Height-resolved ozone information from GOME data

Ricarda Hoogen, Vladimir Rozanov, Klaus Bramstedt, Kai-Uwe Eichmann, Mark Weber, Rüdiger de Beek, Michael Buchwitz & John Burrows

Institute of Remote Sensing (IFE), University of Bremen (BF1), POBox 330440, D-28334 Bremen, Germany
Tel: +49-421-218 4582 – Fax: … 4555 – E-mail: hoogen@gome5.physik.uni-bremen.de

Stratospheric ozone acts as a shield to protect the biosphere from biologically damaging ultraviolet radiation and determines the temperature structure of the stratosphere, thereby having a significant impact on global circulation and climate. The proposal in the 1970's that the stratospheric ozone layer might be endangered by the emissions from high-flying aircraft or the tropospheric release of CFCs (chlorofluorocarbons used in refrigeration and as propellants) stimulated much scientific and public debate.

The concern about the anthropogenic impact on the ozone layer dramatically increased after the unexpected discovery of the Antarctic ozone hole in 1985. This led to an unprecedented scientific effort in the subsequent years to improve our understanding of the natural and anthropogenic influences on the stratospheric ozone layer. GOME is part of this effort. It is a European initiative, which aims at providing a global perspective about the physical and chemical processes which determine the behaviour of troposphere and stratosphere.

The development of the stratospheric ozone hole above Antarctica is now qualitatively explained as follows: Stratospheric chlorine released from the decomposition of the CFCs mainly resides in the so-called reservoir species such as HCl and $ClONO_2$. Chlorine activation, which implies the conversion of the photostabile reservoirs to photolabile compounds such as Cl_2, HOCl and ClONO occurs on polar stratospheric clouds (PSCs), which form mainly within the polar vortex during polar night. The subsequent catalytic photochemical ozone destruction in the polar spring results in an almost complete loss of stratospheric ozone by the middle of October in the Antarctic polar vortex.

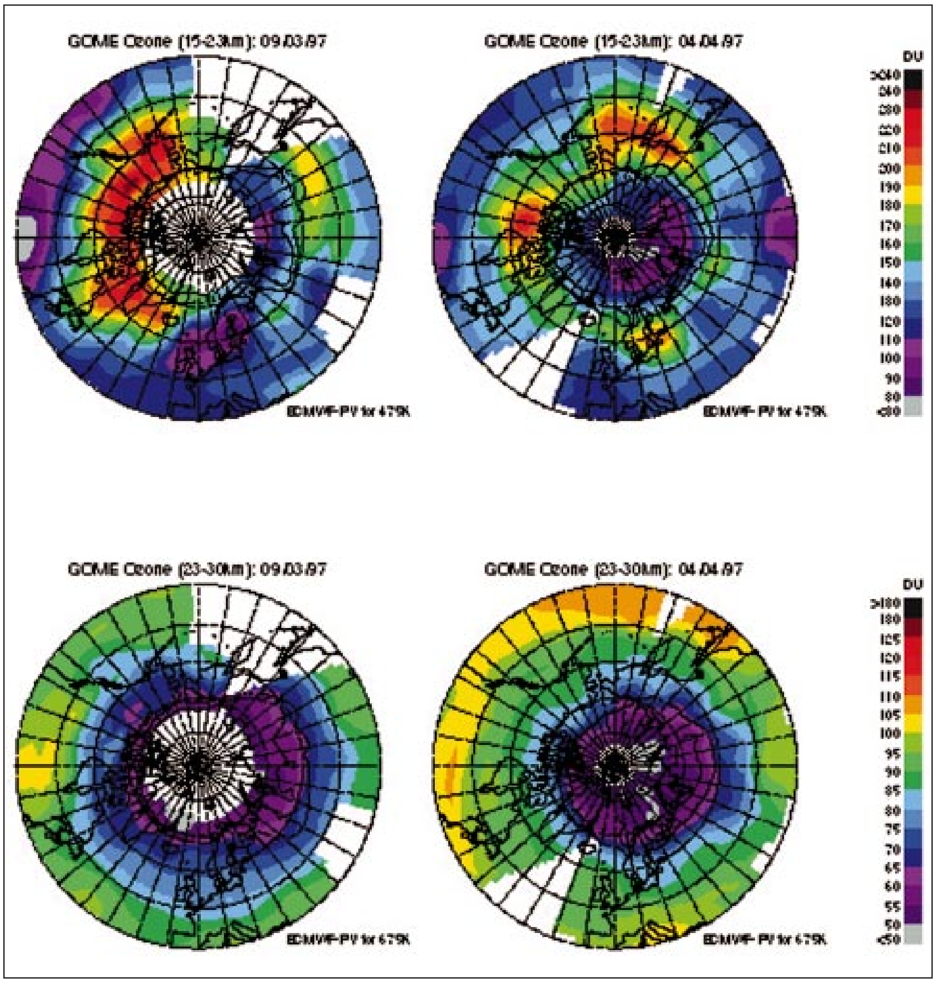
As a result of the more complex dynamics of the Arctic atmosphere, it was initially considered less likely that a springtime O_3 loss similar to that above Antarctica would occur. For similar reasons distinguishing between chemical ozone losses and dynamical ozone variations is more difficult in the Northern Hemisphere.

