National report to the Ozone Secretariat, UNEP, for the 9th WMO/UNEP Ozone Research Managers Meeting May 2014, Geneva, Switzerland

Compiled by

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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. The Dobson #30 was completely refurbished and calibrated by DWD at Hohenpeissenberg in 2010. Efforts have been spent on improving the algorithms for cloud covered skies and the methods to retrieve good observations at low solar elevations since the 1990-ties. Therefore Dobson #30 and the Brewer #6 participated in the CEOS campaign in Sodankylä in 2011, Karppinen et al. (2014).

1.2 Profile measurements of ozone and other gases

Chalmers University of technology (Earth and Space Sciences department) is operating a monitoring station in Norway (60ºN 10.75°E) within the NDACC network (Network for the detection of stratospheric change, www.ndsc.ncep.noaa.gov . Ground based measurements of the sun have been conducted here since 1994 with a high resolution Solar FTIR with a spectral resolution of 2.5□10-3 cm^{-1}. From the recorded spectra the atmospheric columns, and partial columns of up to 25 atmospheric species can be retrieved with good accuracy. This includes stratospheric ozone, reservoir species (HCl, ClONO2, HF, HNO3) and climate gases (CH4, N2O) and species of relevance to atmospheric chemistry (CO and ethane). The data are stored at the NDACC data base.

Today there are 10-15 instruments in operation for atmospheric solar absorption measurements worldwide and within the NDACC Infrared working group Chalmers is doing data comparisons of the measurements and the retrieval algorithms.

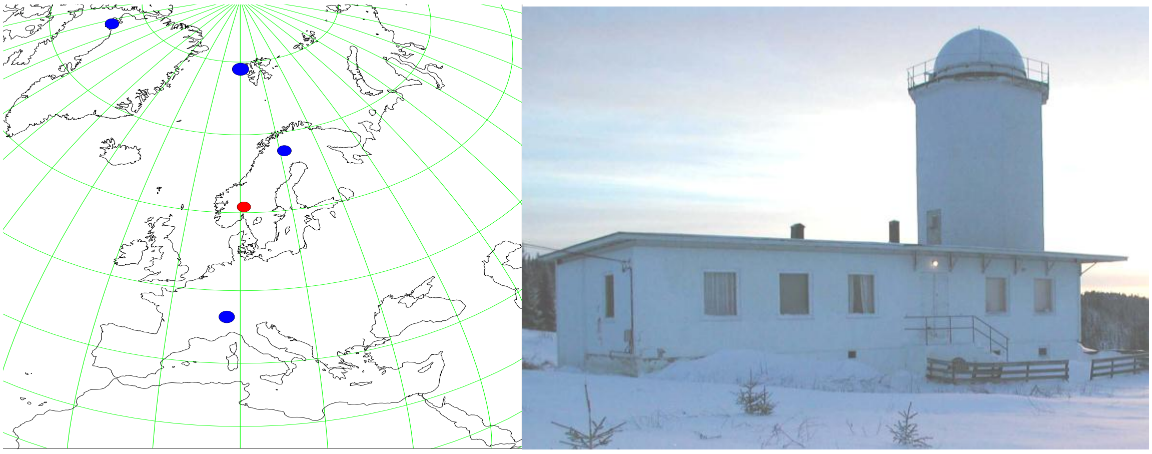

Figure 1. The solar observatory at Harestua with the high resolution FTIR instrument inside, recording infrared spectra of the sun.

At the Swedish Institute of Space Physics in Kiruna there are a number of sophisticated instruments in operation. The ESRAD radar observes the horizontal and vertical winds in the troposphere, the lower stratosphere, and the mesosphere. LIDAR observations give a profile aerosol in the stratosphere, when there are no interfering clouds. There is also an instrument KIMRA (Kiruna Millimeter wave radiometer) that is used to monitor strato-mesospheric O3 and CO. The vertical resolution may not be the best, but it is independent of the weather so it can operate continuously and it has now a time series of ozone measurements since 2002.
Since 1996 the Karlsruhe Institute of Technology (KIT) operates a FTIR (Fourier-Transform Infrared) Spectrometer at the same site to record long-term trends, see Figure 2.2 and 2.3.

