National report to the Ozone Secretariat, UNEP, for the 8th WMO/UNEP Ozone Research Managers Meeting May 2011, Geneva, Switzerland

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1. OBSERVATIONAL ACTIVITIES

1.1 Column measurements of ozone

Total ozone is monitored at two sites in Sweden by SMHI (Swedish Meteorological and Hydrological Institute) on behalf of the Swedish Environmental Protection Agency. Daily measurements started in Norrköping in 1988 using the Brewer #6, which was replaced by Brewer #128 in 1996. In Vindeln manual measurements started in 1991 using the refurbished old Dobson #30 and since 1996 the automatic Brewer #6 is also used.

The instruments are calibrated and served regularly. Efforts have been spent on improving the methods to retrieve good observations at low solar elevations since the 1990-ties, Josefsson (2003) and to improve the algorithms for cloud covered skies Josefsson and Ottosson-Löfvenius (2008). This year one Dobson and one Brewer participated in the CEOS campaign in Sodankylä.

1.2 Profile measurements of ozone and other gases

At the Swedish Institute of Space Physics in Kiruna there are a number of sophisticated instruments in operation. Special radars can track the circulation in the stratosphere. LIDAR gives a profile of the ozone and aerosols in the stratosphere, when there are no interfering clouds. There is also an instrument KIMRA (Kiruna Millimeter wave radiometer) that is used to monitor O_3, ClO, N_2O and HNO_3. The vertical resolution may not be the best, but it is independent of the weather so it can operate continuously.

Forschungszentrum Karlsruhe has located a FTIR (Fourier-Transform Infrared) Spectroradiometer at the same site to record long-term trends, Kohlrepp et al. (2011).

There is also a DOAS-instrument from NIWA and University of Heidelberg recording primarily total ozone and the column amounts of a number of other species.

1.3 Satellite measurements

The satellite Odin (Sweden, France, Canada and Finland) has now been in orbit for more than ten years. On board there are two instruments with connection to stratospheric studies a submillimeter radiometer, SMR, and an optical spectrograph and infrared imaging system, OSIRIS.

1.4 UV measurements

1.4.1 Broadband measurements

Monitoring of broadband UV (CIE-erythema weighted) started relatively early in Sweden. Supported by SSM (the Swedish Radiation Safety Authority) SMHI has been measuring since 1983. Josefsson (2006). There has also been a small network of five stations for a limited period. Presently, SMHI operates one station in Norrköping using a Solar Light Model 501. In the northernmost part of Sweden the Abisko Scientific Research Station is also using a similar instrument.

1.4.2 Narrowband filter instruments

The SSM have operated three stations, Stockholm, Tylösand and Visby, using GUV-instruments.

1.4.3 Spectroradiometers

In the past one UV-spectrum was recorded in between the monitoring of total ozone. Both Brewer instruments operated by SMHI were used. These data have been included in EC-funded projects SUVDAMA, EUDUCE and SCOUT-O3, e.g. Bais et al. (2007), Outer den (2006). In recent years data are still collected despite that funding ceased, but there is no calibration done.

1.5 Calibration activities

The Brewer instruments for total ozone are calibrated and serviced regularly by three year interval by IOS (International Ozone Services Inc.). Thus the output will be traceable to the Brewer Triad, which forms the WMO/GAW calibration centre. The Dobson instrument is recalibrated roughly every fifth year by visits to the WMO regional calibration centre at Hohenpeissenberg, Germany. The last calibrations were in 2007 and in 2010, when the instrument was served, calibrated and the electronics was replaced.

The broadband UV-meter used at Norrköping has participated in a number of international comparisons, see e.g. Gröbner et al (2002), Johnsen et al. (2006) and Josefsson (2006). Also the radiometers used by SSM have participated in comparisons or have been compared to the one of SMHI.

Due to lack of funding the absolute calibration (lamp or intercomparisons) of the spectroradiometers have not been done for recent years.

2. RESULTS FROM OBSERVATIONS AND ANALYSIS

Controlled and processed total ozone and broadband UV-data are available from web-sites of SMHI and/or WOUDC. Below is shown a summary of various observations made at Norrköping, Sweden. Interestingly, the Brewer spectrophotometer data can also be used to compute the aerosol optical depth (AOD), Cheymol et al (2006).

