BrO Measurements from GOME and from the Ground: An Intercomparison Study

A. Richter[1], M. Van Roozendael[2], T. Wagner[3], J.-C. Lambert[2], D.W. Arlander[4], J.P. Burrows
C. Fayt[2], P. V. Johnston[5], R. Jones[6], K. Karlsen Toernkvist[4], K. Kreher[5], K. Pfeilsticker[3],
U. Platt[3], I. Pundt[7], A. South[6], and F. Wittrock[1]

1 Institute of Environmental Physics, University of Bremen, Germany
2 Belgian Institute for Space Aeronomy, Brussels,Belgium
3 Institute for Environmental Physics, Universität Heidelberg, Germany
4 Norwegian Institute for Air Research, Norway
5 National Institute of Water and Atmospheric Research, Lauder, New-Zealand
6 Department of Chemistry, University of Cambridge, UK
7 Service d'Aéronomie du CNRS, Verrières-le-Buisson, France

Abstract
Measurements from the GOME satellite experiment have been analysed for BrO vertical columns and the results compared to a large number of ground-based measurements. Good agreement could be found at some stations, but only when the ground-based measurements are analysed for the time of GOME overpass near local noon. From the comparison it is concluded, that a considerable amount of BrO must be located in the lower atmosphere.

1. Introduction
The Global Ozone Monitoring Experiment (GOME) is a UV/visible nadir viewing spectrometer on board of the European satellite ERS-2 [1]. GOME is a 4 channel double monochromator covering the wavelength range of 230 – 800 nm with a spectral resolution of 0.2 – 0.4 nm. ERS-2 was launched into a polar sun-synchronous orbit in April 1995. The main objective of GOME is the global measurement of ozone columns, but other trace gases such as NO_2, SO_2, HCHO, BrO and OClO can be retrieved from the spectra as well. In this study, GOME spectra have been analysed for BrO by several groups and the resulting vertical columns compared to measurements from the ground-based network of UV/visble zenith-sky viewing spectrometers.

2. Analysis of GOME data
Slant columns of BrO have been derived independently from GOME spectra by IUP-Bremen, IASB and IUP Heidelberg using the DOAS algorithms originally developed for the ground-based measurements [3,5,6]. The slant columns have been converted to vertical columns using airmass factors derived with different radiative transport models using different standard BrO profiles. In summary, excellent agreement was found for the slant columns and good agreement for vertical columns without need for adjustment of analysis parameters. As an example, the results for Kiruna are shown in Figure 1. From this comparison it is concluded. that the uncertainties in the retrieval of vertical BrO columns from GOME are relatively small.

3. Vertical BrO columns at all stations
In Figure 3, vertical BrO columns derived from the GOME measurements are shown for all stations, together with the best estimate of noon columns from zenith-sky measurements (see next section). The figure reveals several important features: Small latitudinal vari-

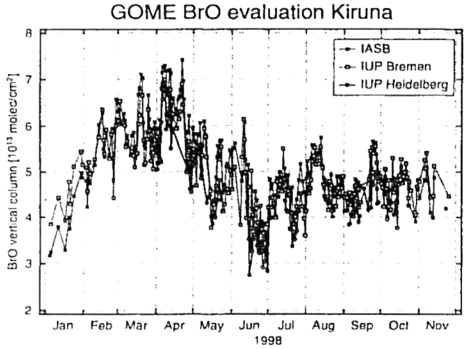

Figure 1. GOME BrO vertical columns above Kiruna as derived by different groups.

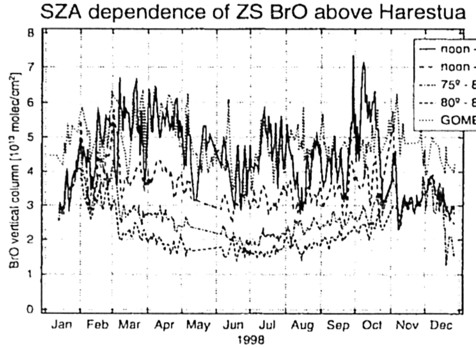

Figure 2. SZA dependence of BrO zenith-sky vertical columns for Harestua.

ations with exception of the winter/spring period, small (if any) seasonal variation, high absolute values (about 2×10^{13} molec/cm^2 higher than expected from model calculations), and large short term variations that are strongly correlated over large distances.