The KIT owned millimeter wave radiometer MIRA2 is operated at RF since November 2012, aiming for long-term observation of ozone and possibly other trace gases, Kohlhepp et al. (2012).
There is also a DOAS-instrument from University of Heidelberg recording primarily the total column density of NO2, but funding provided total column density of ozone and a number of other species would be possible.

1.3 Satellite measurements

The Swedish-led Odin satellite continuous to make global ozone observations and entered its 13th year of operation. Odin was launched on 20 February 2001 and is a project funded by Sweden (SNSB), Canada (CSA), France (CNES), Finland (Tekes), and the 3rd party mission program of the European Space Agency (ESA). This satellite provides valuable long-term time series of ozone and related species from its two instruments, the "Sub-Millimetre Radiometer" (SMR) and the "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. 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 Spectroradiometers

In the past UV-spectra were recorded in between the monitoring of total ozone using Brewer instruments. These data have been included in EC-funded projects SUVDAMA, EUDUCE and SCOUT-O3, e.g. Bais et al. (2007). Measurements have stopped as funding ceased.

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.

1.6 Modelling and process studies

The Meteorological Institute Stockholm University (MISU) has been involved in modelling and process studies mainly regarding PSC (Polar Stratospheric Clouds) and ozone.

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), see e.g. Cheymol et al. (2006).

