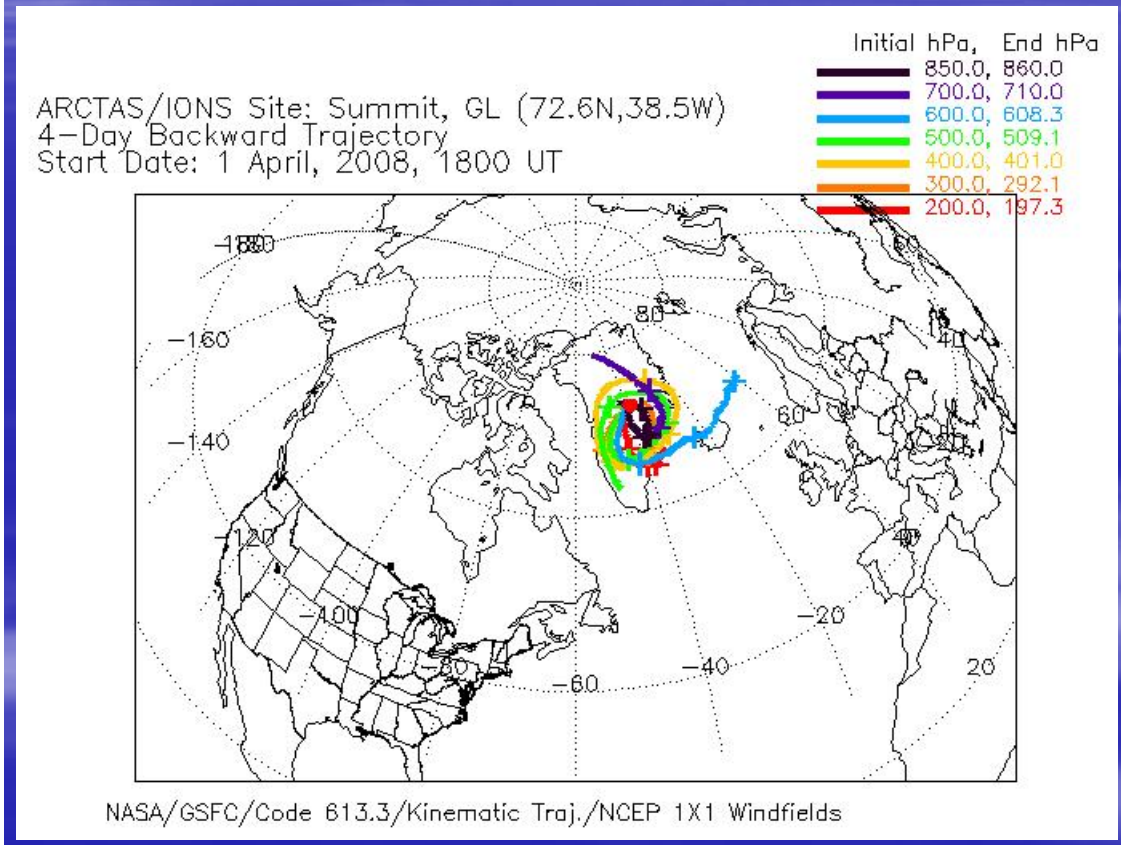




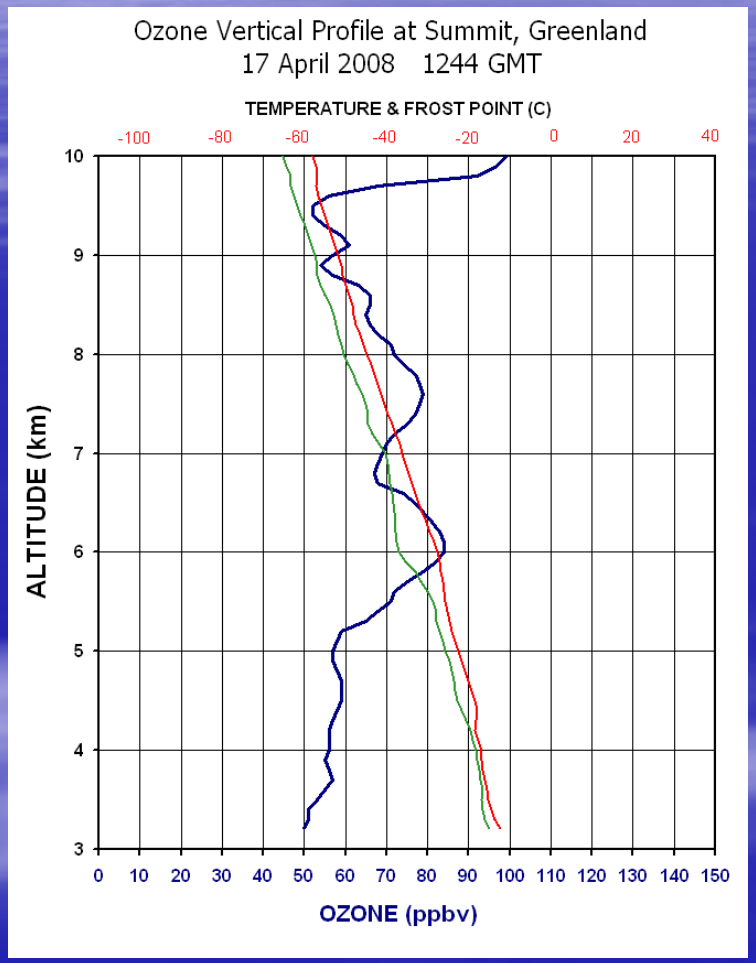


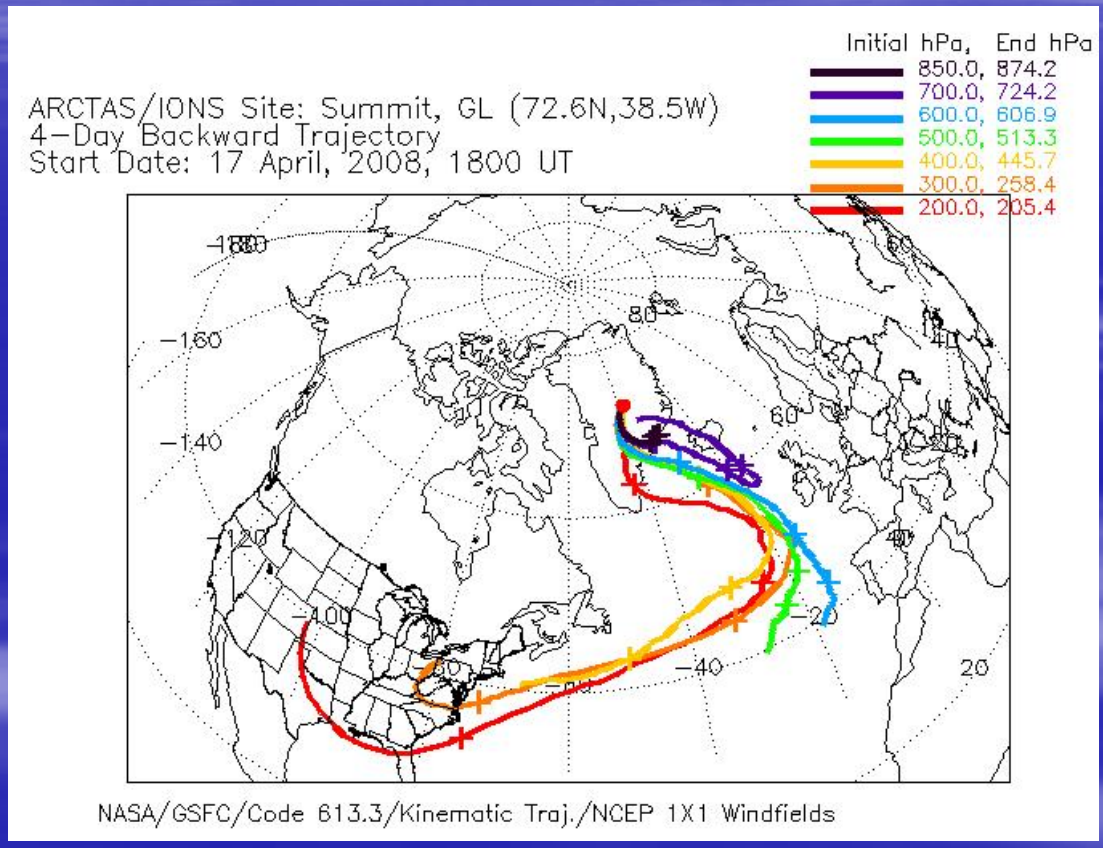
1 April 2008 Profile at Summit



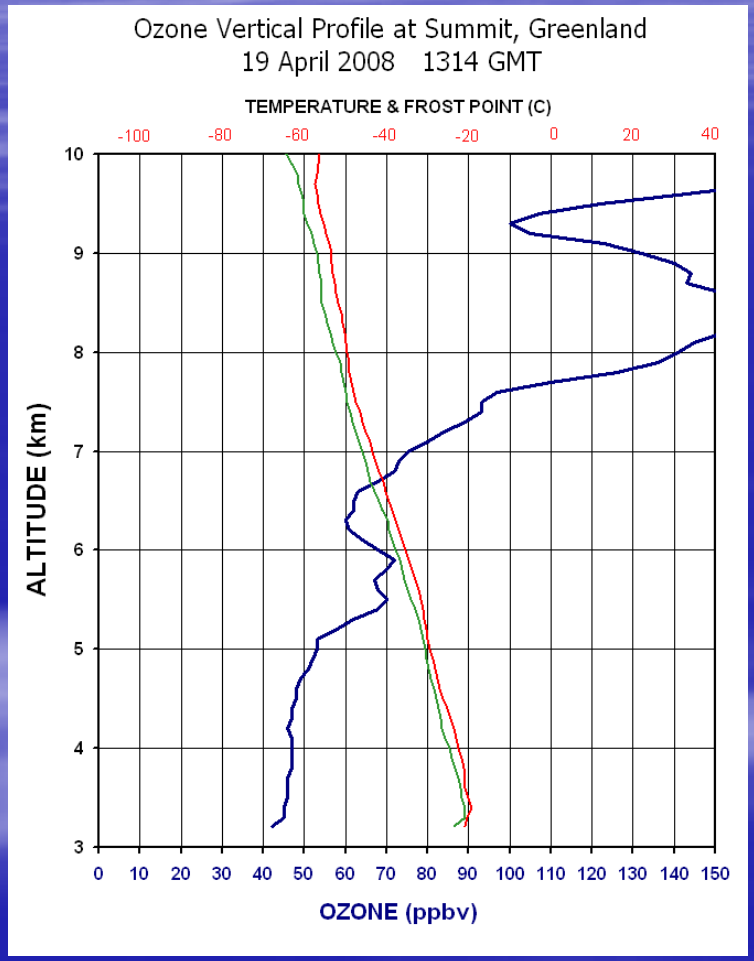


