VALIDATION OF THE ERS-2 GOME OZONE PRODUCTS WITH THE NDSC/ALPINE STATIONS

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ABSTRACT

GOME version 2.0 total ozone obtained from July through November 1996 and correlative ground-based observations from the NDSC Alpine and complementary stations are compared. On average, the GOME and the ground-based total ozone are in close agreement. Within the limited range of solar zenith angle (SZA) and of total column observed at northern mid-latitude, the comparison does not reveal any clear dependence on the GOME SZA nor a difference in sensitivity except at ozone columns below 230 DU. From 24 January through 31 March 1997, 'near-real time' (NRT) preliminary GOME height-resolved ozone is available for the 1997 Arctic winter campaigns. It is also reported on a preliminary comparison of these NRT profiles with correlative ozone vertical distributions measured by ozonesondes from a variety of primary and complementary NDSC stations in the northern hemisphere.

1. INTRODUCTION

The Global Ozone Monitoring Experiment (GOME) on board the ESA ERS-2 environmental platform was launched on 21 April 1995 onto a heliosynchronous polar orbit. Its main scientific objective is the study of trace constituents in the lower and the middle atmosphere. GOME is a combination of four grating spectrometers observing between 240 and 790 nm the solar radiation scattered from the atmosphere or from the Earth's surface. The instrument is operated in the nadir-viewing geometry and the current 960 km swath width is divided into three 320x40 km pixels. Atmospheric trace constituents are detected by means of the Differential Optical Absorption Spectroscopy technique (DOAS). In particular, since July 1996, total vertical columns of ozone are routinely retrieved in the ultraviolet Huggins bands and are available for scientific studies. The potentiality of retrieving height-resolved ozone distributions at the global scale from GOME flight data has already been investigated as well (Munro et al., 1997; Kerridge et al., this issue), and the operational processor for height-resolved ozone retrieval is currently under development. However, from January 24 through March 31, 1997, 'near-real time' (NRT) preliminary GOME ozone profiles are available for the 1997 Arctic winter campaigns, from a joint effort of IUP/IFE Bremen, DFD/DLR and ESA (de Beek et al., this issue).

Part of the GOME Geophysical Validation Campaign started on 20 July 1995, correlative ground-based observations have been collected from a variety of instruments at the Alpine and complementary stations of the Network for the Detection of Stratospheric Changes (NDSC). A first comparison with the GOME v1.20 and v1.21 total ozone was conducted in the Alps, based on 45 days of data from July to December 1995, and was extended to all latitudes using the SAOZ network (Lambert et al., 1996[a,b]). Both exercises concluded to an underestimation of total ozone by the GOME, a significant SZA dependence and a difference in sensitivity between the GOME and the SAOZ. Following the recommendations and conclusions drawn from these first validation exercises, the GOME retrieval of ozone in the Huggins bands has been revisited and improvements have led to the current version 2.0 of the GOME Data Processor (GDP). A first comparison between GOME v2.0 and ground-based total ozone obtained in July-August 1996 was conducted at northern latitudes with Dobson, Brewer and GUV instruments by Van Roozendael et al. (1997[a]) and from pole to pole by Lambert et al. (1997[a]). These works demonstrated a general better agreement between the satellite and the ground-based measurements. Here, we report on the validation of the GOME v2.0 total ozone over the complete period from 28 June to 30 November 1996 by means of the Brewer, Dobson and SAOZ observations at the NDSC Alpine stations listed in Table 1. Investigations on the performances of GOME from pole to pole are reported by

Lambert et al. in the same issue. To ensure the relevance of the preliminary NRT GOME ozone profiles, a quick comparison is also reported here, carried out with correlative ozone profiles measured by ozonesonde from a variety of primary and complementary NDSC stations in the northern hemisphere, listed in Table 2.