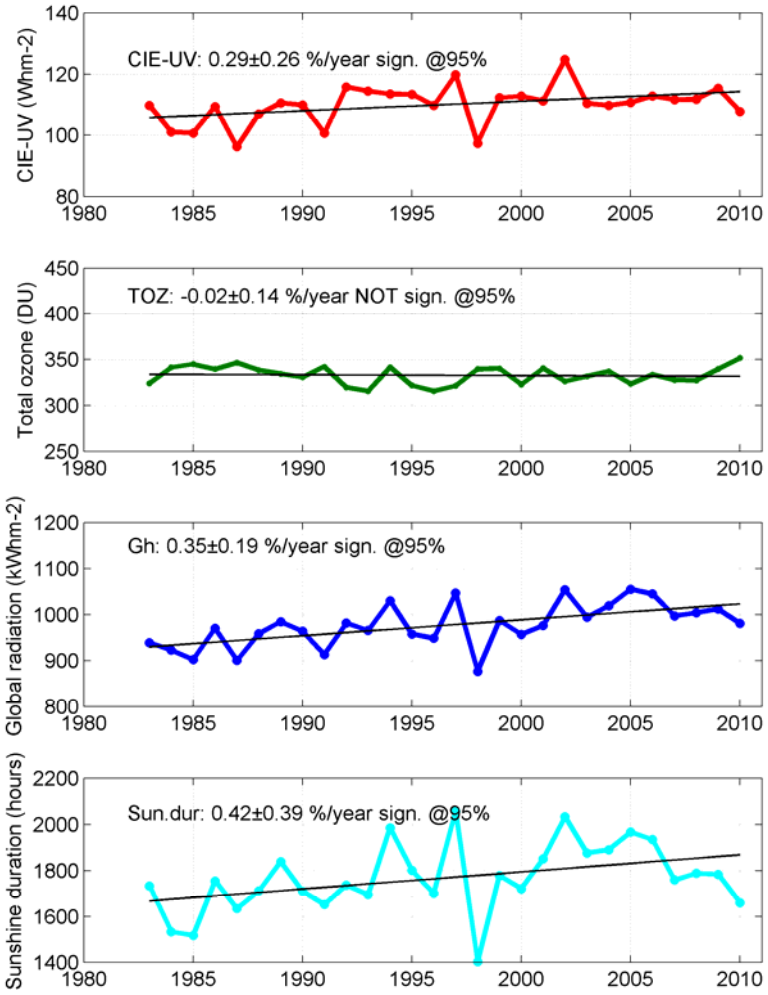

Figure 2.1. Long-term, 1983-2010, CIE-weighted UV, total ozone, global radiation and sunshine duration from Norrköping, Sweden. A linear trend is tested on the level of 95% significance for each variable.

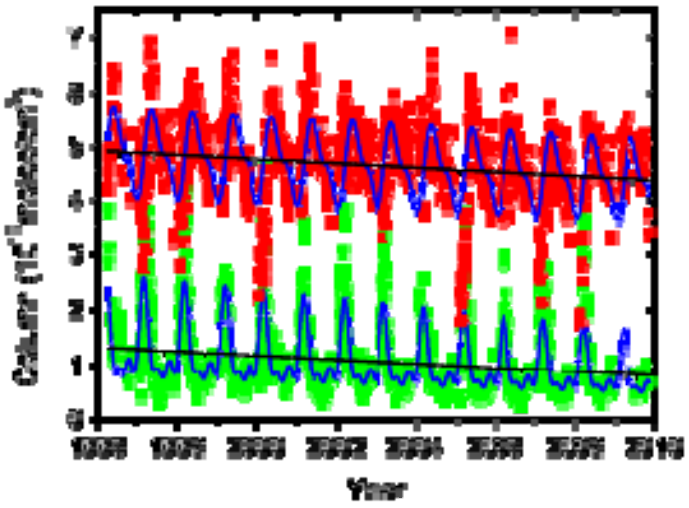

Figure 1.1 HCl and $ClONO_2$ from FTIR-measurements over Kiruna, from Kohlrepp et al. (2011).