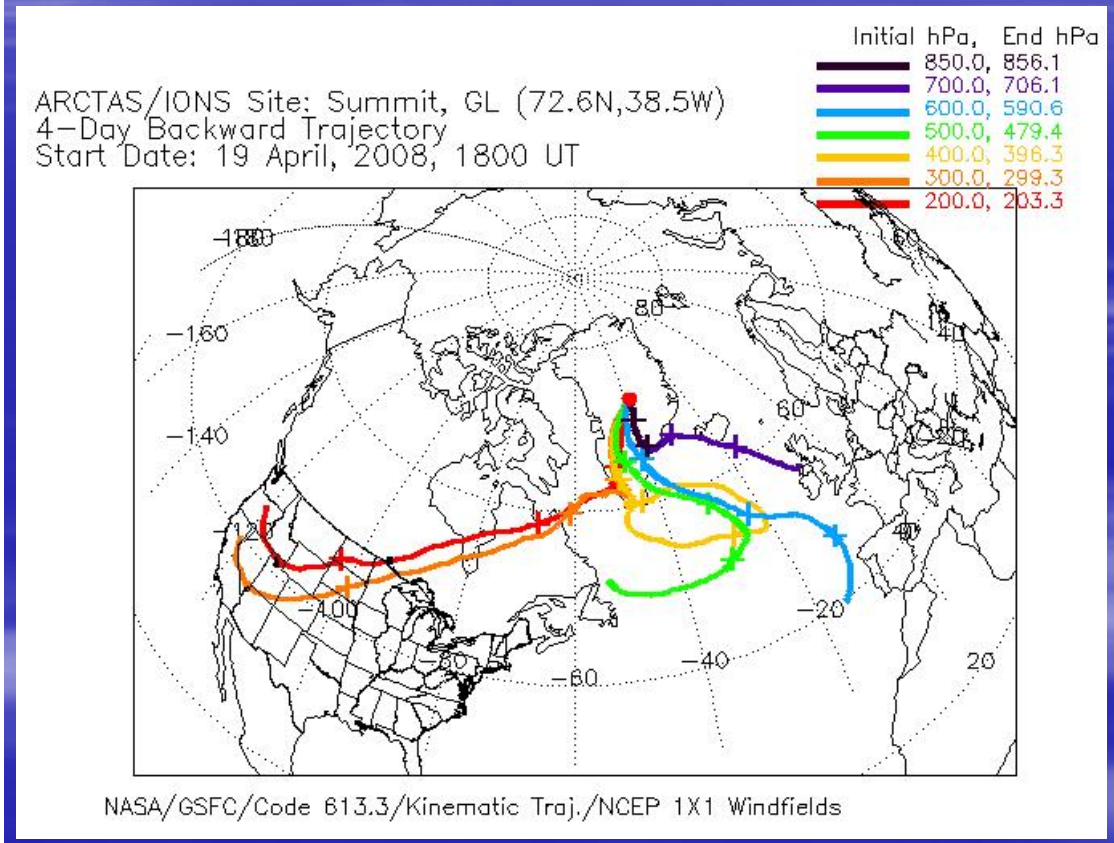
17 April 2008 Profile at Summit



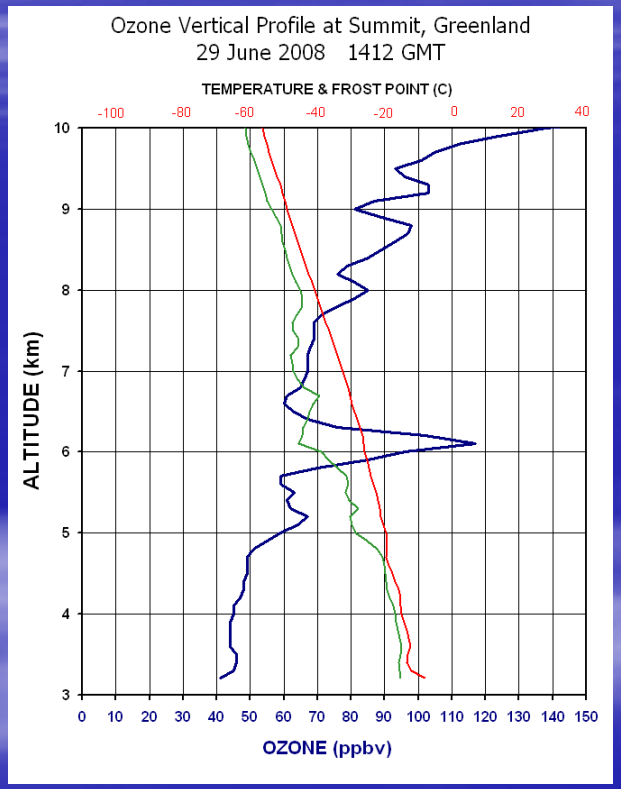


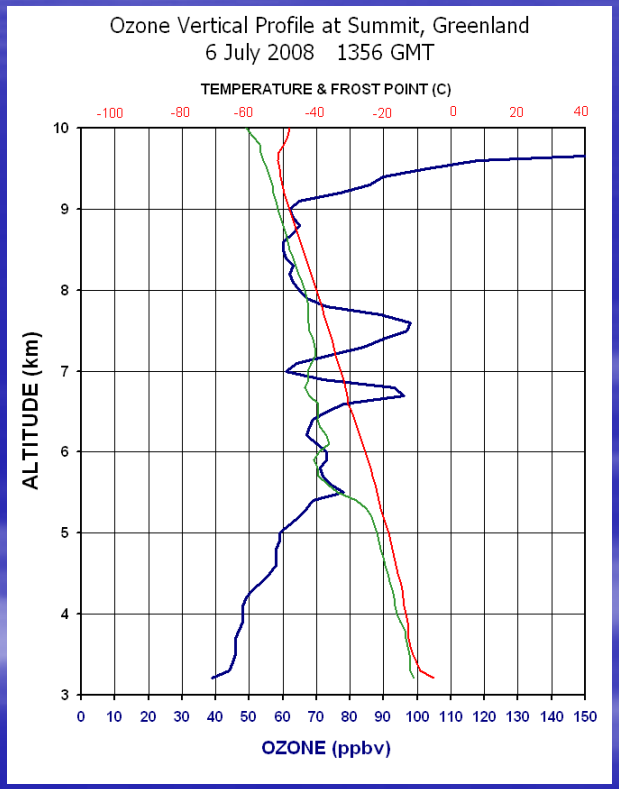