2. TOTAL OZONE

In this section, GOME v2.0 total ozone obtained from July through November 1996 is analysed with respect to a variety of ground-based observations from several NDSC Alpine and complementary stations. The methodology used to compare measurements of GOME with those from the various ground-based observation techniques has already been described by Lambert et al. (1996[a], 1997[b]). This methodology takes into account the spatial and temporal variability of the ozone field as well as the uncertainty on the various ground-based measurement. In particular, to account for large horizontal gradients in the vertical columns, GOME pixels are selected where intersecting the effective geolocation of the ground-based measurement. Brewer and Dobson data are selected within a time window of three hours around the ERS overpass, except for Hohenpeißenberg where only daily means were available for this work.

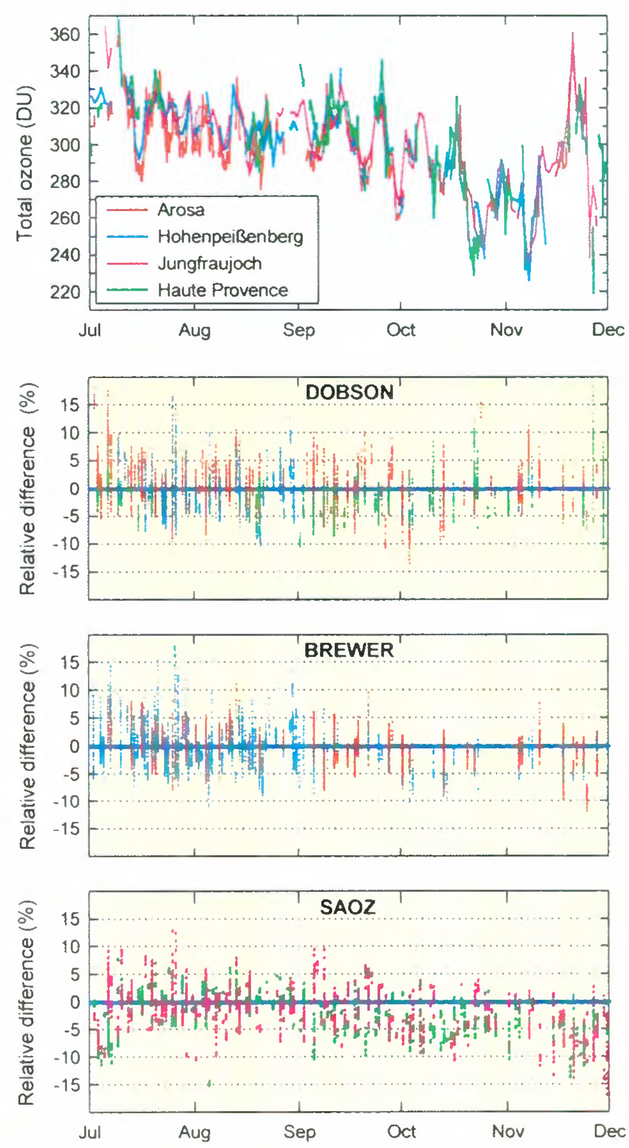
Figure 2-a depicts time series of total ozone measured at four stations in the Alps with two Brewer, three Dobson and two SAOZ instruments, and the corresponding relative differences with GOME observations. At first glance, results are remarkably consistent among the various locations and observation techniques. On average, the difference between the satellite and the ground-based data does not exceed ± 3% for the whole period, that is within the known uncertainty of the ground-based measurements. Intercomparisons between co-located ground-based instruments themselves yield similar results (see e.g. Vaughan et al., 1997). The comparison of the GOME with the Brewer and Dobson spectrophotometers does not reveal any clear dependence on the season nor on the solar zenith angle in the observed 25-65 range. A seasonal dependence appears after mid September in the comparison with the two SAOZ spectrometers. This dependence is likely to reflect the seasonal variation of the Air Mass Factor (AMF) used in the SAOZ retrieval to convert ozone column densities along the line of sight into vertical columns. The real time SAOZ data are based on the use of a standard AMF calculated at 60°N in winter, and hence do not take into account the seasonal change in the shape of the ozone and density profiles that generates a systematic cycle in the AMF of about 3-4% at 44°N (Hoiskar et al., 1995; Van Roozendael et al., 1997[b]; Sarkissian et al., 1997). At the Jungfraujoch, after taking properly into account the 4% seasonal cycle of the SAOZ AMF and the altitude of the station (3580 m a.s.l.), GOME and SAOZ total ozone are on average consistent within 2%.

