Pergamon
www.elsevier.com/locate/asr

Adv. Space Res. Vol. 29, No. 11, pp. 1637–1642, 2002

Printed in Great Britain
0273-1177/02 $22.00 + 0.00
PII: S0273-1177(02)00090-X

GOME OZONE PROFILES: A GLOBAL VALIDATION WITH HALOE MEASUREMENTS

K. Bramstedt, K.-U. Eichmann, M. Weber, V. Rozanov, and J. P. Burrows

Institute of Remote Sensing, University of Bremen, P.O. Box 33 04 40, D-28334 Bremen, Germany

ABSTRACT

The Global Ozone Monitoring Experiment (GOME) aboard ESA's ERS-2 satellite measures the reflected and backscattered radiation from the earth in the UV/visible spectral range at moderate spectral resolution. Vertical ozone profiles can be derived from top-of-atmosphere (TOA) nadir observations using the FUll Retrieval Method FURM, which is based upon an advanced Optimal Estimation inversion scheme. These ozone profiles are validated with profiles from the HALogen Occultation Experiment (HALOE). For the year 1998, over 2100 coincident measurements of the instruments were found. These measurements are divided into 20 subsets of five zonal bands and four seasons. For each subset, the mean relative deviation between the corresponding profiles are calculated. In most cases the mean deviations between the HALOE and GOME profiles are below 10 % for the altitude range from 15 to 35 km.

INTRODUCTION

The Global Ozone Monitoring Experiment (GOME) is a grating spectrometer aboard the ERS-2 satellite, which has been launched in April 1995 (Burrows et al., 1999). GOME covers a spectral range from 240 nm to 790 nm, with a spectral resolution between 0.2 nm (UV) and 0.4 nm (visible). It is a nadir viewing instrument, measuring the radiation scattered back or reflected from the earth and its atmosphere. The short-wave region of GOME covers the Hartley-Huggins ozone bands, which contains information about the vertical ozone distribution. The retrieval algorithm FURM (FUll Retrieval Method) has been developed to derive ozone profiles from the UV/vis spectral range. FURM consists of two major parts: first, a forward model, the pseudo-spherical multiple scattering radiative transfer model GOMETRAN (Rozanov et al., 1997), calculating the top-of-atmosphere (TOA) radiance for a given state of the atmosphere, second, an iterative inversion scheme, that adjusts this state to match the calculated with the measured TOA radiance, utilizing the so-called weighting functions also provided by GOMETRAN. Because this inversion problem is under-constrained, an optimal estimation approach (Rodgers, 1976) was chosen, which combines the information from the measurement with a-priori information from a climatology. A detailed description of FURM can be found in (Hoogen et al., 1999).

The HALOE was launched on the Upper Atmosphere Research Satellite (UARS) spacecraft in September 1991. The experiment uses solar occultation to measure vertical profiles of ozone and other trace gases with an instantaneous vertical field of view of 1.6 km at the Earth limb. Ozone is derived from absorption bands in the thermal infrared region between 9.22 μm and 10.42 μm. Version 17 of the HALOE ozone products were extensively validated against ground based and airborne ozone measurements as well as satellite measurements (Brühl et al., 1996). In most cases, the relative deviation was below 10 % in the stratosphere and the lower mesosphere. A comparison of HALOE version 18 ozone profiles with SAGE II measurements showed an even better agreement than with version 17, mainly in the lower stratosphere (Jianjun et al., 1996). For this work, the current version 19 of HALOE data was used to validate the ozone profiles from GOME.

