FIRST VALIDATION OF SCIAMACHY BRO COLUMNS

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ABSTRACT

Retrievals of BrO columns using version 5.01 of the SCIAMACHY NRT processor as well as independent non-operational algorithms are compared with GOME and with ground-based measurements from two Arctic stations. NRT BrO columns are found to agree with GOME and non-operational data sets to within 20% for moderate and large slant columns, while for slant columns smaller than 1.5×10^{14} molec/cm^2, the NRT product reports larger values by 20 to 100%. First comparisons with ground-based measurements in Harestua (60°N) and Ny-Alesund (79°), tentatively evaluated at the time of the SCIAMACHY overpasses, provide encouraging results although more work is still needed for a detailed quantitative validation of BrO.

Key words: SCIAMACHY, BrO column, DOAS

1. INTRODUCTION

Bromine monoxide (BrO) is a key atmospheric trace gas due to its large efficiency as a catalyst of the ozone destruction in the both the stratosphere and the troposphere [Wagner et al., 1998; et al., 1998]. Onboard the ENVISAT platform, the SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY) measures the sunlight reflected, backscattered or transmitted by the Earth's atmosphere in the ultraviolet, visible and near-infrared spectral regions [Bovensmann, 1999]. Among other geophysical data products, the vertical column of bromine monoxide (BrO) can be derived from SCIAMACHY nadir measurements, by the technique of Differential Optical Absorption Spectroscopy (DOAS) [Platt, 1994]. In preparation of this ACVE-2 Symposium, BrO columns have been retrieved from a set of 1927 measurement states of SCIAMACHY all acquired between July and December 2002 (the so-called Validation Master Set), using the current SCIAMACHY Near-Real-Time (NRT) operational processor (Ver 5.01). In addition the available level 1b nadir data set was also processed for BrO at the Institute of Environmental Physics at the University of Bremen (IUP-Bremen), and at the Belgian Institute for Space Aeronomy (BIRA-IASB) with independent algorithms developed for scientific purposes. The later data sets will be referred to in the following as "non-operational" or "scientific" BrO data products, by opposition to the ESA "operational" product.

This paper summarises the current status of the verification and validation activities having taken place regarding SCIAMACHY BrO column measurements. In section 2, important aspects of the DOAS retrieval optimisation are outlined. This is followed in section 3 by results of comparisons between SCIAMACHY and GOME BrO evaluations, while the consistency between operational and non-operational data products is addressed in section 4. Section 5 presents first validation results based on comparisons with ground-based measurements from two stations. Conclusions are given in section 6.

2. SCIAMACHY BRO RETRIEVAL

BrO slant columns are generally derived in the wavelength interval from 344 to 359 nm, making use of the characteristic absorption structures of BrO in this region. Precise analysis settings providing best accuracy have been established and documented in the literature based on many years of experience with ground-based instruments as well as with the Global Ozone Monitoring Experiment (GOME) on the ESA ERS-2 platform (see e.g. Aliwell et al., 2002; Richter et al., 2002; Wagner et al., 2001).

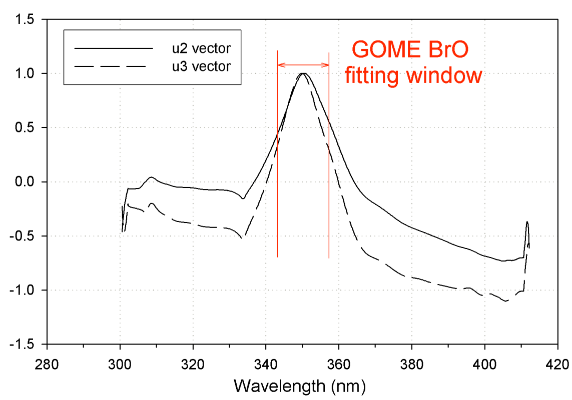

Figure 1. Polarisation sensitivity vectors measured in the SCIAMACHY channel 2. Strong features are present in the middle of the spectral interval used for GOME BrO fitting.