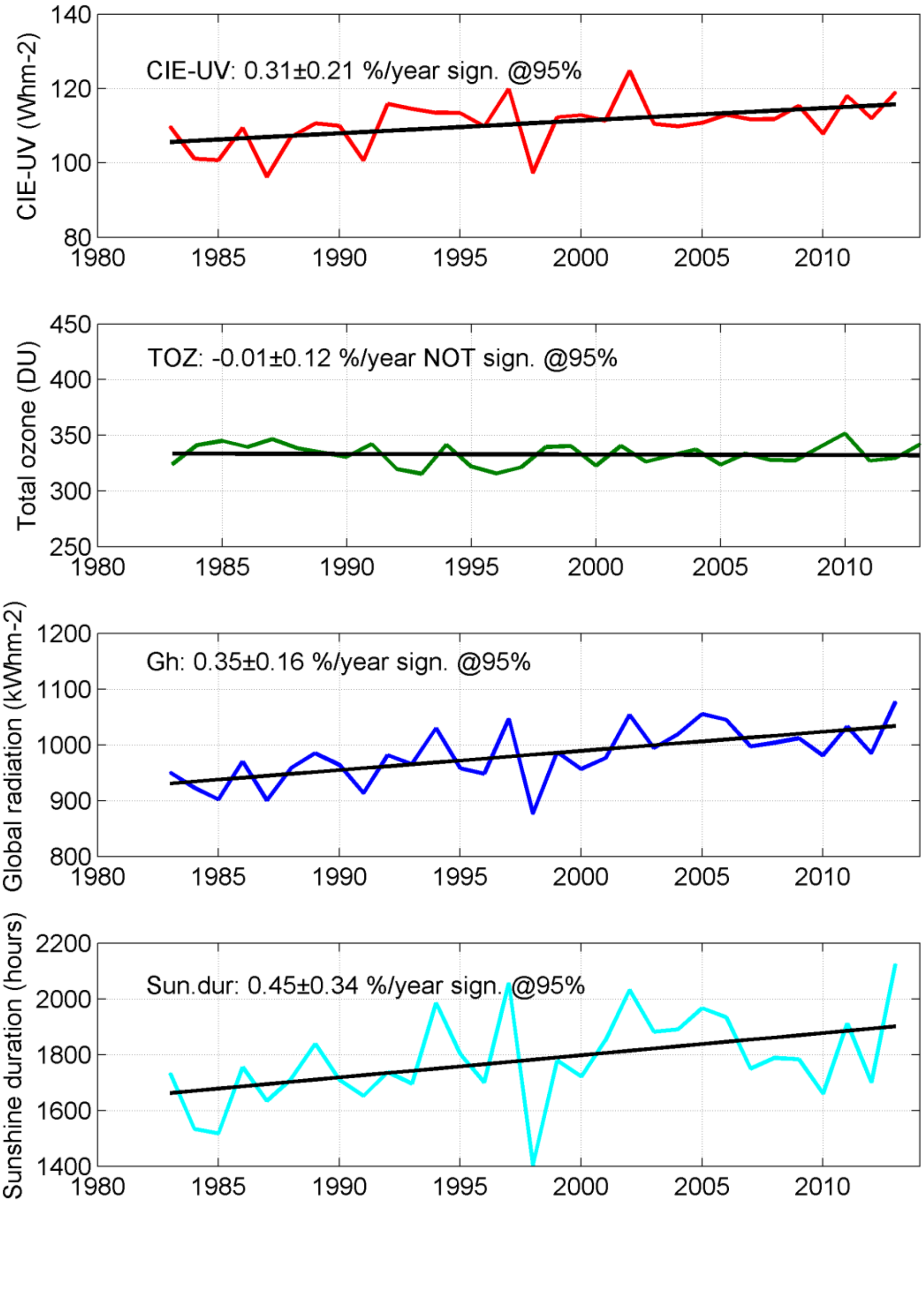

Figure 2.1. Long-term, 1983-2013, CIE-weighted UV, total ozone, global radiation and sunshine duration from Norrköping, Sweden. A linear trend is tested on the level of 95% significance for each variable.

Since 1996 the Karlsruhe Institute of Technology (KIT) operates a FTIR (Fourier-Transform Infrared) Spectrometer at Kiruna to record long-term trends, see Figure 2.2 and 2.3.

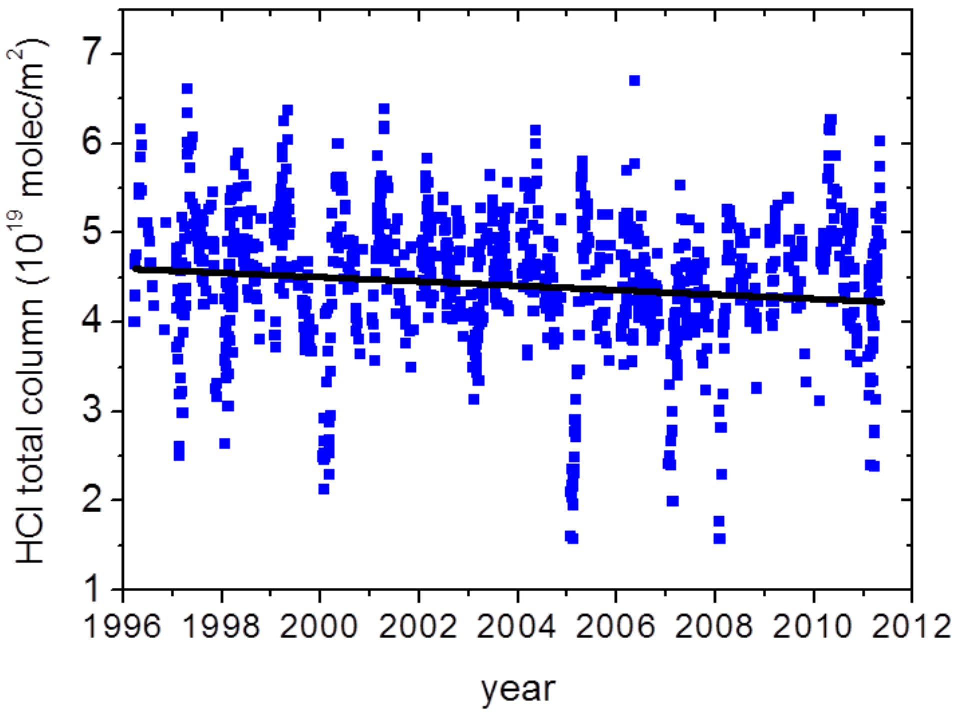

Figure 2.2 HCl total column from FTIR-measurements over Kiruna. Linear trend -0.5±0.2 % per year, update from Kohlrepp et al. (2011).