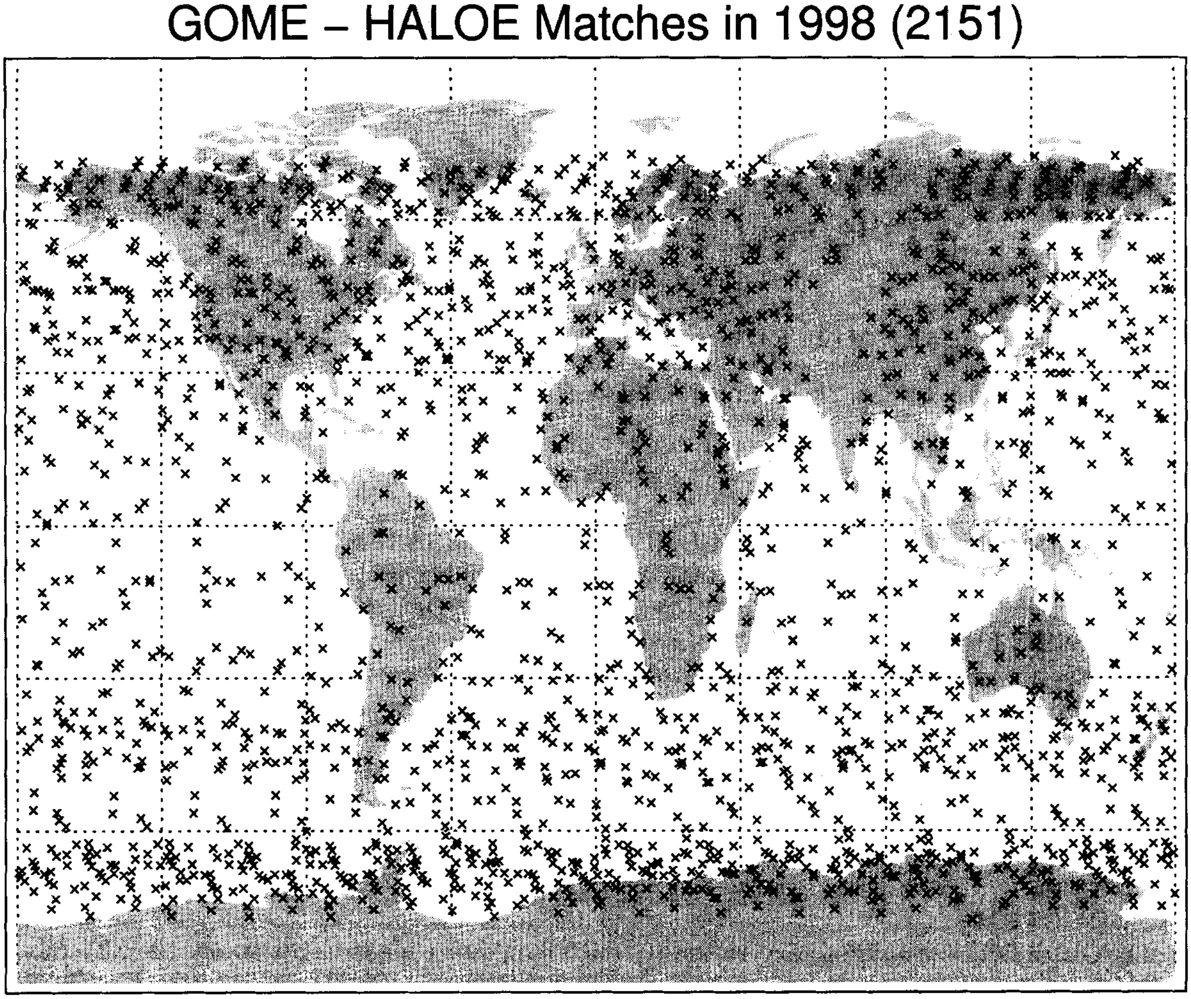

Fig. 1: Locations of coincident measurements of GOME and HALOE in 1998.

COINCIDENT MEASUREMENTS IN 1998

The complete datasets from GOME and HALOE of the year 1998 were searched for coincident measurements. Two measurements are defined as coincident, if they were taken at the same day and the distance between the tangent point of the HALOE measurement and the center of the nearest GOME ground pixel is less than 160 km. Because of the nominal groundpixel size of $40 \times 320\,km^2$, this ensures in most cases, that the tangent point is covered by the GOME ground pixel. A total of 2151 coincidences are found, uniformly distributed over the earth except the polar regions as indicated in Figure 1.

In this work, the spectral range from 290 nm to 345 nm of the GOME spectra is used to derive ozone profiles. For wavelength shorter than 307 nm the integration time of the detector is elongated and the long wavelengths part of the spectra have to be co-added to match the integration time. Therefore, the GOME ground pixel size for profile retrieval is $960 \times 100\,km^2$ (across track $\times$ along track). The a-priori ozone distribution is taken from an ozone climatology derived from combined ozone sonde and satellite measurements during 1980-1991 (Fortuin and Kelder, 1998). Temperature and pressure profiles are taken from the United Kingdom Meteorological Office (UKMO) assimilated dataset (Swinbank et al., 1994). Information about the surface height and albedo are taken from a database (Guzzi, 1993), which is a reclassification of a database compiled from about 100 sources (Matthews, 1985). The cloud cover is calculated from the measurements of the broadband Polarization Measurement Devices (PMD) of GOME (Kurosu, 1998). From the fractional cloud cover an effective ground albedo is determined.

The ozone number density is retrieved on 71 equidistant altitude levels from 0 to 71 km. Additional scalar fit parameters are retrieved: surface albedo, aerosol extinction, a scaling factor for the pressure profile, the Ring amplitude, and an offset for the temperature profile. The current setup is limited to solar zenith angles below 76°. This version also contains corrections to the instrument calibration (Hoogen et al., 1999).