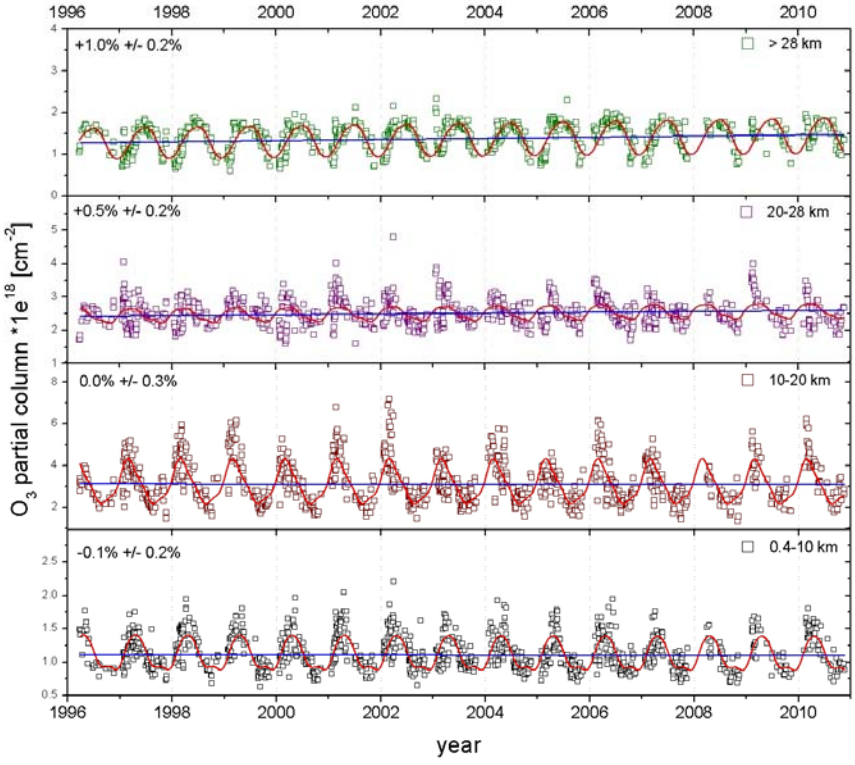

Figure 1.2 The ozone change in several atmospheric layers over Kiruna has been studied using the FTIR, from Barthlott et al. (2011).

3. THEORY, MODELLING, AND OTHER RESEARCH

3.1 Modelling

In early 2000 the STRÅNG-model system Landelius, Josefsson and Persson (2001) was launched, see http://strang.smhi.se/ as a co-operation between SMHI, the Swedish Environmental Protection Agency and the Swedish Radiation Safety Authority. Now, there is over 10 years of hourly data available for anyone to download, period 1999- up to yesterday. The modelled variables are CIE-weighted UV, global radiation, direct solar radiation, sunshine duration and photosynthetic photon density (PAR). The geographical area covers a large part of northern Europe with a present spatial resolution of 11 km.

Swedish UV-data has also been used for validation of re-constructed past UV-variation based on ERA-40 data, for validation of models based on satellite input and for validation of various UV-models, see e.g. Feister et al. (2008), Kaurola et al (2007), Kaurola et al (2010), Lindfors et al (2007), Lindfors et al (2009) and den Outer et al. (2010).

3.2 Satellite

Results from the Odin satellite instruments have published see e.g section 1.3 and Rösevall et al.(2007, 2007a, 2007b, 2008), Jones et al. (2009).

The observations have been compared with data from CTMs (Chemical Transport Models) see Khosrawi et al. (2008) and Khosrawi et al. (2009).

