Low Ozone over the Arctic in January 2011

Hommel R, Rozanov A, Eichmann K–U, Aschmann J, Richter A, Bramstedt K, Weber M, Burrows JP
von Savigny C * and Khosrawi F **

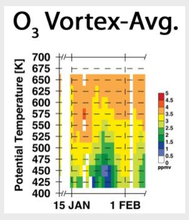
Institute of Environmental Physics, University of Bremen, P.O. Box 33 04 40, 28334 Bremen, Germany (rene.hommel@iup.physik.uni-bremen.de)
** Ernst Moritz Arndt University Greifswald, DE*
*** Department of Meteorology, Stockholm University, SW*

Summary

Remarkably large ozone losses were observed in spring 2011 over the Arctic (e.g. Manney et al., 2011). Although several studies showed that this ozone loss was caused by heterogeneous processes in the presence of PSCs, so far not much attention is being given to a period showing very low ozone in the second half of January 2011. Here we show that for ten days commencing 21 January 2011 GOME-2 observed total ozone as low as 200 DU. Height-resolved vortex-averaged ozone profiles from SCIAMACHY limb measurements show that those losses occurred below the 500 K isentropic surface (≈22 km during this time). That is the same altitudinal range where halogens are activated and catalytic cycles effectively destroy ozone. Whether the January 2011 losses result from a chemical decomposition or a specific meteorological situation caused the ozone low is examined in a paper recently submitted to ACPD by the authors and is briefly discussed here. It turns out that a superposition of two independently evolving synoptic-scale intrusions of tropospheric air lifted the tropopause over the Asian continent that diverged the above lying stratospheric ozone column. The induced adiabatic cooling of the stratosphere enhanced PSC formation so that subsequent chlorine activation was amplified. In turn, the January 2011 low ozone event indirectly influenced the scale of the tremendous ozone destruction later in spring. The area where low ozone was found in January 2011 covered approximately 1×10^7 km^2, which is almost a third larger than typical "ozone mini-hole" sizes and almost as large as the area covered by the Antarctic ozone hole in southern hemispheric spring.

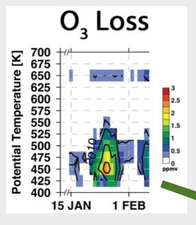
But What Happend in January 2011 ?

Apparent large O_3 reduction up to 60% below 500 K (≈22 km) in 2nd half of January 2011. Chemical destruction?



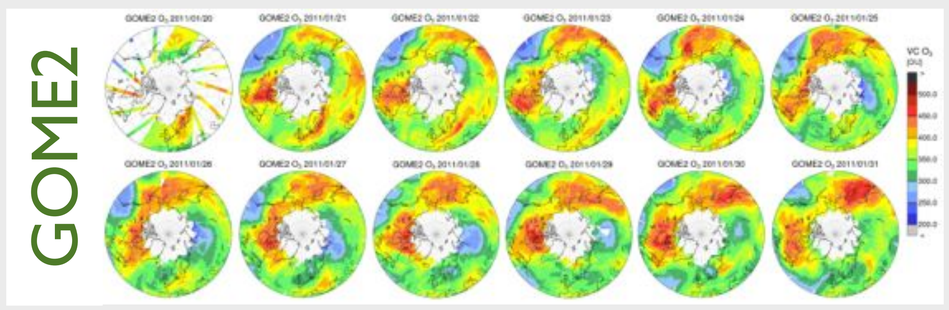
➡ Unlikely in mid-winter, because halogens not yet fully activated

Feature real or an artefact caused by the methods applied?

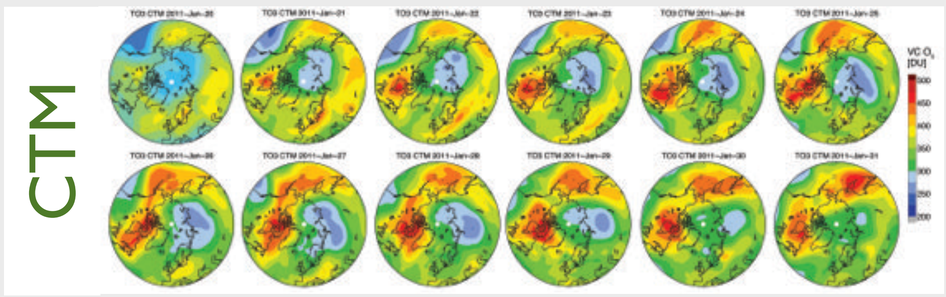


Very Low Total O3 in January 2011

- Total O_3 (here GOME2) lower than 300 DU commencing 21 January 2011
- Low as 200 DU between 25 - 27 January 2011
- Situation lasts for 10 days