The dataset of coincident measurements was divided into subsets of five zonal bands and four seasons. The zonal bands cover the high latitudes (80° N – 60° N and 60° S – 80° S), the mid-latitudes and subtropics (60° N – 30° N and 30° S – 60° S) and the tropics (30° N – 30° S). The four seasons are April to June, July to September, October to December, and January to March, corresponding to Northern hemispheric spring, summer, autumn, and winter. This gives a total number of 19 subsets, excluding the southern high latitudes where no matches were found from April to June. For each subset, the mean relative deviations between the GOME and HALOE ozone profiles as well as variances of the mean relative deviations are calculated.

RESULTS

Figures 2 and 3 show the results of the validation, arranged from top to bottom by the seasons and from left to right by the zonal bands. The altitude is limited to the range of 15 km to 40 km. HALOE usually cannot determine reliable ozone information below 15 km, and the selected spectral range in the FURM retrieval does not contain height resolved ozone information above 40 km.

In most cases, the relative deviation, defined as (GOME - HALOE) / HALOE, is below 10 % from 17 to 32 km. In the Northern high latitudes in autumn and summer, GOME shows ozone values about 15 % to high around 30 km. In the Tropics, the relative deviation is zero or even lower around 20 km, whereas around 29 km the values are 10 to 20 % to high. This wavelike pattern is caused by an overestimation of 1 to 2 km of the ozone maximum altitude by GOME. The large deviations at at the lowest altitudes are caused by the limitations of the HALOE instrument to retrieve data below the tropopause.

In Southern high latitudes, the mean deviations are very high for the July to September and October to December period. At 20 km, about -20 % can be observed, whereas above 30 km up to 40 % deviations are found. Additionally, the variability of the observed deviations is rather large. In these time periods, many of the coincidences are at the edge of the Southern polar vortex, where the ozone content is rapidly changing on small distances across the vortex boundary because of the ozone hole. Both, GOME ozone profiles with a ground pixel size of $960 \times 100\,\mathrm{km}^2$ and HALOE measurements (along the line-of-sight) covers large areas. Therefore, a reliable validation in this regions requires careful checks, that both instruments observe the same air masses, which is beyond the scope of this paper. No problems occurred in the corresponding time period in the northern high latitudes, because the Northern polar vortex was rather weak with low ozone depletion rates in 1998 (Eichmann et al., 1998).

To summarize, the GOME ozone profiles agree very well with the HALOE ozone profiles up to 35 km. In most cases, the mean deviation is below 10 %. GOME ozone profiles are proven to have the capability for global observation of vertical ozone distributions.

REFERENCES

Brühl, C., S.R. Drayson, J.M. Russell III, P.J. Crutzen, J.M. McInerney, P.N. Purcell, H. Claude, H. Gernandt, T.J. McGee, I.S. McDermid, and M.R Gunson, Haloe Occultation Experiment ozone channel validation, *J. Geophys. Res.*, **101, D6**, 10217–10240, 1996.

Burrows, J.P. , M. Weber, M. Buchwitz, V.V. Rozanov, A. Ladstädter-Weissenmayer, A. Richter, R. de Beek, R. Hoogen, K. Bramstedt, K.-U. Eichmann, M. Eisinger and D. Perner, The Global Ozone Monitoring Experiment (GOME): Mission Concept and First Scientific Results, *J. Atm. Sc.*, **56**, 151–175, 1999.

Eichmann, K.-U., M. Weber, K. Bramstedt, R. Hoogen, V.V. Rozanov and J.P. Burrows, Ozone profile distributions in the Arctic from GOME satellite observations during spring 1997 and 1998, *Proc. SPIE*, **3495**, 1998.

Guzzi, R., Surface type and height database, *priv. com.*, 1993.