19 April 2008 Profile at Summit

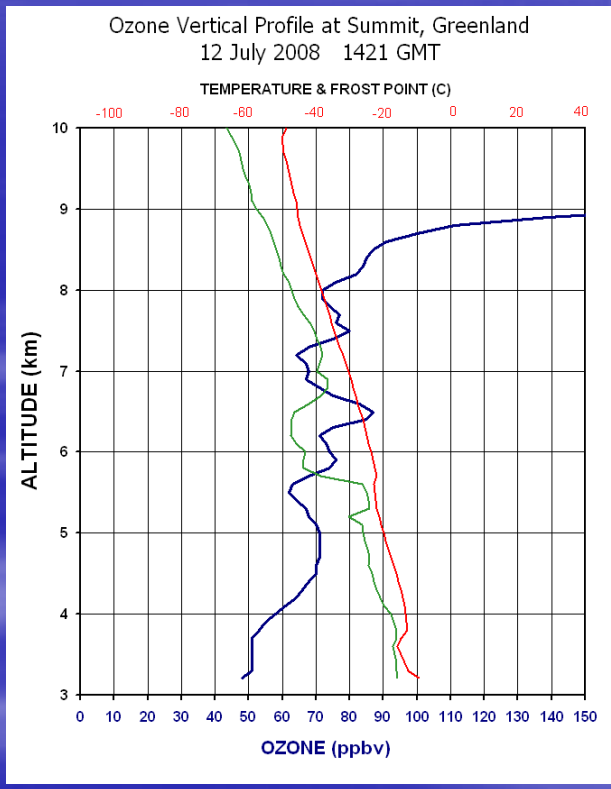




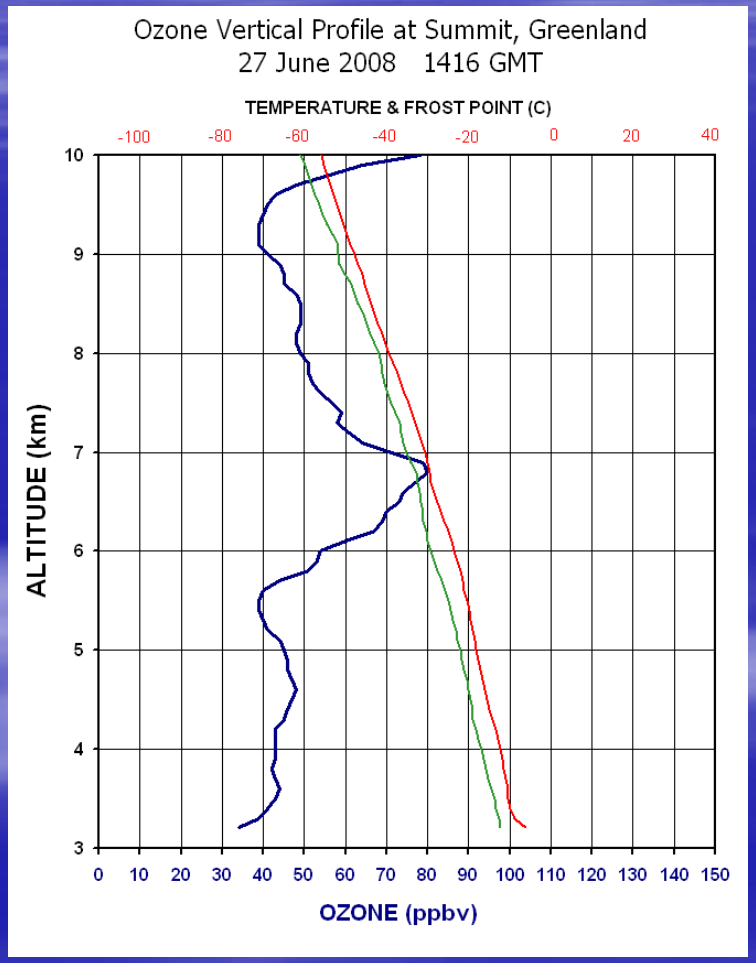
June and July 2008 Profiles at Summit

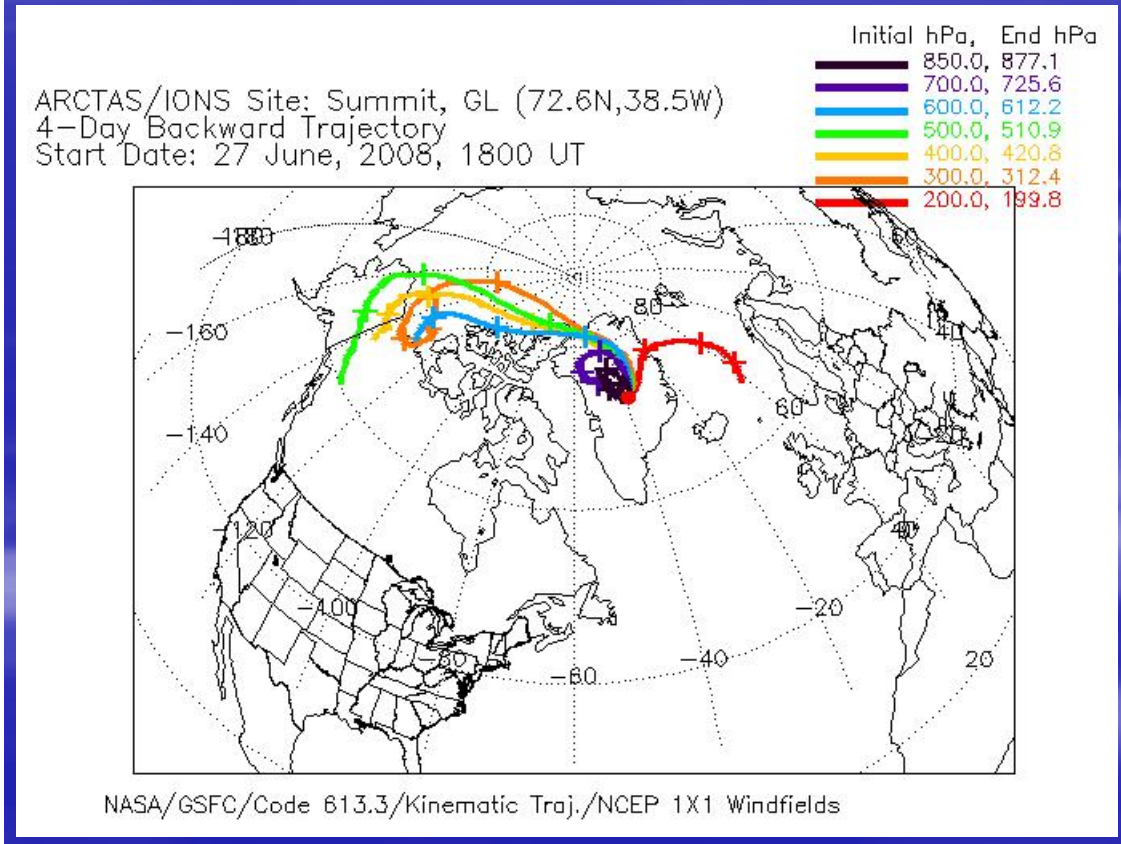