Nicely reproduced by the CTM operated at IUP Bremen (e.g. Sinnhuber et al. 2003, Aschmann et al., 2011) and driven by ERA-Interim meteorology:

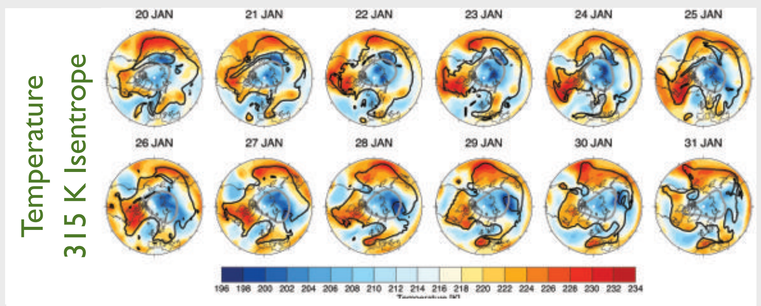


Meteorological Situation in January 2011

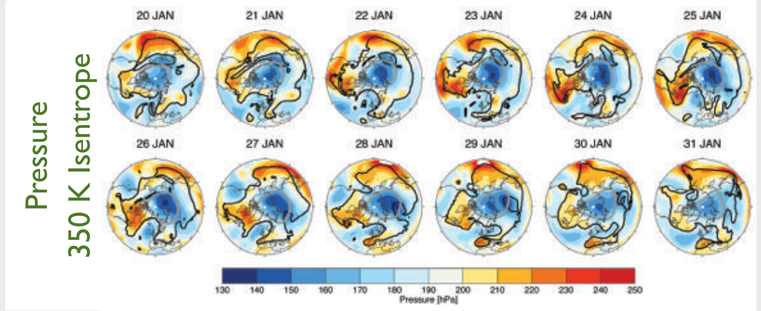
Large intrusions of low-lat tropospheric air entered the tropopause region below the vortex over East Siberia and later over the Ural region.

➡ 2 independent **O_3 mini hole** situations occurred which had a combined effect on vortex O_3 for 10 days!