Another idiosyncracy of the ozone story is that since the end of the 1980's a global reduction in total ozone has been measured by ground-based and satellite-borne instruments, the largest changes being observed at northern mid-latides in winter. Even though several causes for these losses have been suggested, the mid-latitude O_3 loss is not yet explained.

Measurements of total ozone columns alone are insufficient to gain a thorough understanding of the chemical and dynamical processes determining the ozone variations. Height resolved ozone information on a global scale over an extended time period and with reasonable temporal and spatial resolution is needed. Here, the GOME project is able to make an important contribution. GOME measures the solar radiation backscattered by the system earth-atmosphere in the UV-visible spectral range. The ozone absorption in the UV strongly decreases with increasing wavelength. As a result the penetration depth of UV solar radiation into the atmosphere strongly increases with wavelength and, therefore, the GOME measured spectra contain height resolved information about the ozone content.

At the Institute of Remote Sensing the Full Retrieval Method (FURM) was developed to derive vertical ozone distributions from GOME data. FURM is based on an optimised optimal estimation approach, which in this form is being used in satellite remote sensing for the first time. The vertical resolution that can be achieved with a nadir viewing UV-backscatter instrument like GOME is of the order of 6-10 km in the lower and middle stratosphere. For cloud-free or low clouds scenes the tropospheric ozone column is also readily retrieved. With the current scan strategy global coverage at the equator is reached within three days, the horizontal resolution being 960 km x 100 km. Comparisons of GOME ozone profiles with those from selected ozonesonde measurements show good agreement. An extended validation with various ground-based and satellite-borne sensors is being undertaken.

To illustrate the capability of the FURM algorithm, colour-coded maps of ozone amounts in two different altitude bands are displayed in Figure 1 for two selected days. The layers, extending from 15 to 23 km and from 23 to 30 km height respectively, correspond approximately to the lower and middle stratosphere. The isolines of the potential vorticity (PV) derived from ECMWF analyses are plotted to show the extent of the polar vortex. The latter is a strong circumpolar circulation isolating relatively well mixed, cold air in its centre from the rest of the stratosphere. For the 475 K potential temperature surface, which can be regarded as being representative of the lower stratosphere, the 40 PV-units



Ozone amounts in Dobson Units for the 15-23 km layer (upper row) and for the 23-30 km layer (lower row) for 9 March and 4 April 1997, respectively. The vortex edge is indicated by potential vorticity isolines derived from ECMWF analyses on the 475 K surface for the 15-23 km layer (thick line: 48 PV units, thin line: 42 PV units) and on the 675 K surface for the 23-30 km layer (thick line: 230 PV units, thin line: 200 PV units).

isoline defines the boundary of the polar vortex. Similarly, for the 675 K surface, which is representative of the upper stratosphere, values of PV higher than about 200 PV-units are typical for the vortex region.

The highest ozone variability can be observed in the lower stratosphere. On 9 March 1997, high ozone values are measured in a region stretching from Iceland westward to the Aleutes. These high ozone values correlate with high temperatures in this region. The low ozone values above Northwestern Europe are most probably dynamically induced by a rather persistent high-pressure system with a high tropo-pause. However, some chemical loss may also occur and more detailed analysis is required to establish its significance. The most prominent feature in the lower stratosphere on 4 April is the depleted region north of 70° between 0 and 130° E. These low ozone values are thought to be mainly due to chemical loss. This hypothesis is supported by the GOME observations of low NO_2 indicating denitrification and by the fact that in 1997 the Arctic vortex was weak in November and December but strengthened in January and then remained stable and centered close to the North Pole until breaking up at the end of April. The presence of PSCs during this period was confirmed by various measurements. The 23-30 km layer shows decreasing ozone values towards the North Pole with much less zonal variability.

In summary, the height resolved O_3 amounts derived from GOME data by the FURM routine indicate a strong O_3 depletion in the polar vortex above the Northern Hemisphere in spring 1997. Taking into account the low NO_2 values measured simultaneously by GOME and the occurrence of PSC's, it can be concluded that processes similar to those leading to the Antarctic ozone hole took place in the Arctic in the winter 1996/97.

References

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