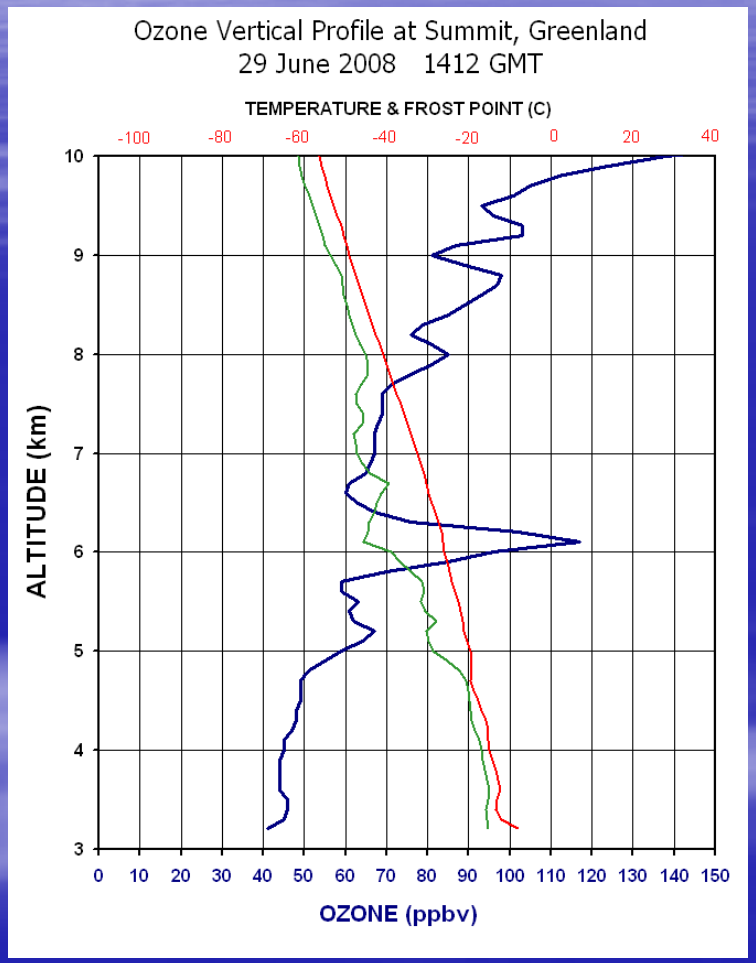


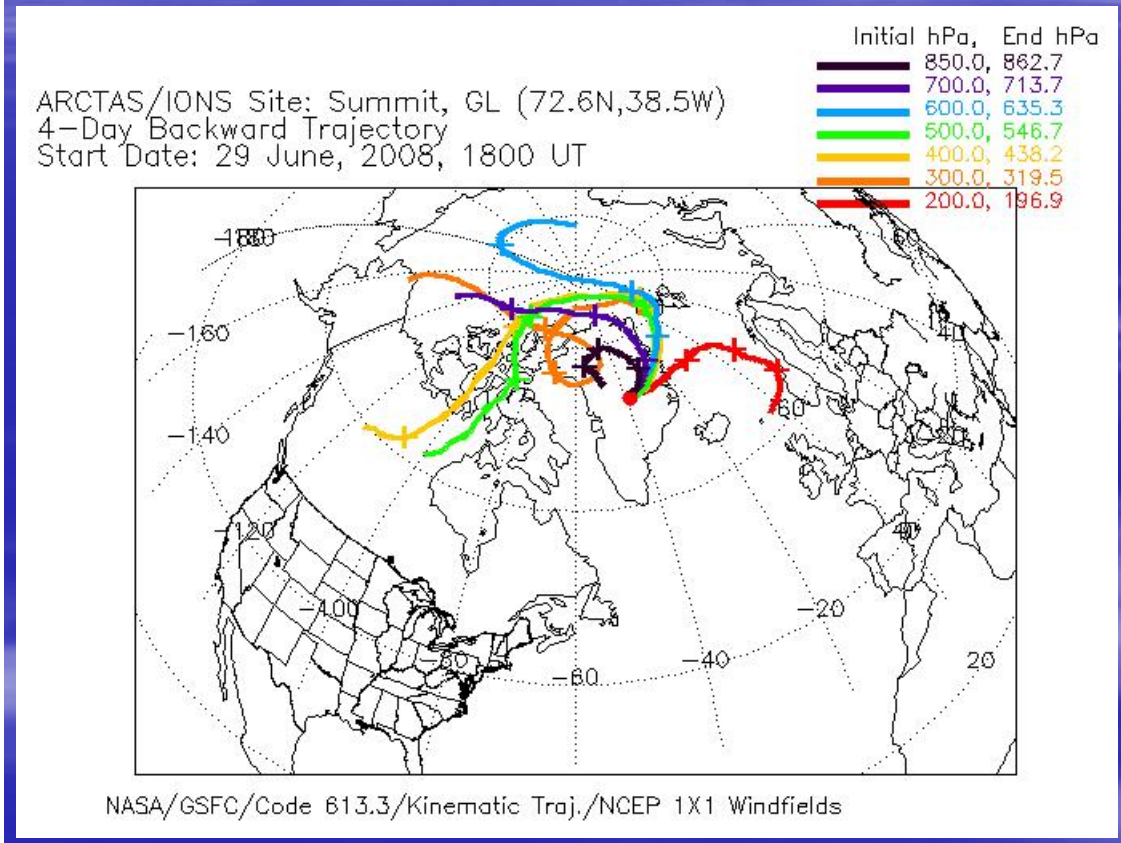
27 June 2008 Profile at Summit



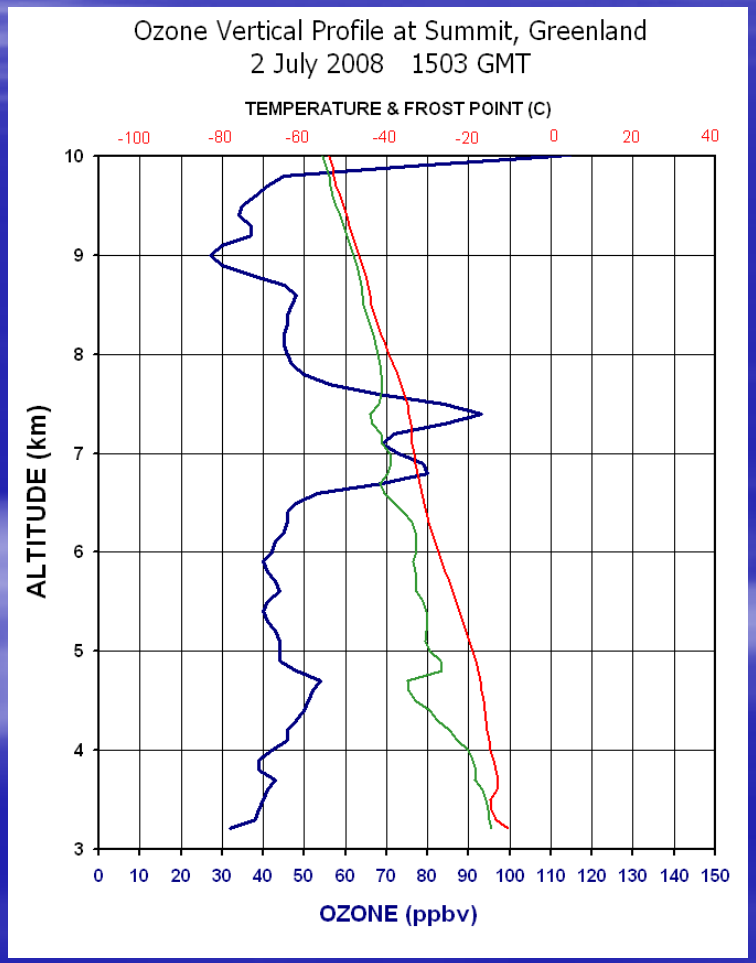


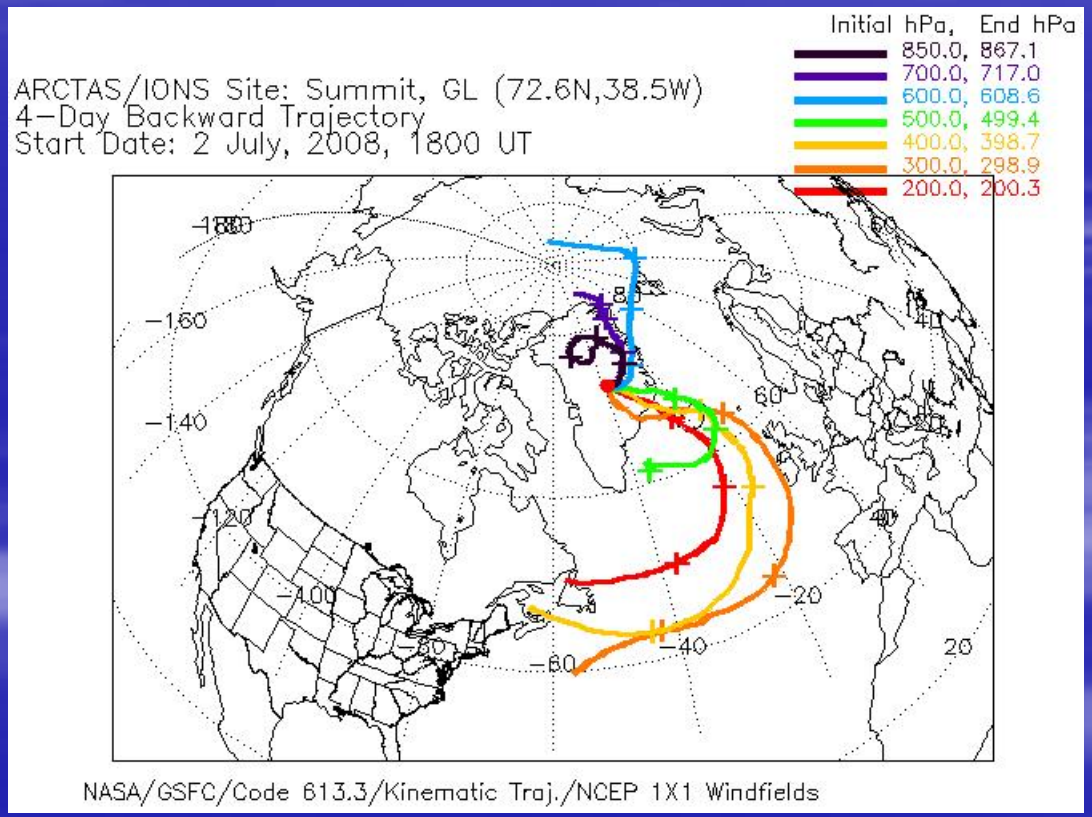