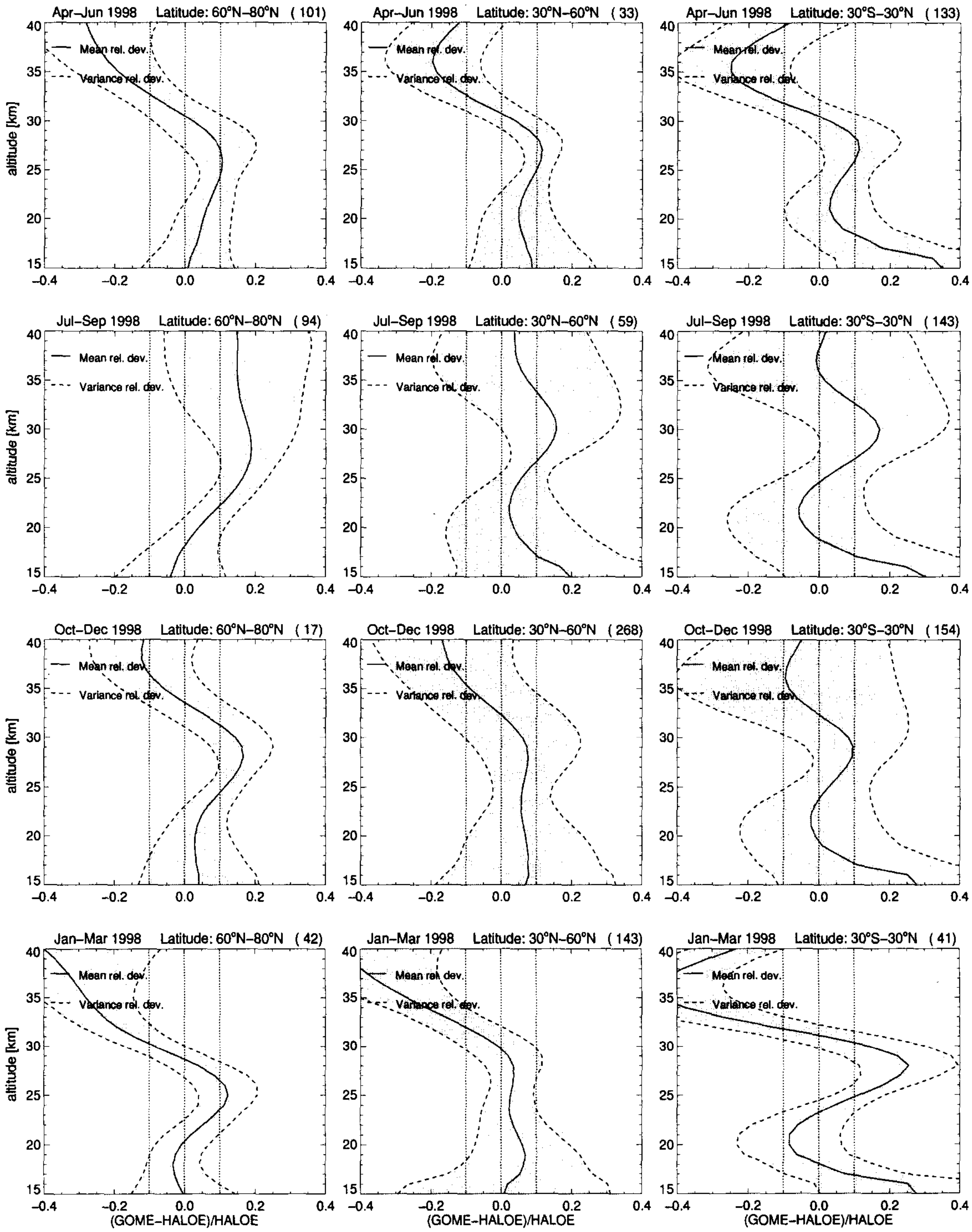

Fig. 2: Statistics of the comparisons of GOME ozone profiles with HALOE profiles. The solid lines give the mean relative deviation, the grey shaded areas indicate the variance of the mean relative deviation. **From top to bottom:** April – June, July – September, October – December, January – March. **From left to right:** 80° N – 60° N , 60° N – 30° N , 30° N – 30° S .