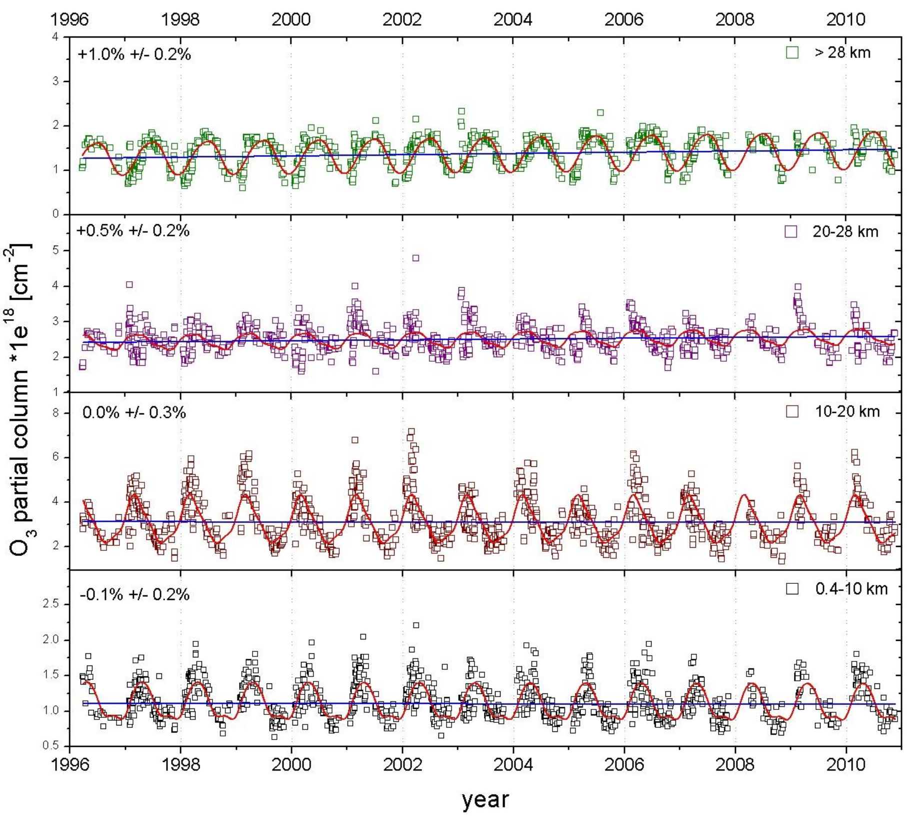

Figure 2.3 The ozone change in several atmospheric layers over Kiruna has been studied using the FTIR, from Barthlott et al. (2011).

Ground based measurements from Harestua of the column ozone using a high resolution Solar FTIR, Figure 2.4.

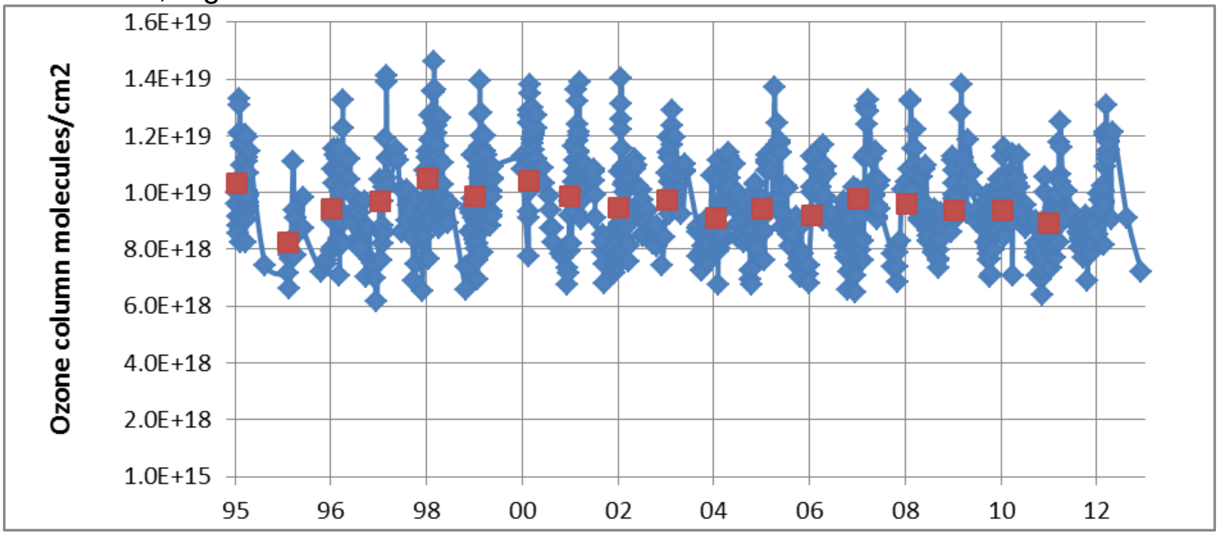

Figure 2.4. The ozone columns (daily and annual average) measured above Harestua between 1995 and 2012.