Attempts to apply these settings to SCIAMACHY however rapidly proved to be unsuccessful, mainly due to the existence of strong polarisation features in the channel 2 of SCIAMACHY (Figure 1) not fully eliminated by the current operational Lv1 processor and generating spurious interferences with the BrO spectral structures. To overcome this problem, a new UV-shifted fitting interval (335-347 nm) has been proposed for SCIAMACHY and tested for stability and consistency with GOME. This optimisation work was performed in parallel at BIRA-IASB, IUP-Bremen and University of Heidelberg as part of the SCIAMACHY Verification Team (for further information, see De Smedt et al., 2003). Based on these results, recommendations for optimal BrO DOAS settings have been provided to ESA in April 2004 taking into account current limitations in the flexibility of the operational environment. These were implemented in the latest version of the NRT processor (NRT v.5.01) and used to process the Validation Master Set.

3. COMPARISON WITH GOME

Observations of BrO total columns have been acquired from space since 1995 by GOME on board ERS-2. In the period from July 2002 until June 2003, GOME and SCIAMACHY were operated simultaneously so that the consistency between both instruments could be investigated. Figure 2 shows a comparison between BrO slant columns retrieved from GOME and SCIAMACHY for two spatially overlapping orbit files (BIRA-IASB evaluations). Despite the time difference of 30 minutes between the two instruments, results display a good agreement. The larger apparent noise of SCIAMACHY retrievals is largely due to the smaller size of the SCIAMACHY pixels, leading to reduced S/N ratio on individual measurements.

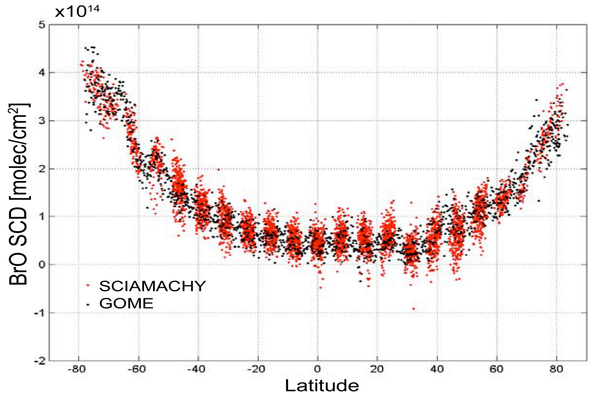

Figure 2. Slant column density of BrO retrieved from GOME and SCIAMACHY for two overlapping orbits recorded on 23 September 2002 (BIRA-IASB analysis, checked for consistency with IUP-Bremen retrieval).

The consistency between GOME and SCIAMACHY non-operational BrO data products has been investigated more systematically at BIRA-IASB based on available data in the period from July 2002 until June 2003. In Figure 3, monthly averages of BrO vertical columns derived from both instruments over the Arctic from January until May 2003 are displayed. In both cases, the conversion from slant to vertical columns was obtained using simple stratospheric air mass factors (AMFs) [Van Roozendael et al., 1999]. Although color plots show obvious differences related to the different sampling and spatial resolutions of GOME and SCIAMACHY, both instruments also show excellent consistency as to the way they capture the general features of polar spring BrO emissions.