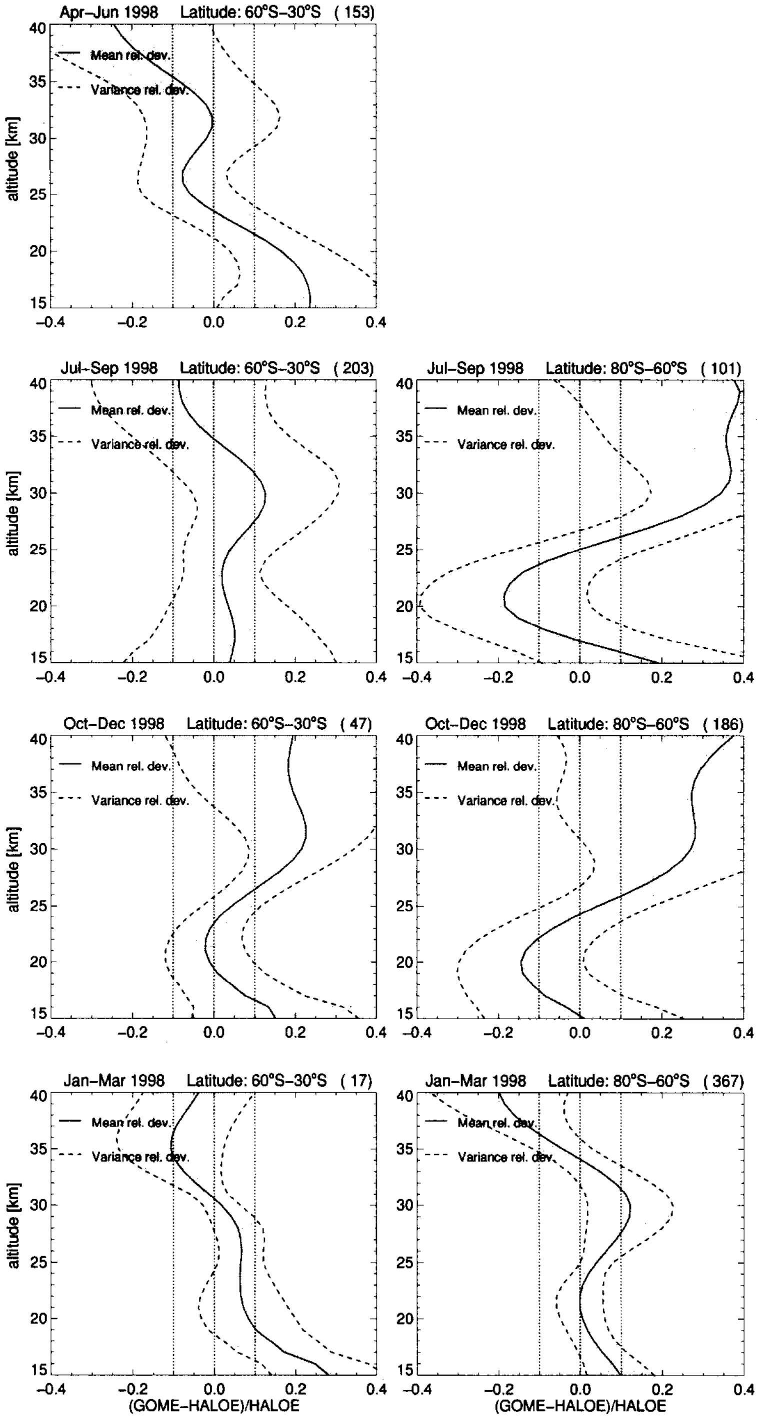

Fig. 3: Statistics of the comparisons of GOME ozone profiles with HALOE profiles. The solid lines give the mean relative deviation, the grey shaded areas indicate the variance of the mean relative deviation. **From top to bottom:** April – June, July – September, October – December, January – March. **From left to right:** 30° S – 60° S , 60° S – 80° S .

Fortuin, P. and H. Kelder, An ozone climatology based on ozonesonde and satellite measurements, *J. Geophys. Res.*, **103, D24**, 31709–31734, 1998.

Hoogen, R., V.V. Rozanov and J.P. Burrows, Ozone Profiles from GOME Satellite Data: Algorithm Description and First Validation, *J. Geophys. Res.*, **104**, 8263-8280, 1999.

Jianjun, L., V.A. Mohnen, G.K. Yue, R.J. Atkinson and W.A. Matthews, Intercomparison of stratospheric ozone profiles obtained by Stratospheric Aerosol and Gas Experiment II, Halogen Occultation Experiment, and ozonesondes in 1994–1995, *J. Geophys. Res.*, **102, D13**, 16137–16144, 1997.

Matthews, E., Atlas of archived vegetation, land-use and seasonal albedo data sets, *NSA tech. memorandum 86199 NOAA*, 1985.

Kurosu, T., PMD cloud detection algorithm for the GOME instrument, *Annex to the ESA CADAPA Study Contract No. 11572/95/NL/CN*, 1998.

Rodgers, C.D., Retrieval of Atmospheric Temperature and Composition from Remote Measurements of Thermal Radiation, *Rev. of Geophys. and Space Phys.*, **14, 4**, 609–624,1976.

Rozanov, V.V., D. Diebel, R.J.D. Spurr and J.P. Burrows, GOMETRAN: A Radiative Transfer Model for the Satellite Project GOME, The Plane-Parallel Version, *J. Geophys. Res.*, **102, D14**, 16683–16695, 1997.

Swinbank, R. and A. O'Neill, A Stratosphere-Troposphere Data Assimilation System, *Monthly Weather Review*, **122**, 686–702, 1994.