This is in sharp contrast to the results from ground-based zenith-sky observations using the difference between 90° and 80° measurements (see for example [4]). These show decreasing columns from high to low latitudes, a pronounced seasonal variation, good agreement with model results, and relatively small day-to-day variations.

One major difference between ground-based and GOME measurements is the time of the measurements: While GOME observes most locations around local noon, zenith-sky measurements are usually performed during twilight. As it turns out, analysing the ground-based measurements not at twilight, but at the time of GOME overpass greatly improves the agreement between the two data sets.

4. Solar zenith angle dependence of BrO columns

Zenith-sky measurements of BrO are usually performed during twilight when the signal is best. However, at high sun BrO vertical columns increase significantly if the data are analysed assuming a purely stratospheric BrO profile. This is demonstrated in Figure 2 for Harestua, but similar results are obtained at all stations. In this analysis, the vertical BrO column is derived with the Langley plot method, implicitly assuming constant columns for the solar zenith range used.

Two possible explanations can be given for the observed increase of BrO towards noon: Absorptions by tropospheric BrO (the instrument sensitivity towards the troposphere increases with rising sun) or large diurnal variation of stratospheric BrO due to photochemical reactions. The latter can explain some changes during twilight, but the high noon values observed are not consistent with current model results and Br_y measurements. The presence of a tropospheric BrO background therefore seems the more probable explanation and this is to be confirmed by direct measurements in the future.

An alternative approach to derive the BrO vertical column is the use of a fixed background spectrum and the analysis of a the spectra taken at the time of the GOME overpass. The amount of BrO in the background spectrum is estimated using the Langley plot method. With this procedure, excellent agreement could be obtained between ground-based and satellite measurements in Harestua, OHP and Kiruna (Figure 3), but some discrepancies remain at the other stations. Possible reasons are instrumental drifts or latitudinal differences in the proposed tropospheric BrO concentrations.

