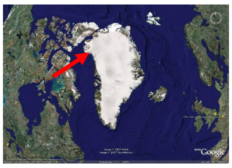
Measurements of the winter stratospheric structure and composition from the NDACC station at Thule, Greenland: long-term evolution and the exceptional winters of 2008-2009 and 2010-2011

A. G. di Sarra[1], C. Di Biagio[1,2], G. Muscari[3], P. Bertagnolio[3,2], M. Cacciani[4], R.L. De Zafra[5], P. Eriksen[6], G. Fiocco[4], and D. Fuà[4]

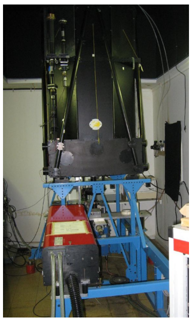
alcide.disarra@enea.it

[1]ENEA/UTMEA-TER, S. Maria di Galeria, Italy; [2]University of Siena, Siena, Italy; [3]Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy; [4]"Sapienza" University of Rome, Rome, Italy; [5]State University at Stony Brook, New York, USA; [6]Danish Meteorological Institute, Copenhagen, Denmark



Position of Thule.

The station at Thule: instrumentation

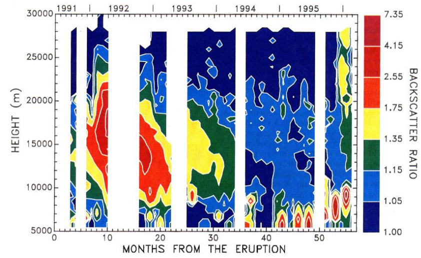


LIDAR SYSTEM

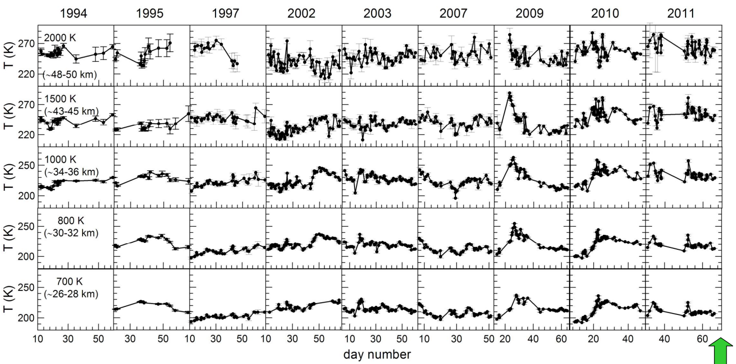
Several instruments are operational at Thule (76.5°N, 68.8°W) as part of the Network for Detection of Atmospheric Composition Change. A **lidar** was installed in 1990 and has been operational particularly during the winter season. The Lidar uses a Nd:YAG laser, three telescopes, and four receiving channels to measure the aerosol backscatter ratio and depolarization in the troposphere and lower stratosphere, and the atmospheric temperature (T) profile from 25 up to 70 km altitude.

A ground-based millimeter-wave spectrometer (**GBMS**) was installed at Thule in 2001, and has been operational during the winter seasons of 2001-2003 and 2009-2011. The GBMS permits to derive the atmospheric concentration profiles of different chemical species, such as O_3, CO, N_2O, and HNO_3, between about 15 and 80 km at a resolution of 8-12 km.

GBMS

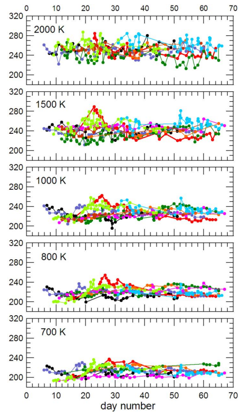


Backscatter ratio versus height obtained at Thule in the period September 1991 to February 1996. The lidar has permitted to show the build up and the decay of the volcanic aerosols originated from the eruption of Mount Pinatubo in June 1991 [*di Sarra et al.*, 1998].



Temporal evolution of the temperature measured by lidar at 5 different potential temperature levels between 700 K (26-28 km) to 2000 K (48-50 km) in the period 1994-2011.

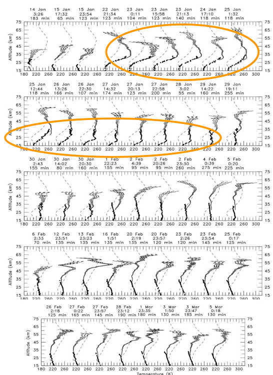
Temporal evolution of the temperature measured at Thule by lidar at the potential temperature levels of 700, 800, 1000, 1500, and and 2000 K in the period January – early March of 9 years between 1994 and 2011.