➡ **Unusually long-lasting and strong!**

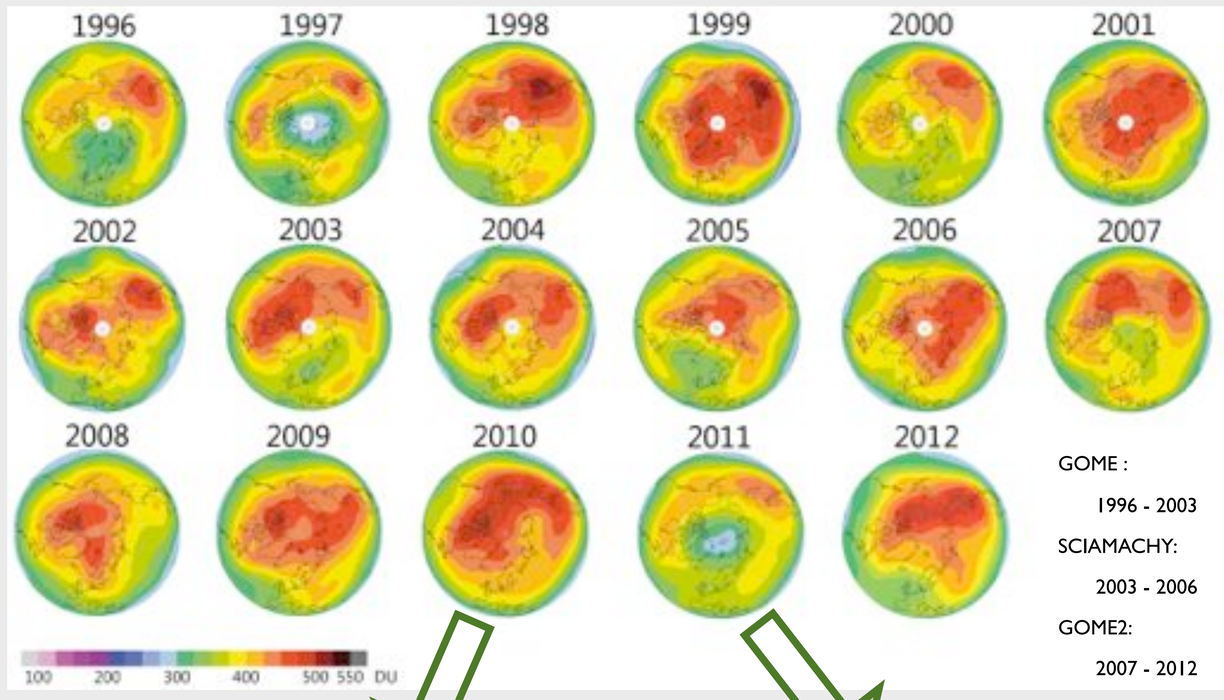


Polar stereographic maps of meteorological conditions at approximate tropopause level (315 K and 350 K isentropic surfaces) during the period when large reductions in the GOME-2 column ozone are observed. The vortex edge is indicated by the gray contour of the 38 PVU potential vorticity at the 475 K isentrope. The thick black contour denotes the 3 PVU potential vorticity at 315 K, roughly separating polar airmasses (low tropopause) from subtropical air masses (high tropopause). Obtained from the ECMWF ERA-Interim

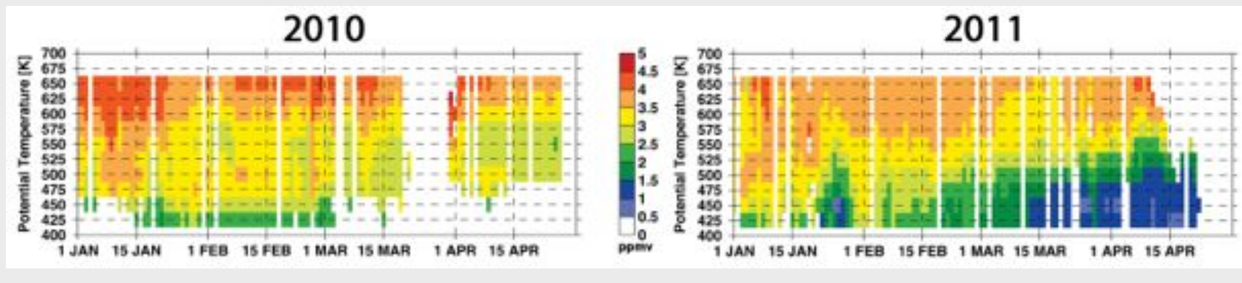


GOME/SCIAMACHY/GOME-2 Arctic Total O_3

Apparent large variability - exceptional low total O_3 in 1997 and 2011

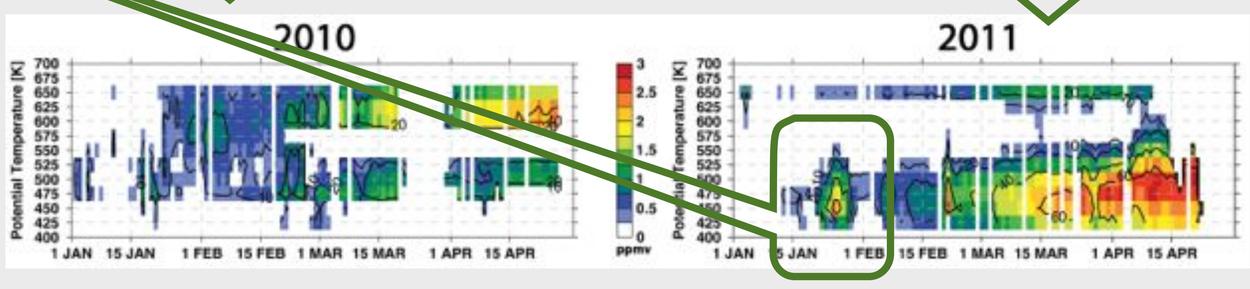


SCIAMACHY Limb Vortex Averaged Arctic O_3



- Generally lower O_3 levels in 2011 also seen in height resolved vortex averages
- Chemical O_3 destruction in spring 2011 clearly seen