3. THEORY, MODELLING, AND OTHER RESEARCH

3.1 Modelling

At MISU some work has been done on the O3/N2O relationship as well as studies of the formation of Polar Stratospheric Clouds (PSC), Achtert et al. (2011), Koshrawi et al. (2011) and Koshrawi et al. (2012)

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.

3.2 Satellite

The Swedish led Odin satellite continues to provide relevant data for monitoring and understanding the development of the ozone layer. Data assimilation techniques are used to access ozone loss see e.g. Rösevall et al. (2008), the time series is now over 11 years long and is being incorporated into several international initiatives such as ESAs Essential climate variable initiative Sofieva et al. (2013) and SPARC's data initiative. The data assimilation work is continuing to obtain a series of ozone loss measurements for both Antarctic and Arctic pole and for other instruments, ACPD, Sagi et al. (2014).

The Odin ozone data are for example used in international activities in preparation of the 2014 WMO ozone assessment, such as the so-called "SI2N" activity on changes in the vertical distribution of ozone, an activity supported by WCRP/SPARC (World Climate Research program / Stratosphere-troposphere processes and their role in climate), IOC (International Ozone Commission), IGACO-O3/UV (GAW) and NDACC (Network for Detection of Atmospheric Composition Change), e.g. http://www.sparc-climate.org/activities/ozone-profile-ii/

Odin ozone data are also used together with ozone observation from other satellites in the O3-CCI (ozone climate change initiative) project funded by the European Space Agency ESA. The objective is to create long-term quality-assessed time-series of essential climate variables to be used in climate research, and ozone is one of the essential climate variables under study. http://www.esa-ozone-cci.org/

Odin data with relevance for ozone are also exploited within the SPARC data initiative on Trace Gas Climatology which aims to inter-compare vertically-resolved chemical trace gas climatologies derived from a large number of satellites in order to improve our knowledge and ability to test chemistry-climate models, e.g. Tegtmeier, S. et al. (2013) http://www.sparc-climate.org/activities/trace-gas-climatologies/

Measurements by the Odin satellite are also used on a regular basis in order to quantify ozone loss and explore responsible chemical mechanisms in the spring-time polar lower stratosphere in the Antarctic ("ozone hole") and in the Arctic, e.g. http://www.rss.chalmers.se/~jo/SMRquicklook/Arctic-winter-2011-report/Odin-NH2011-report.pdf

Odin data are also used in ozone and climate related activities such as the SPARC WaVAS stratospheric water vapour assessment and activities like SPARC/HEPPA (High Energy Particle Precipitation in the Atmosphere) focusing on exploring the effect of solar activity on the atmosphere, e.g. http://www.sparc-climate.org/activities/water-vapour-ii/
and http://www.sparc-climate.org/activities/solar-influence/

Finally, it should be noted that presently work is going on in Sweden in preparation of the STEAM (Stratosphere-Troposphere Exchange and Climate Monitor) satellite instrument which will besides its main (climate related) objectives also has the capability to make global observations of ozone.

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/

In an annual follow-up of the environmental quality objectives, an assessment is made of whether the policy instruments decided on and the measures to be introduced before 2020 will be sufficient to achieve the healthy environment which the objectives describe. A protective ozone layer is one of the objectives. Every few years, a more in-depth evaluation is carried out. The results are coordinated and collated by the SEPA (Swedish Environmental Protection Agency). General information and the results can be found at www.miljomal.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 tanning behavior of people mainly directed towards children.

One activity was to publish and distribute “A book about the sun” to all kindergartens in Sweden, another one was to educate the teachers of preschools and primary schools on the basics of and risks of UV, see http://www.stralsakerhetsmyndigheten.se/start/Sol-och-solarier/

Another one is films see e.g. http://www.stralsakerhetsmyndigheten.se/start/Sol-och-solarier/njut-av-solen/450-nyanser-av-rott/ There is also an app for smart phones that calculates possible time in the sun without sunburn.

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

Concerning 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

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