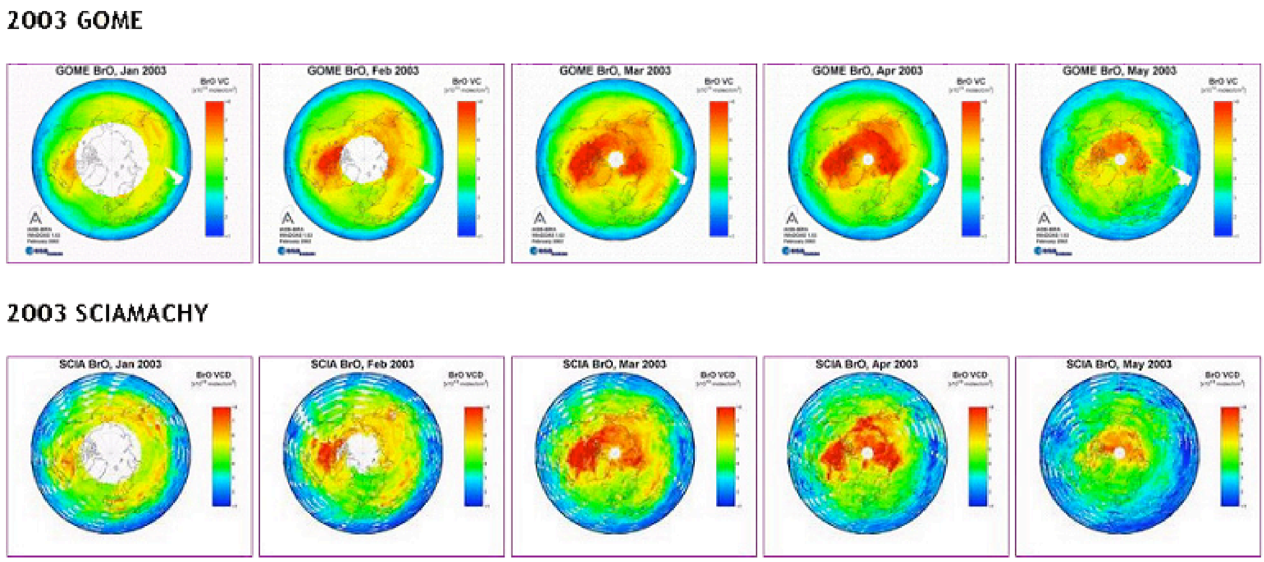

Figure 3. Monthly averaged BrO vertical columns over the Northern Hemisphere, derived from GOME and SCIAMACHY between January and May 2003. GOME and SCIAMACHY capture polar spring emissions in a consistent way.

4. COMPARISON BETWEEN OPERATIONAL AND NON-OPERATIONAL PRODUCTS

BrO slant columns produced by the NRT data processor (version 5.01) have been compared with non-operational retrievals from BIRA-IASB for the 1927 states of the Validation Master Set. It is important to note that although both ESA NRT and non-operational retrievals used an optimised UV-shifted interval (see section 2), analysis settings were not fully identical. In particular the NRT processor used as Fraunhoffer reference the solar spectra measured from the SCIAMACHY ESM Diffuser (imposed by operational constraints despite the known spectral artefacts they may introduce), while the BIRA-IASB algorithm used instead a radiance spectrum taken over the equatorial region.

The relative differences in BrO slant columns (NRT – BIRA/IASB) are represented in Figure 4 as a function of the BrO SCD derived by BIRA. Results display a marked column dependency of the differences, characterised by a good agreement within 20% for large and moderate SCDs (>2x10^{14} molec/cm^2) while the NRT product systematically reports higher values by 20 to 100% for BrO SCDs smaller than 1.5x10^{14} molec/cm^2.

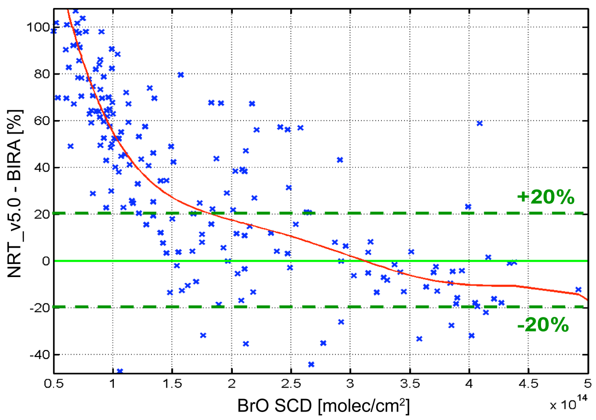

Figure 4. Column dependency of the relative differences between NRT 5.01 and non-operational (BIRA-IASB) BrO slant columns.

5. COMPARISON WITH GROUND-BASED MEASUREMENTS

BrO slant columns observations are regularly performed at various ground-based stations worldwide, most of them being part of the international Network for the Detection of Stratospheric Change (NDSC). These observations however are generally conducted at twilight in conditions where the retrieved quantities (differential slant columns) provide high sensitivity to the *stratospheric* BrO column around 90 degrees of solar zenith angle (SZA). In contrast SCIAMACHY (and GOME) observations are representative of *total* BrO columns (stratosphere + troposphere) around noon. Since BrO is characterised by a strong diurnal cycle [Sinnhuber et al., 2002] and that its tropospheric content is significant not only in polar regions but likely also at mid-latitudes [Van Roozendael et al., 2002], the standard ground-based twilight observations cannot be easily converted to vertical columns adequate for satellite validation. Instead, ground-based measurement must be evaluated in a non-standard way in order to provide the needed noontime total columns. This represents a challenging task due to the typically low sensitivity of ground-based measurements at high sun. Hence methods are still under development and so far first results have only been obtained at two high-latitude pilot stations: Ny-Alesund (IUP-Bremen) and Harestua (BIRA-IASB).