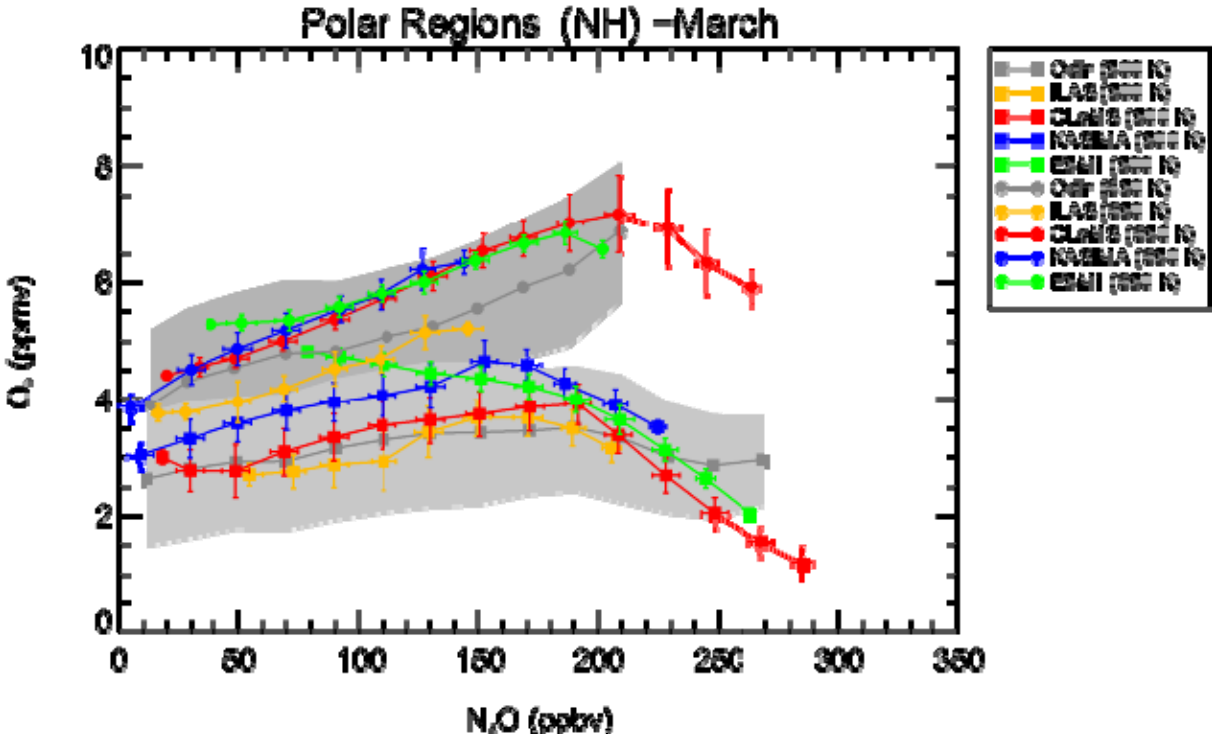

Figure 1.2. Here two CTMs (CLaMS and Kasima) and one CCM (E5M1) are compared to the Odin/SMR data at two potential temperatures levels (500 and 650 K) for one month, namely March. Addtionally the ILAS/ILAS-II data has been included in this comparison. The 500 K level is the one to look at how well ozone loss during Arctic spring is represented by the models. In general, models tend to underestimate ozone loss as can be seen from the deviation of the curves, they all show higher values than the observations from Odin/SMR or ILAS/ILAS-II, from Koshrawi et al (2009).

4. DISSEMINATION OF RESULTS

4.1 Data reporting

Daily total ozone data are submitted once a month to the WOUDC. These data are also available at the www.smhi.se where also daily UV can be downloaded.

4.2 Information to the public

General information on the stratospheric ozone and UV-radiation can be found at www.smhi.se and at www.naturvardsverket.se/

The SSM (the Swedish Radiation Safety Authority) has more public information on their web-site www.ssm.se. This governmental authority also produce brochures and some of them are possible to download from their web site. They also have had activities with the goal to change the behaviour of people mainly directed towards children. One activity was to publish and distribute "A book about the sun" to all kindergartens (8000) in Sweden, http://www.ssi.se/UVindex/PDFer/EnBokOmSolen.pdf another one was to educate the teachers of preschools and primary schools on the basics of and risks of UV. Collaboration with the Swedish Life Saving Society offers sun protection information to many thousands of children every year.

The distribution of daily UV-index forecasts started in 1993 from SMHI. In 1996 the UV-index forecast was introduced on the web (http://www.smhi.se) as a Table for 15 regions in Sweden and three resorts. Next year, 1997, the graphical layout was improved and since then the daily course of the UV-index is presented for a number of climatological similar regions in Sweden. During the first winters there was no forecasting of UV-index done. The season started in late March and stopped at the end of August. Since the year 2000, it is in operation all the year around. There is also some additional text presenting some specific features of interest regarding UV-radiation in general.

5. RECOMMENDATIONS

Concering future research and activities regarding the ozone layer monitoring is still needed using both ground and space based instruments. Models needs to be improved, especially the CCMs. Predictions about when and to what extent the ozone layer will recover have still uncertainties and the model results deviate from each other by one or two decades.

Another valuable contribution from long-term measurements of ozone and related species from ground or from satellites are their connection to the climate change issue.

Relevant scientific papers

Bais A.F., S. Kazadzis, C. Meleti, N. Kouremeti, J. Kaurola, K. Lakkala, H. Slaper, P.N. den Outer, W. Josefsson, U. Feister and M. Janouch (2007), Variability in spectral UV irradiance at seven European stations, pp.27- Proceedings of the UV confrerence 18-20 September 2007, Davos, Switzerland, Edt J Gröbner, PMOD, Davos, Switzerland, July 2007.