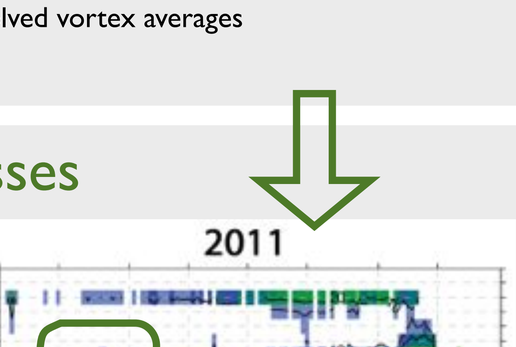
Inferred O_3 Losses

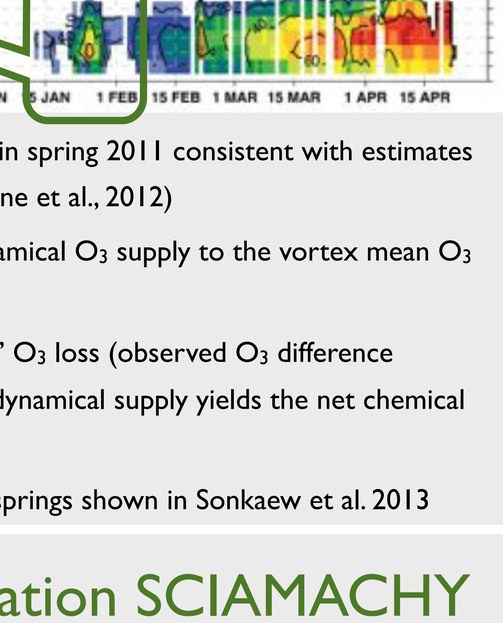


- Relative O_3 losses of up to 70 % (shown as contour lines) in spring 2011 consistent with estimates of others (Manney et al., 2011; Sinnhuber et al., 2011; Arnone et al., 2012)
- From the calculated vortex mean diabatic descent, the dynamical O_3 supply to the vortex mean O_3 at a given isentropic level is calculated
- At the end of the winter–spring the sum of the "measured" O_3 loss (observed O_3 difference between starting date and end date) and the accumulated dynamical supply yields the net chemical O_3 loss at a given isentrope (Eichmann et al., 2002)
- SCIAMACHY limb inferred O_3 losses of preceding winter-springs shown in Sonkaew et al. 2013

2011 PSCs & Chlorine Activation SCIAMACHY

- Total supply of PSCs in 2011 was the strongest and long-lasting ever observed
- Because vortex was unusually stable and cold until spring
- 3 periods of PSC formation: at the beginning of JAN, 18 JAN - 01 FEB and after 08 FEB
- O_3 mini hole in Jan 2011 triggered PSC formation, hence, substantially contributed that O_3 destruction later in spring became as intense as observed
- Until then also chlorine activation was the strongest in the entire SCIAMACHY period
- CTM data are also shown here - but they are based on an estimate of the slant column to be comparable with the nadir measurements





References

Arnone et al., Atmos. Chem. Phys., 12, 9149–9165, doi: 10.5194/acp-12-9149-2012, 2012.
Aschmann et al. Atmos. Chem. Phys., 11, 2671–2687, doi: 10.5194/acp-11-2671-2011.
Eichmann et al. J. Geophys. Res., 107, 8280, doi: 10.1029/2001JD001148, 2002.
James, Geophys. Res. Lett., 25, 301–304, 1998.
Khosrawi et al., Atmos. Chem. Phys., 11, 8471–8487, doi: 10.5194/acp-11-8471-2011, 2011.
Khosrawi et al. Proceedings of the ESA Atmospheric Science Conference 18–22 June 2012, Bruges, Belgium, ESA-SP-708, Eur. Space Agency Spec. Publ., November 2012, ISBN/ISSN:978-92-9092-272-8, 2012.
Krzyscin, Int. J. Climatol., 22, 1425–1439, doi:10.1002/joc.812, 2002.
Manney et al., Nature, 478, 469-475, 2011.
Rozanov et al., Atmos. Meas. Tech., 4, 1319-1359, 2011.
Sonkaew et al., Atmos. Chem. Phys., doi:10.5194/acp-13-1809-2013, 2013.
Sinnhuber et al., Geophys. Res. Lett., 38, L24814, doi: 10.1029/2011GL049784, 2011.
von Savigny et al., Atmos. Chem. Phys., 5, 3071-3079, 2005.
WMO, Scientific Assessment of Ozone Depletion: 2010, Global Ozone Research and Monitoring Project - Report No. 52, 516pp, Geneva, Switzerland, 2011.