Table 1. Total ozone observations

Location	Lat.	Long.	Instruments
Hohenpeißenberg	48N	11E	Dobson, Brewer
Jungfraujoch	47N	8E	SAOZ
Arosa	46N	9E	Dobson, Brewer
Bordeaux	46N	1W	Dobson
O. Haute Provence	44N	6E	Dobson, SAOZ

Table 2. Ozone profile observations

Location	Lat.	Long.	Instruments
Orlandet	63N	9E	ECC
Gardermoen	60N	11E	ECC
Aberystwyth	52N	4W	ECC
Payerne	46N	7E	Brewer-Mast



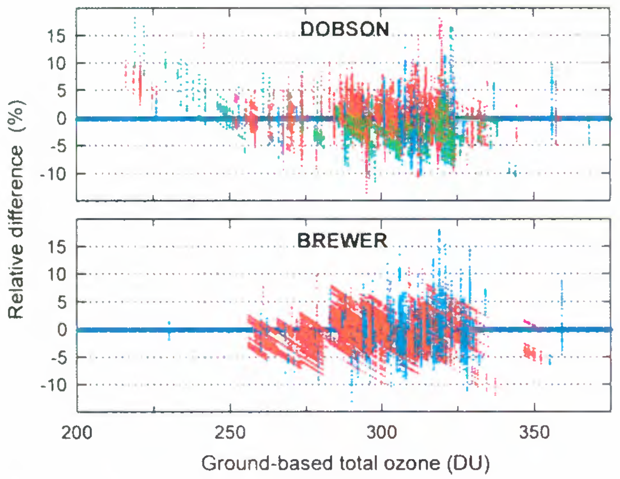


Figure 2-b. Percent relative differences between GOME and ground-based total ozone in the Alps as a function of the ozone vertical column, from July through November 1996.

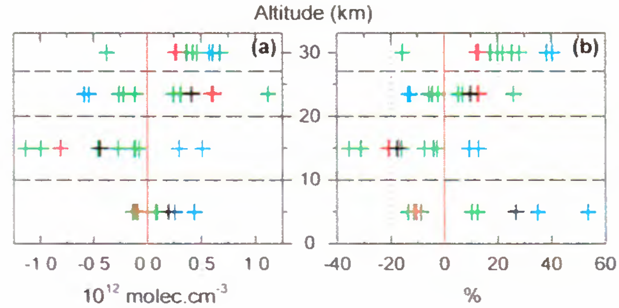
The monthly mean scatter (1 sigma) ranges from 2.5 up to 5%, with an average value of ±4%. As shown in Figure 2-a, a random degradation of the agreement between satellite and ground-based data can originate i) in the variation of the ozone field between the ground-based and GOME observations and ii) in the difference in air mass probed in noon nadir (GOME), noon direct Sun (Brewer and Dobson) and twilight zenith (SAOZ) viewings combined to the presence of horizontal gradients. Other possible sources for this dispersion are: iii) the use of a constant AMF in the SAOZ retrieval instead of the real AMF corresponding to the actual ozone profile, which can account for 1% scatter; iv) a similar contribution from the constant climatic GOME AMF; v) the temperature dependence of the ozone absorption cross-sections in the Huggins bands; vi) the dispersion generated in the SAOZ measurements by tropospheric multiple scattering in presence of dense clouds or haze, combined with local ozone changes (Van Roozendael et al., 1994); and vii) the contribution of clouds to the GOME measurement which mask the tropospheric contribution.