29 June 2008 Profile at Summit



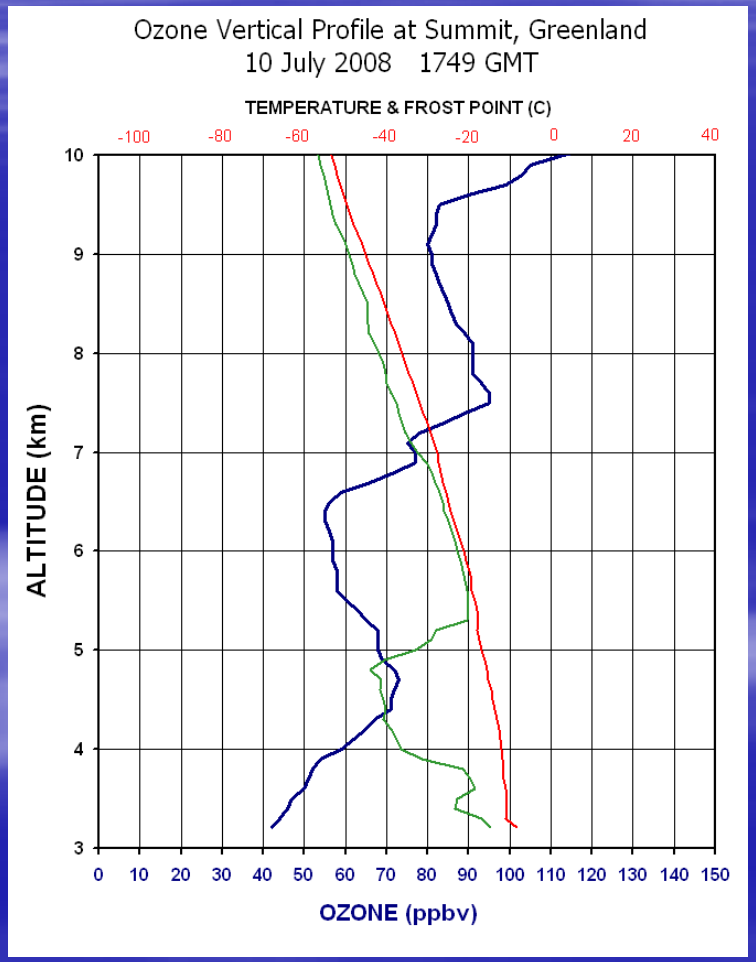


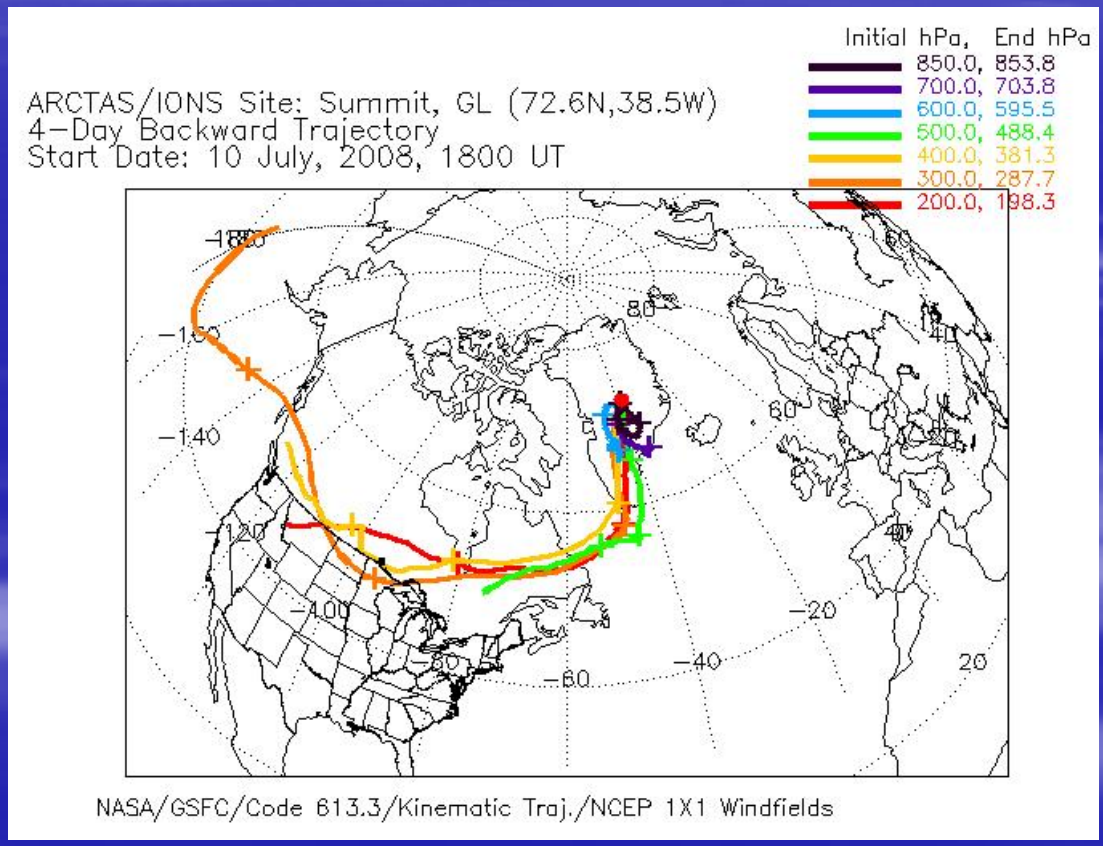
2 July 2008 Profile at Summit





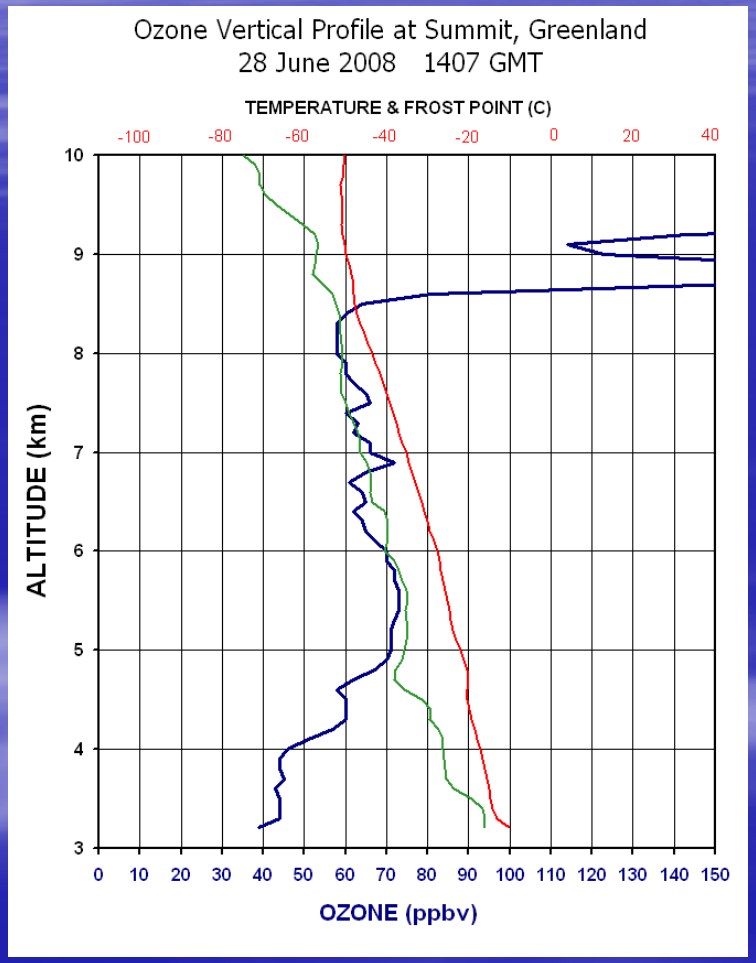