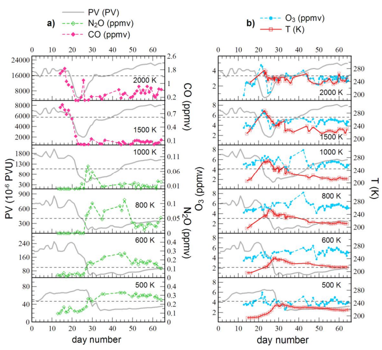


The 2008-2009 winter

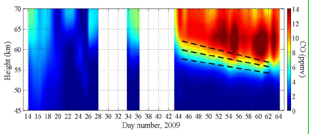
The 2008-2009 Arctic winter has been characterized by the most intense Sudden Stratospheric Warming (SSW) event ever observed. The maximum of the warming was detected over Greenland. The SSW produced a large effect also on the stratospheric chemical composition.

Temperature profiles obtained by lidar between 14 January and 5 March 2009 at Thule. T, T+σ, and T-σ are shown. The dashed line represents the CIRA 1986 model [*Barnett and Corney*, 1985] for the month. Dotted profiles are radiosonde data that are the closest in time data (from Eureka or Alert, depending on the data availability). Date, time, and integration time in minutes are reported.





Temporal evolution of: a) Potential Vorticity, N_2O and CO mixing ratio; b) O_3 mixing ratio and temperature, at different θ levels between 14 January and 5 March 2009 (days 14-64). Horizontal dashed lines are indicative threshold values for the inner vortex edge.

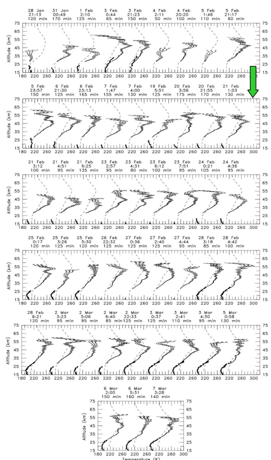


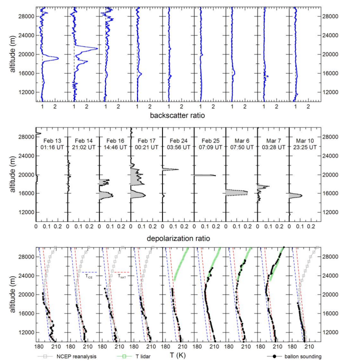
Contour plot of CO mixing ratio between 45 and 70 km in the period 14 January – 5 March 2009. Linear fits to CO mixing ratio levels of 5, 8 and 11 ppmv altitude versus time are also shown (dashed lines). The descent rate in the newly reformed vortex was about 0.25 km/day.

The 2010-2011 winter

The lower stratosphere was very cold and stable during Winter 2011, and a large number of PSCs were observed by lidar from mid February to mid March. The massive presence of PSCs determined the record ozone loss of about 40% in March-April 2011 at Thule.

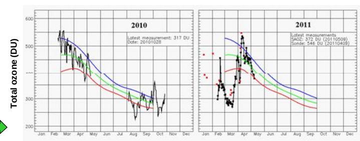
Temperature profiles obtained by lidar between 28 January and 7 March 2011 at Thule. T, T+σ, and T-σ are shown. The dashed line represents the CIRA 1986 model [*Barnett and Corney*, 1985] for the month. Dotted profiles are radiosonde data that are the closest in time data (from Eureka or Alert, depending on the data availability). Date, time, and integration time in minutes are reported.





Lidar backscatter ratio between 10 and 30 km for the total component of the signal acquired between 13 February and 10 March 2011 (top graph); depolaritazion ratio (mid graph); closest in time temperature profiles measured by lidar, obtained through balloon soundings at Eureka and from daily NCEP reanalysis over TAB (bottom graph) ; the dashed lines indicate the temperature thresholds for ICE and NAT particles assuming 5 ppmv concentration of water vapour and 10 ppbv of nitric acid.

Total ozone measured with a SAOZ spectrometer at TAB by DMI in 2010 and 2011 (black line); 1979-1988 mean, ±1 σ, of the NASA/TOMS ozone measurements over the Arctic (green, blue, and red lines).



References

Barnett, J. J., and M. Corney (1985), Middle atmosphere reference model derived from satellite data, Handbk. MAP, 16, 47–137.

di Sarra, A., L. Bernardini, M. Cacciani, G. Fiocco and D. Fuà (1998), Stratospheric aerosols observed by lidar over northern Greenland in the aftermath of the Pinatubo eruption, *J. Geophys. Res.*, 103, 13873- 13891.