Barthlott Sabine, M. Schneider, T. Blumenstock, F. Hase, and R. Kohlhepp (2011), Data & characterisation using FTIR partial columns from NDACC, oral presentation at SPARC/IO3C/WMO-IGACO-03/UV Workshop on Past Changes in the Vertical Distribution of Ozone, January 2011, WMO, Geneva, Switzerland

Cheymol, A., H. De Backer, W. Josefsson, and R. Stübi (2006), Comparison and validation of the aerosol optical depth obtained with the Langley plot method in the UV-B from Brewer Ozone Spectrophotometer measurements, J. Geophys. Res., 111, D16202, doi:10.1029/2006JD007131.

Feister, U., Junk, J., Woldt, M., Bais, A., Helbig, A., Janouch, M., Josefsson, W., Kazantzidis, A., Lindfors, A., den Outer, P. N., and Slaper, H. (2008), Long-term solar UV radiation reconstructed by ANN modelling with emphasis on spatial characteristics of input data, Atmos. Chem. Phys., 8, 3107-3118, 2008. http://www.atmos-chem-phys.net/8/3107/2008/acp-8-3107-2008.pdf

Gröbner J., D.Rembges, A.F. Bais, M. Blumthaler, T. Cabot, W. Josefsson, T. Koskela, T.M. Thorseth, A. R. Webb, and U. Wester (2002), Quality assurance of reference standards from nine European solar-ultraviolet monitoring laboratories, Applied Optics, Vol.41, No.21, 20 July 2002.

Johnsen B. et al. (2006), International intercomparison of multiband filter radiometers in Oslo 2005. In Proceedings of SPIE Europe Remote Sensing conference in Stockholm 11-14 Sept 2006.
Lindfors, A., J. Kaurola, A. Arola, T. Koskela, K. Lakkala, W. Josefsson, J. A. Olseth, and B. Johnsen (2007), A method for reconstruction of past UV radiation based on radiative transfer modeling: Applied to four stations in northern Europe, J. Geophys. Res., 112, D23201, doi:10.1029/2007JD008454.

Jones, Ashley; Urban, Joachim; Murtagh, Donal P.; Eriksson, Patrick; Brohede, Samuel; Haley, C.; Degenstein, D.; Bourassa, A.; von Savigny, C.; Sonkaev, T.; Rozanov, A.; Bovensmann, H.; Burrows, J. (2009), Evolution of stratospheric ozone and water vapour time series studied with satellite measurements. *Atmospheric Chemistry & Physics*, 9 pp. 6055-6075.

Josefsson, W., 2003. Quality of Total Ozone Measured by the Focused Sun Method Using a Brewer Spectrophotometer, *J. Appl. Meteor.*, Vol. 42., No.1, pp.74-82.

Josefsson W., 2006, UV-radiation 1983–2003 measured at Norrköping, Sweden, Theoretical and Applied Climatology, V.83, No.1-4, pp. 59-76, ISSN: 0177-798X (Paper) 1434-4483 (Online),
DOI: 10.1007/s00704-005-0160-1, Date: January 2006.

Josefsson W. and M. Ottosson Löfvenius (2008), Total ozone from zenith radiance measurements - An empirical model approach, Meteorologi Nr.130, ISSN 0283-7730 SMHI Meteorology
http://www.smhi.se/content/1/c6/03/36/29/attatchments/meteorologi_130.pdf

Kaurola J., A. Lindfors, Lakkala K., Josefsson W., Hansen G., Vuilleumier L. (2007), Estimated changes in surface UV over the last 4 decades using ERA-40 data, Proceedings of the UV conference 18-20 September 2007, Davos, Switzerland, Edt J Gröbner, PMOD, Davos, Switzerland, July 2007.

Kaurola J., A. Lindfors, K. Lakkala, G. Hansen, W. Josefsson, and L. Vuilleumier (2010), On the usability of the ERA-40 re-analysis in the estimation of past surface UV radiation over Europe, J. Geophys. Res., VOL. 115, D24107, 13 PP., 2010, doi:10.1029/2010JD013810.
http://www.agu.org/journals/jd/jd1024/2010JD013810/2010JD013810.pdf

Khosrawi, F., R. Müller, M. H. Proffitt, and H. Nakajima (2006), Monthly averages of nitrous oxide and ozone for the Northern and Southern Hemisphere high latitudes: A ‘‘1-year climatology’’ derived from ILAS/ILAS-II observations, J. Geophys. Res., 111, D11S11, doi:10.1029/2005JD006384.