10 July 2008 Profile at Summit

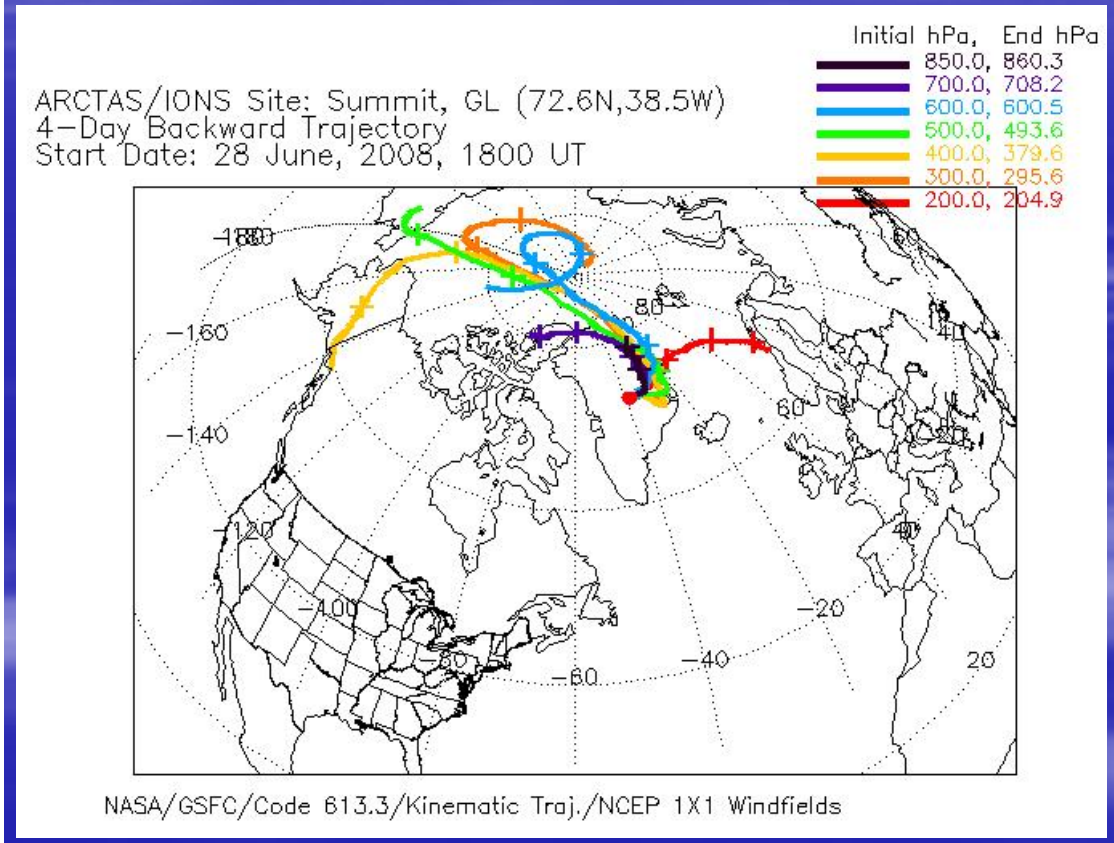




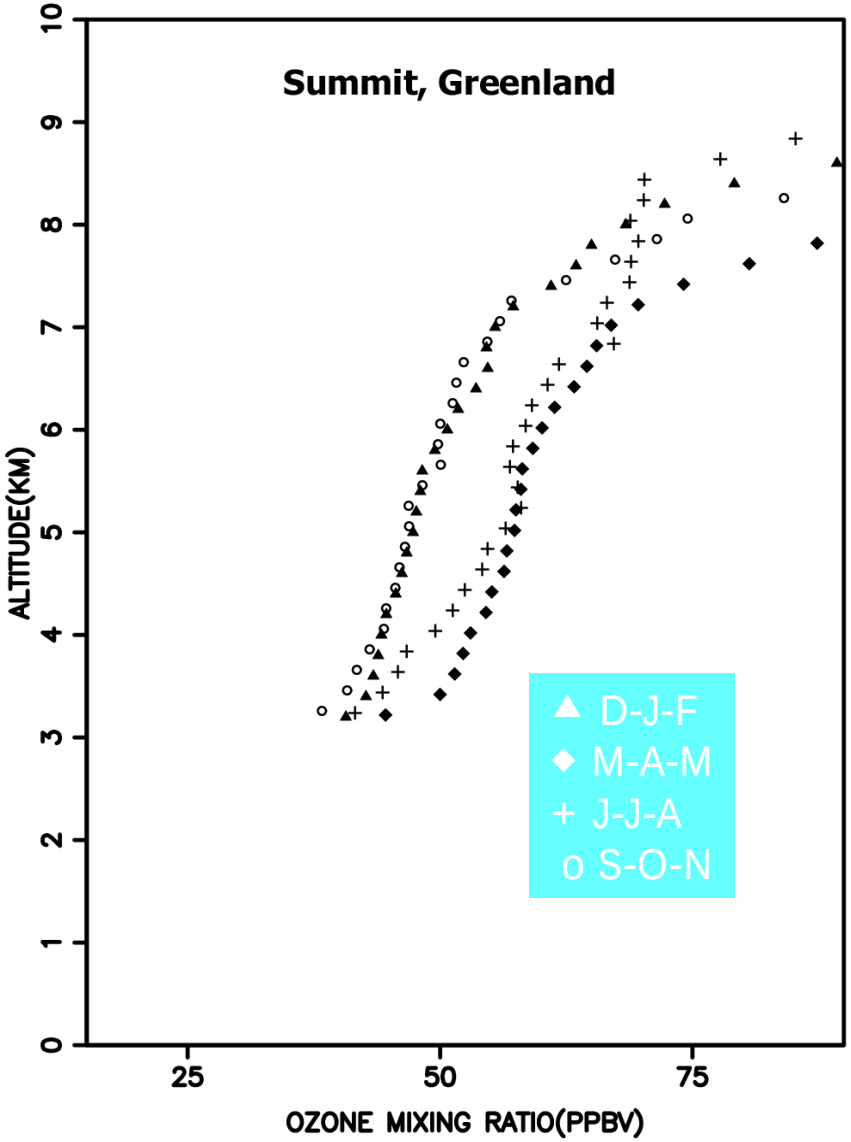
Conclusions

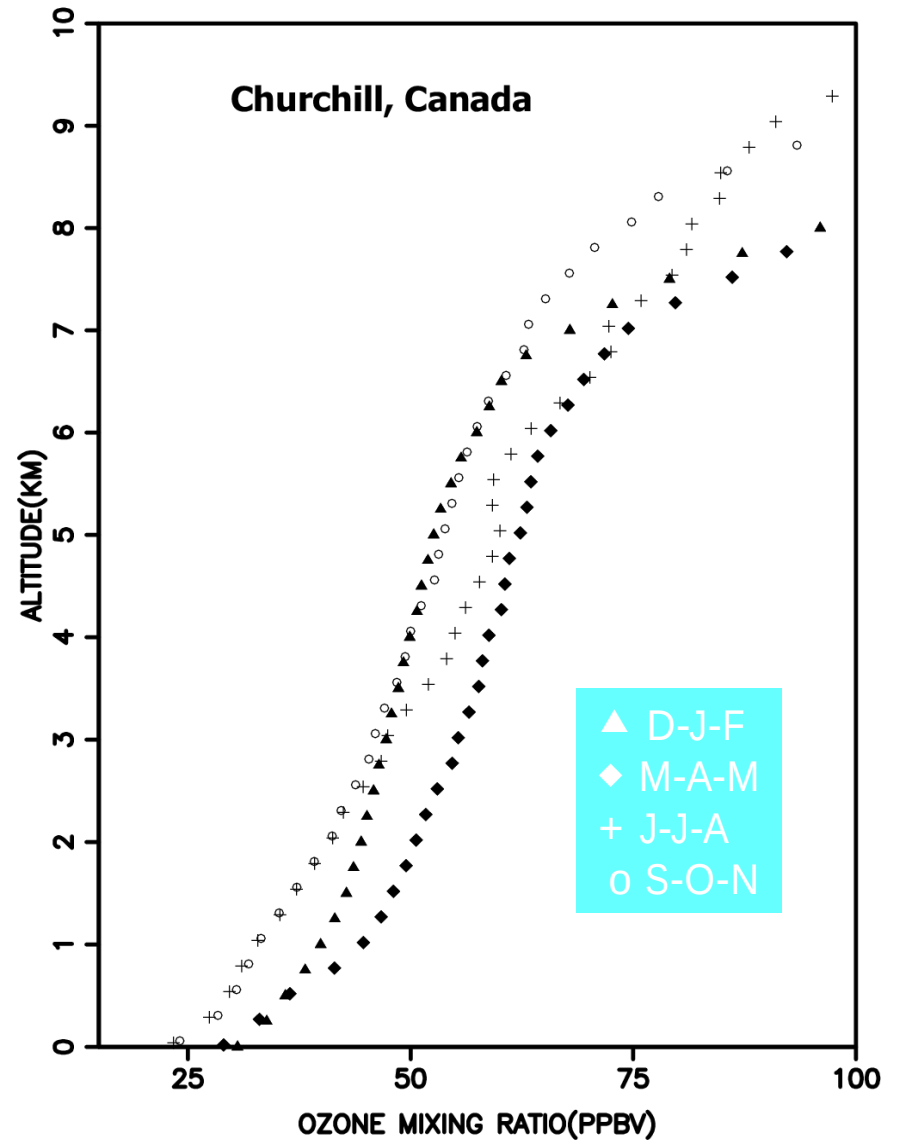