The relative difference between GOME and Brewer/Dobson observations is depicted in Figure 2-b as a function of the ozone vertical amount. While there is no clear difference in sensitivity for columns larger than 230 DU, GOME total ozone is systematically higher than Dobson measurements for lower columns. The reasons for this difference in sensitivity have not yet been identified.

3. PRELIMINARY OZONE PROFILES

To ensure the relevance of the preliminary NRT GOME ozone profiles available during the winter 1997 Arctic campaign, a quick comparison is carried out with correlative ozone density profiles measured by ECC and Brewer-Mast ozonesondes from a variety of primary and complementary NDSC stations in the northern hemisphere. Similar investigations using data from NDSC lidars and microwave radiometers will be performed in a near future. When a coincidence of at least 3° latitude and 8° longitude occurs between the GOME ground pixel centre and the ground-based launch site, correlative profiles are integrated through the four lowest NRT GOME layers (0-10, 10-20, 20-27, and 27-33 km) and then compared to satellite data. Comparison results are reported here for February and March 1997. Due to the poor spatial coverage of the current available NRT GOME information, only a few coincidences were found out of more than 200 ozone soundings: 12 in February and 5 in March. Therefore, conclusions drawn here are only preliminary and subject to change.

As illustrated in Figure 3, the average agreement between NRT GOME and ozone soundings in the stratospheric layer from 20 to 27 km is reasonable, between 10 and 15% ([GOME-sonde]/sonde), although scattered. Larger deviations up to 30-40 % and more can occur in the tropospheric and lowest stratospheric layers, where comparison results are also more scattered. Above 30 km, uncertainties on the ozone sounding deteriorates the reliability of the comparison. Large variability of ozone between the GOME and the sonde measurement time of as well as sharp horizontal and vertical gradients in the ozone field within the 320 x 40 km ground pixel can contribute significantly to difference between the GOME and the ozonesonde, especially in winter and spring, and must be taken into account for accurate analysis, what is not the purpose of this quick exercise. The influence of natural variability appears clearly at Aberystwyth on 5 February 1997 where four adjacent coincidences were found. Depending on the ground pixel, the agreement varies on this day from -15% to -3% in the 10-20 km layer and from -6% to +8% at 20-27 km. Nevertheless, natural variability inside the pixel can not explain the systematic offsets of -15% and +23% observed respectively in the troposphere and at 27-33 km. Similarly, the general agreement between the NRT GOME and the various ozone soundings is found to be constrained by the shape of the true ozone vertical distribution inside the GOME layer. For layers between 10 and 27 km, largest deviations are usually observed in presence of sharp laminae. To a less extent, the



agreement in the 0-10 km layer is better when tropopause and its related increase of ozone density are located outside or not too deeply inside the layer. The most striking feature in the 0-10 km layer is that the layer content from GOME is closer to the *a priori* used in the NRT retrieval than to the ozonesonde observation. An illustration of this feature is the strong degradation of the agreement between February and March. In February, the first layer's content in the *a priori* is about 9.3 10^{16} molecules km^{-1} cm^{-2}. Since this value is on average close to the integrated ozonesonde observations, the difference between NRT GOME and the sondes never exceeds 25%. The largest tropospheric deviations of +30% to +55% depicted in Figure 3 are observed at Orlandet in March, when the first layer's content measured by the ozonesondes was much lower than the tropospheric content in the *a priori*, that is 1.3 10^{17} molecules km^{-1} cm^{-2} in March. In addition, at several occasions in winter-spring 1994 to 1997, two or three ozonesondes were launched at Aberystwyth the same day within a few hours. For each set of these ozone soundings, the difference between the two or three ozone density profiles integrated in the lowest NRT GOME layer ranges from 0.05 to 0.3 10^{12} molecules cm^{-3} (that is 5% on average, with an extreme case of 25%), and hence does not support natural variability as the main contribution to the observed differences of +30% to +55%, even if the homogeneity of the air mass within the GOME pixel is corrupted by a meteorological front inside this pixel.

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