At Ny-Alesund, ground-based BrO vertical columns (VCDs) were evaluated around 80° SZA using AMFs accounting for 1 ppt of tropospheric BrO, and compared to SCIAMACHY retrievals during 10 days in May 2003 (Figure 5). Values agree qualitatively and both data sets display an interesting event of enhanced BrO.

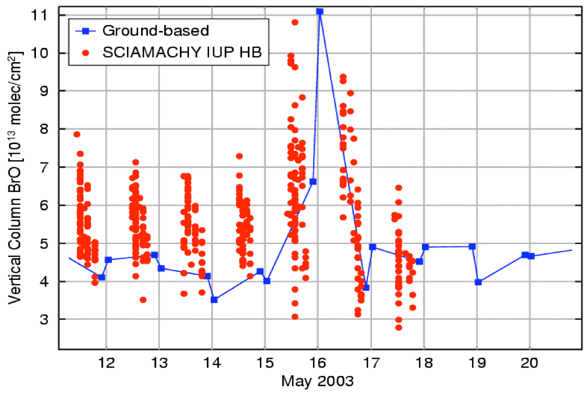

Figure 5. DOAS and SCIAMACHY BrO vertical columns derived by IUP-Bremen above Ny-Alesund (79°N)

At Harestua, ground-based BrO vertical columns were evaluated at the time of the satellite overpass using as Fraunhoffer reference a noon spectrum recorded in summer 2003 when BrO columns were at their lowest level. The residual amount of BrO in this spectrum was evaluated using a modified Langley-plot taking into account the diurnal variation of the stratospheric BrO. Resulting absolute slant columns at SCIAMACHY and GOME overpass time were converted to vertical column using AMFs accounting for 1 ppt of tropospheric BrO. The same assumption was also used for the calculation of satellite AMFs. Comparisons between these ground-based evaluations and coincident GOME and SCIAMACHY BrO VCDs are displayed in Figure 6, for the period from August 2002 until July 2003. Satellite data points are daily averages of all pixels falling within a radius of 200 km around the station. As can be seen, both seasonal and short-term fluctuations in the BrO VCDs are captured in the same way by all instruments including SCIAMACHY (non-operational data). BrO VCDs evaluated from the ESA NRT 5.01 BrO SCDs using the same AMFs as for non-operational data also agree well with ground-based measurements from September until December 2002, while summer time low columns are generally strongly overestimated by the NRT processor.

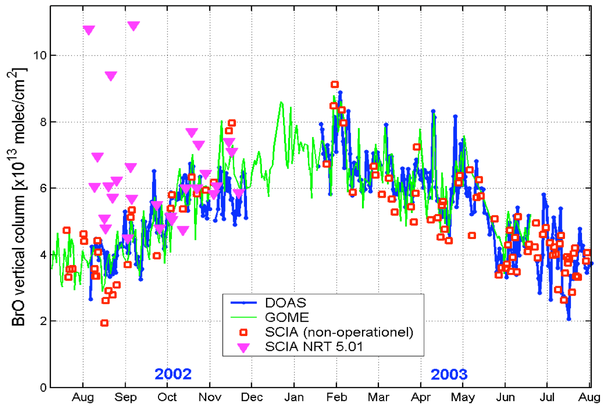

Figure 6. DOAS, GOME and SCIAMACHY BrO vertical columns derived by BIRA-IASB above Harestua (60°N).

6. CONCLUSIONS

SCIAMACHY BrO columns retrieved by non-operational algorithms and by the version 5.01 of the ESA NRT processor using DOAS analysis settings optimised for SCIAMACHY have been compared to GOME and to ground-based measurements from two Arctic stations. Non-operational retrievals applied to one year of SCIAMACHY observations demonstrate that a good consistency can be achieved with GOME, an important results for future long-term geophysical studies. BrO slant columns from the ESA NRT 5.01 processor agree with GOME and with non-operational analysis to better than 20% for moderate and large BrO columns (SCDs>1.5x10^{13} molec/cm^2). However for smaller slant columns, the NRT product reports systematically higher values by 20 to 100%. It is nonetheless expected that operational products will reach similar quality as non-operational ones after further optimisation of the settings. First comparisons with ground-based data are encouraging, although more work is needed to further develop comparison techniques according to the difficult behaviour of BrO.

7. ACKNOWLEDGMENTS

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