28 June 2008 Profile at Summit



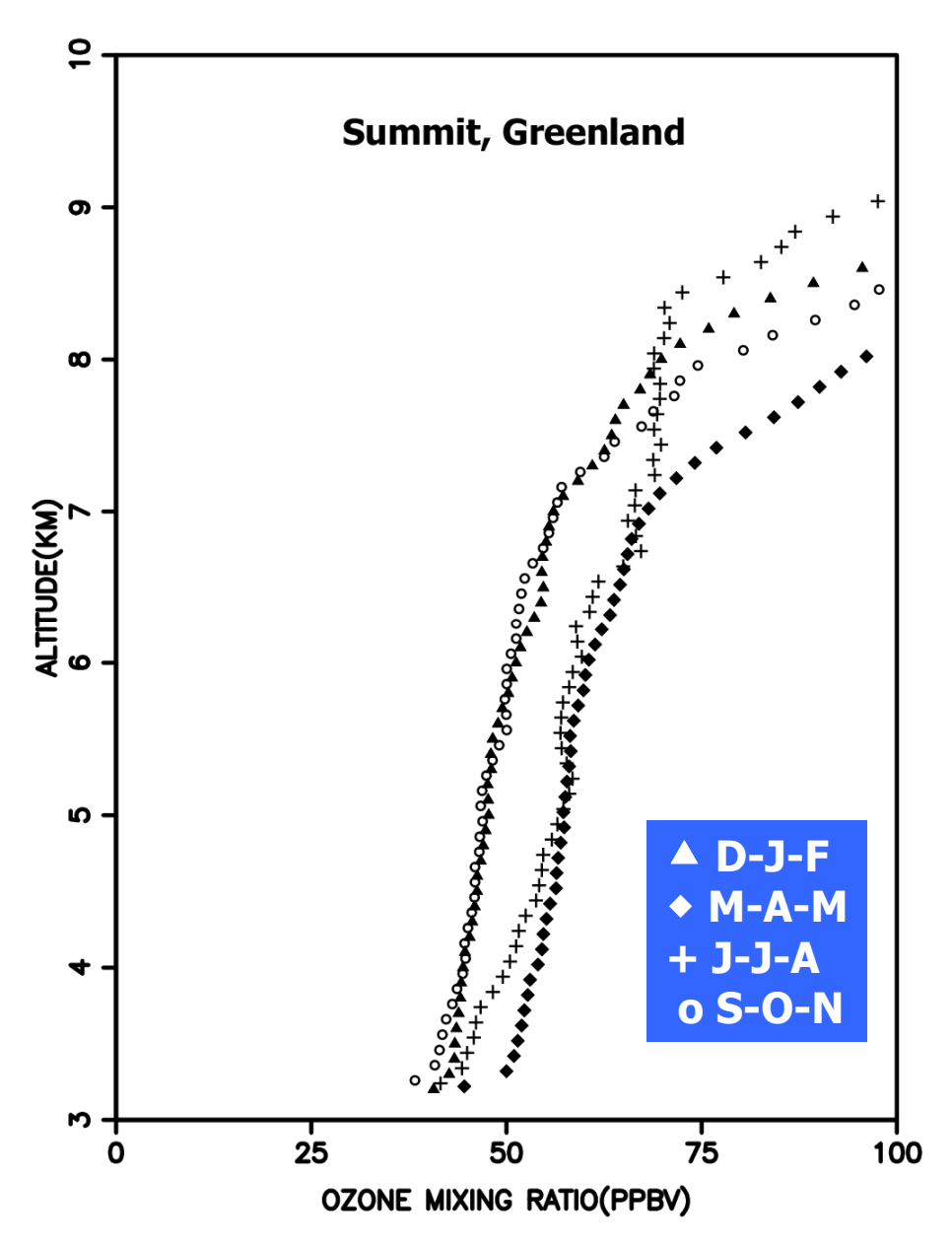


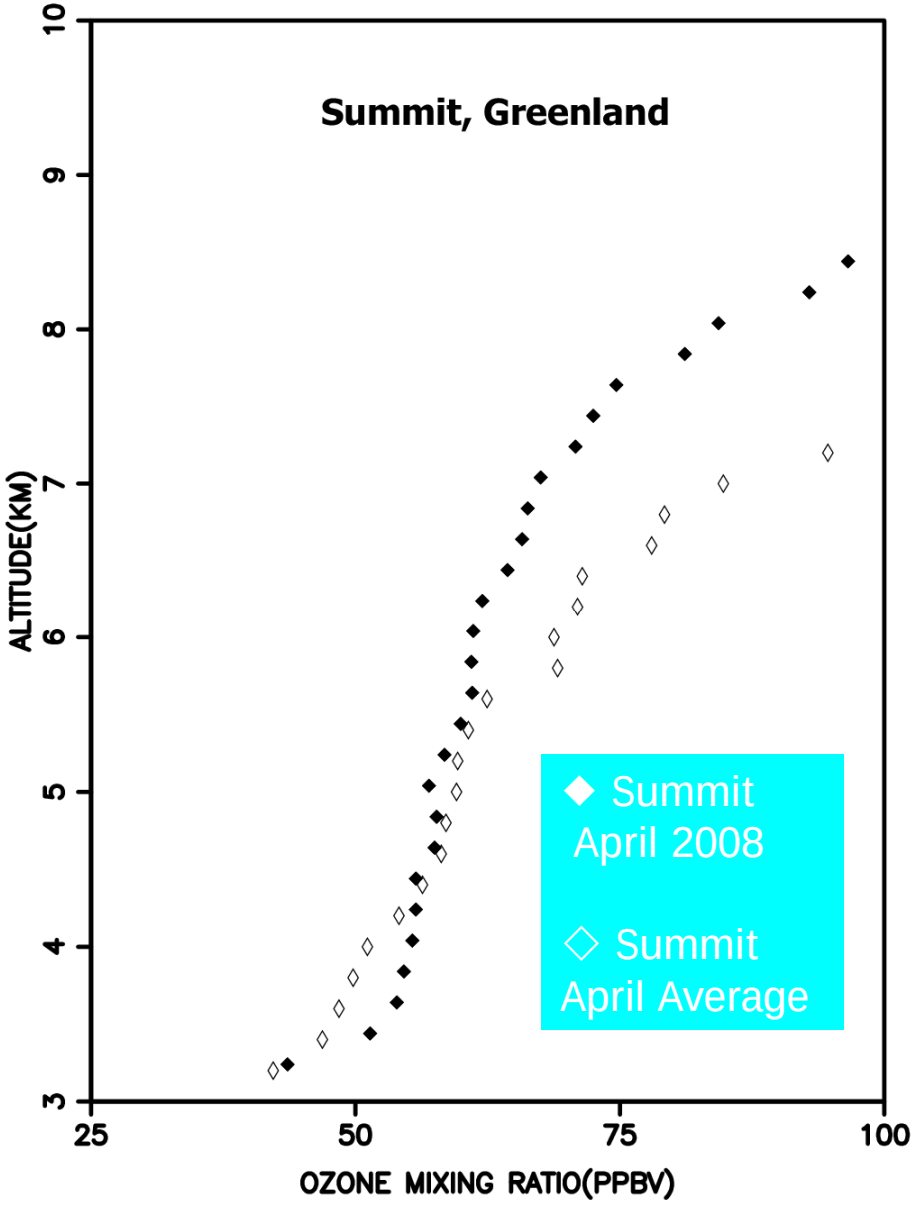
Average Seasonal Profiles at Summit (left) and Churchill, Canada (59N)