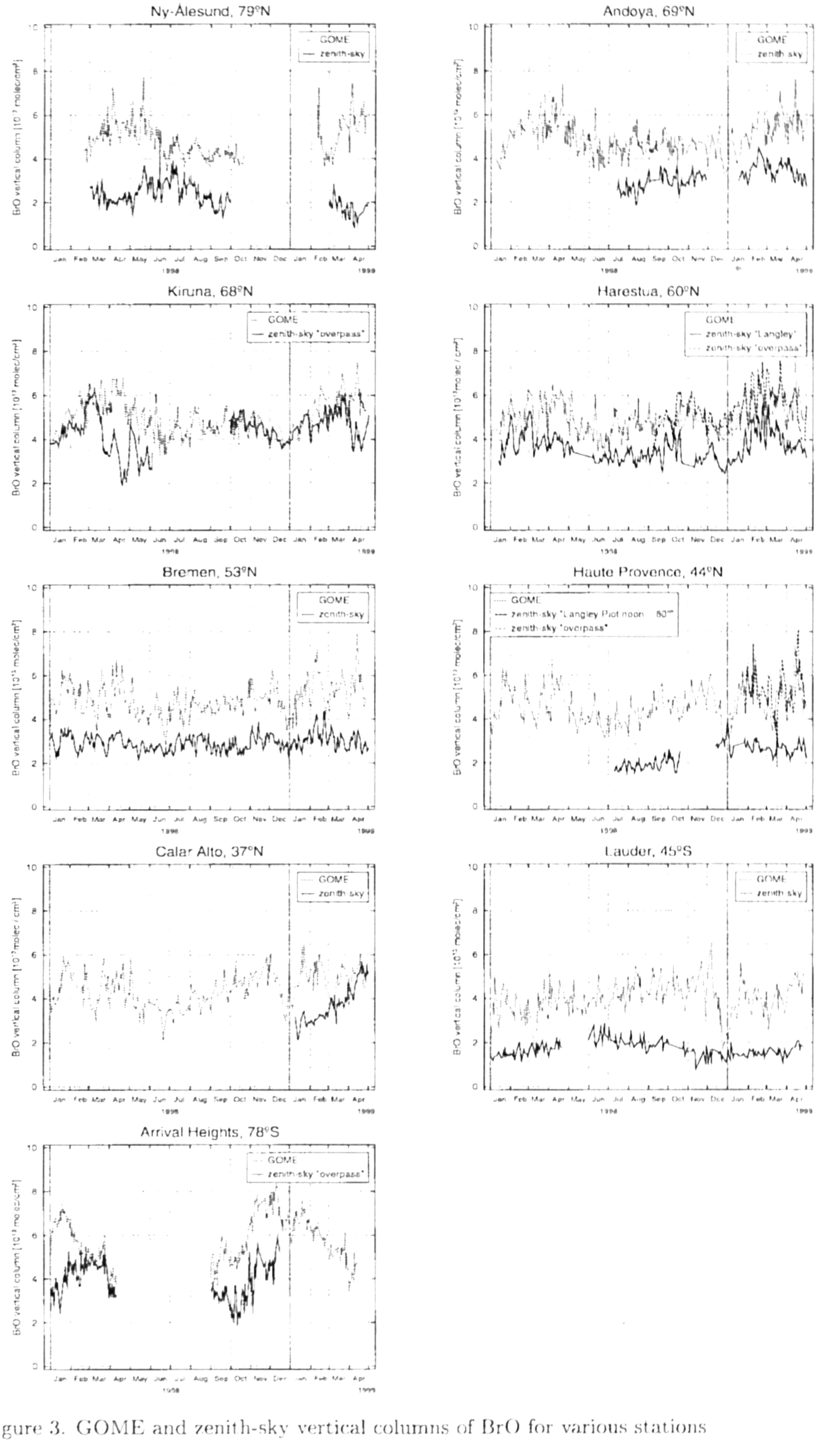

Figure 3. GOME and zenith-sky vertical columns of BrO for various stations

5. Discussion

Comparing GOME and ground-based results for all stations, it is clear that good agreement can only be found for Kiruna in winter and for Harestua and OHP using the BrO values for the GOME overpass. At all other stations, GOME measures more BrO than the zenith-sky instruments, both in mid- and in high latitudes. Some correlation exists for short term variations but they seem to be much larger in the GOME measurements. Some discrepancies remain between the results from the individual stations, but in summary, the data strongly support the assumption of a considerable BrO tropospheric background concentration.

6. Summary

GOME measurements above 9 stations in high and mid-latitudes in both hemispheres have been analysed for vertical BrO columns. Excellent agreement has been found between GOME columns derived by IUP Bremen, IASB and IUP Heidelberg using different analysis tools.

GOME BrO columns show small seasonal and latitudinal variation but strong short term fluctuations correlated over long distances. This is in contrast to twilight zenith-sky measurements that show pronounced seasonal and latitudinal variations but smaller short term fluctuations.

Analysis of the ground-based measurements for the time of the GOME overpass (near local noon) improves the agreement between the two data sets, but only for a limited set of stations (Harestua, Kiruna, OHP) and not too high sun are the results satisfying. For all other stations and times GOME measures more BrO than the zenith-sky experiments. The observed differences between BrO retrieved from the two viewing geometries indicate, that a considerable amount of BrO is present throughout the troposphere at all latitudes and seasons. This supports the conclusions drawn earlier from comparison of ground-based and balloon measurements (see [2] for a more detailed discussion) . Some discrepancies between the ground-based measurements at different locations and GOME data remain, possibly related to instrumental problems at high sun or latitudinal variations of the proposed tropospheric BrO.

Acknowledgements

Parts of this work have been funded by the University of Bremen and the European Union. GOME level-1 and level-2 data have been provided by ESA through DLR Oberpfaffenhofen, Germany.

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