Khosrawi, F., R. Müller, M. H. Proffitt, J. Urban, D. Murtagh, R. Ruhnke, J.-U. Grooß, and H. Nakajima (2008), Seasonal cycle of averages of nitrous oxide and ozone in the Northern and Southern Hemisphere polar, midlatitude, and tropical regions derived from ILAS/ILAS-II and Odin/SMR observations, *J. Geophys. Res.*, 113, D18305, doi:10.1029/2007JD009556.

Khosrawi, F., Müller, R., Proffitt, M. H., Ruhnke, R., Kirner, O., Jöckel, P., Grooß, J.-U., Urban, J., Murtagh, D., and Nakajima, H.: Evaluation of CLaMS, KASIMA and ECHAM5/MESSy1 simulations in the lower stratosphere using observations of Odin/SMR and ILAS/ILAS-II, Atmos. Chem. Phys., 9, 5759-5783, doi:10.5194/acp-9-5759-2009, 2009.

Kohlhepp, R., Barthlott, S., Blumenstock, T., Hase, F., Kaiser, I., Raffalski, U., and Ruhnke, R.: Trends of HCl, $ClONO_2$ and HF column abundances from ground-based FTIR measurements in Kiruna (Sweden) in comparison with KASIMA model calculations, Atmos. Chem. Phys. Discuss., 11, 1489-1510, doi:10.5194/acpd-11-1489-2011, 2011.

Landelius T, Josefsson W and Persson T (2001), A system for modelling solar radiation parameters with mesoscale spatial resolution, SMHI Reports Meteorology and Climatology, RMK No.96, May 2001, ISSN 0347-2116.

Lindfors, A., J. Kaurola, A. Arola, T. Koskela, K. Lakkala, W. Josefsson, J. A. Olseth, and B. Johnsen (2007), A method for reconstruction of past UV radiation based on radiative transfer modeling: Applied to four stations in northern Europe, J. Geophys. Res., 112, D23201, doi:10.1029/2007JD008454.

Lindfors, A.; Tanskanen, A.; Arola, A.; van der A, R.; Bais, A.; Feister, U.; Janouch, M.; Josefsson, W.; Koskela, T.; Lakkala, K.; den Outer, P. N.; Smedley, A. R. D.; Slaper, H.; Webb, A. R. (2009), The PROMOTE UV Record: Toward a Global Satellite-Based Climatology of Surface Ultraviolet Irradiance, Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Journal of, Volume 2, Issue 3, Sept. 2009 Page(s):207 – 212. Digital Object Identifier 10.1109/JSTARS.2009.2030876

den Outer, P.N., H. Slaper, J. Kaurola, A. Lindfors, A. Kazantzidis, A.F. Bais, U. Feister, J. Junk, M. Janouch, and W. Josefsson (2010), Reconstructing of erythemal ultraviolet radiation levels in Europe for the past 4 decades, J. Geophys. Res., 115, D10102, doi:10.1029/2009JD012827.
http://www.agu.org/journals/jd/jd1010/2009JD012827/2009JD012827.pdf

Outer P den, Slaper H, Bais A, Feister U, Josefsson W, Janouch M, Kaurola J, Koskela T (2006), UV climatology from quality controlled ground-based spectral UV-measurements, In: Slusser JR, Schaefer K, Comeron A, eds. Remote sensing of clouds and the atmosphere XI. Proceedings of SPIE. Volume 6362. Bellingham: International Society for Optical Engineering.

Rösevall J.D. (2007), On Numerical Tracer Advection in the Stratosphere and Assimilation of Data from Satellites -Development of a Method for Quantifying Polar Ozone Depletion ISBN 978-91-7385-052-0 Thesis Chalmers Tekniska Högskola, Serie nr 2733, ISSN 0346-718X.

Rösevall J.D., D.P. Murtagh, J. Urban and A. K. Jones, A Study of Polar Ozone Depletion based on Sequential Assimilation of Satellite Data from the ENVISAT/MIPAS and Odin/SMR Instruments (2007a), Atmos. Chem. Phys., Vol. 7, 899-911.

Rösevall J. D., D. P. Murtagh and J. Urban (2007b), Ozone Depletion in the 2006/2007 Arctic Winter, Geophys. Res. Lett., Vol. 34, L21809, doi:10.1029/2007GL030620.

Rösevall J. D., D. P. Murtagh ,J. Urban, W. Feng, P. Eriksson and S. Brohede (2008), A Study of Polar Ozone Depletion in the 2004/2005 Arctic Winter based on Data from Odin/SMR and Aura/MLS, J. Geophys. Res. doi:10.1029/2007JD009560