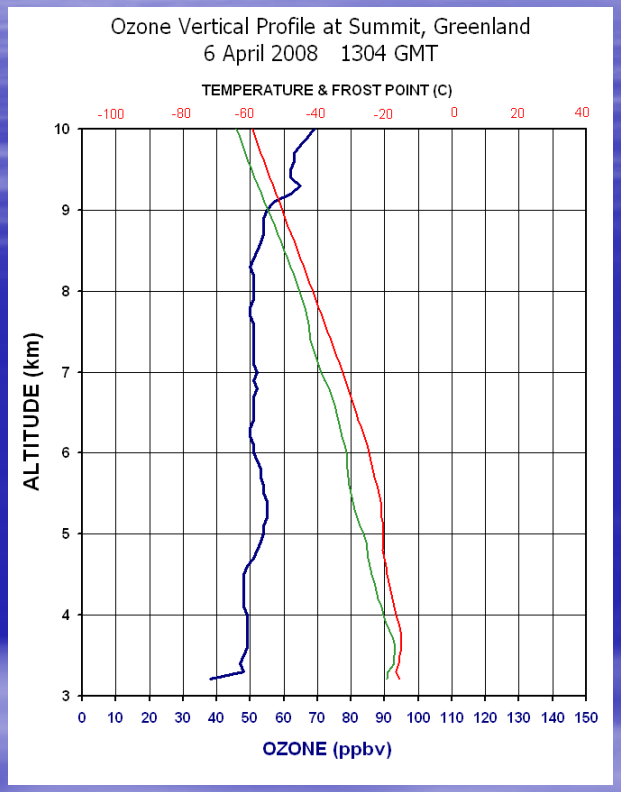
Average Seasonal Profiles at Summit

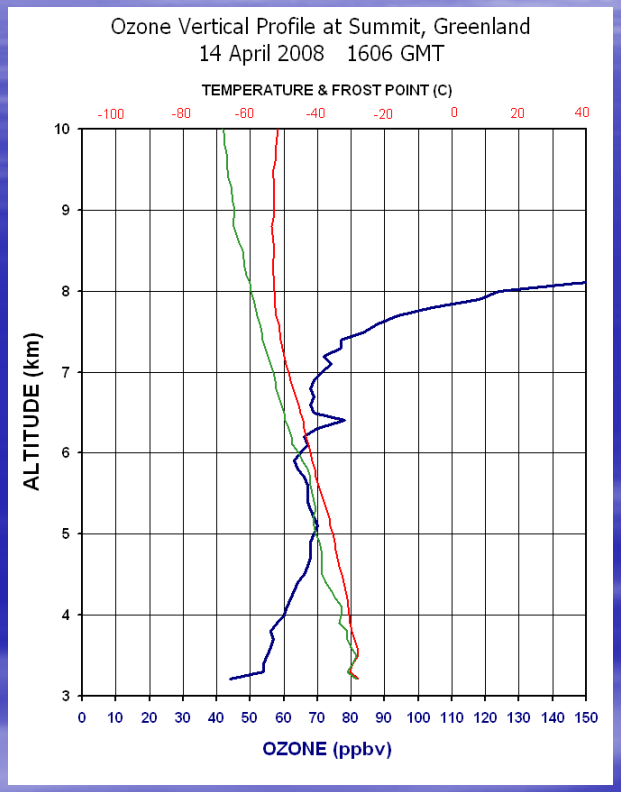


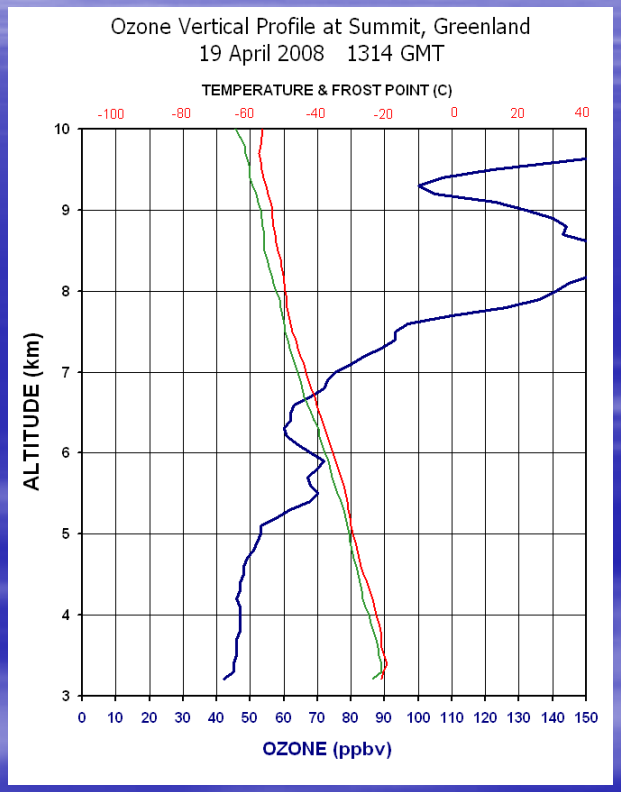


Comparison of the average April tropospheric ozone profile at Summit with April 2008

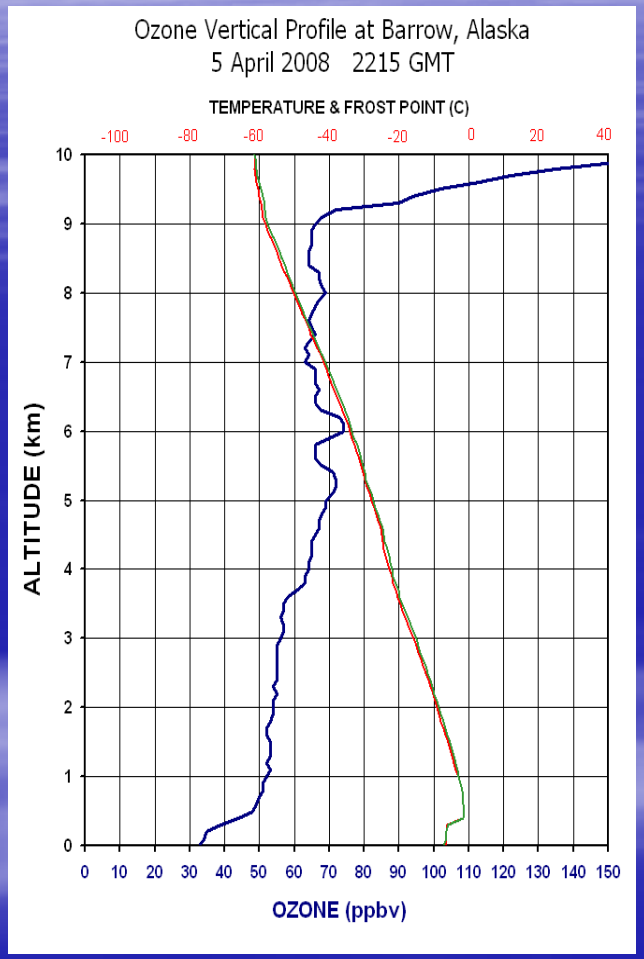
April 2008 Profiles at Summit

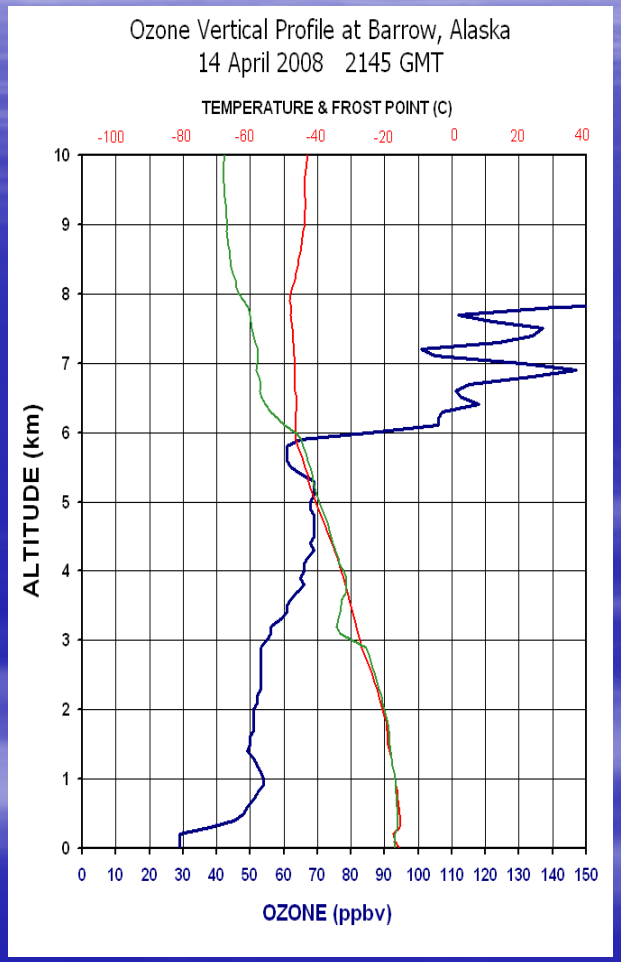


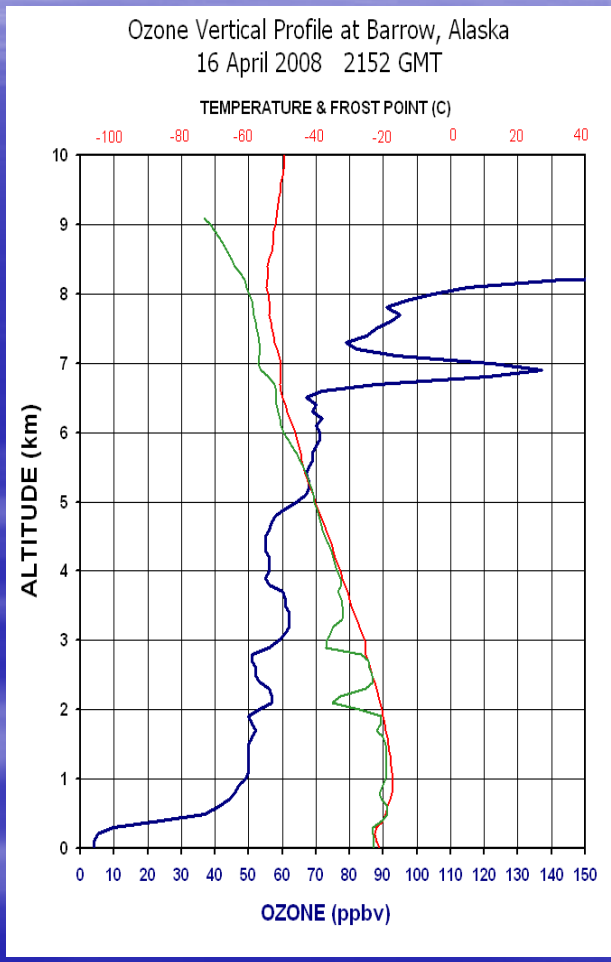




April 2008 Profiles at Barrow







Ozone Profiles at Barrow During the Period April 14-19, 2008