Improved OMI BrO and OClO

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ABSTRACT

We present improved operational algorithms and data products for OMI bromine monoxide (BrO) and chlorine dioxide (OClO). The algorithms are, as before, based on the direct fitting of radiances. BrO is fitted from 319.0-347.5 nm, within the UV-2 channel of OMI, while OClO is fitted from 358.5.5-392.0 nm, in the visible channel. The model that is fitted to each measurement consists of the solar reference, attenuated by contributions from the target gas and interfering gases, rotational Raman scattering, additive and multiplicative closure polynomials and a common mode spectrum. The common mode spectra (one per cross-track position, computed on-line) are the average of several hundred fitting residuals and include any instrument effects that are unrelated to molecular scattering and absorption cross sections.

The BrO retrieval uses albedo and wavelength-dependent air mass factors (AMFs), which have been pre-computed using climatological BrO profiles. The wavelength-dependent AMF is applied pre-fit to the BrO cross-sections, and the spectral fit retrieves vertical column densities directly. For OClO only slant columns are provided. Flagging for the OMI row anomaly is now included in the BrO and OClO products.

OMI Instrument

OMI is a **UV/Visible (270-500 nm) nadir-viewing** sensor on the EOS/Aura spacecraft. Aura orbits the Earth at ~700 km altitude in a sun-synchronous orbit, with a **1338h equator crossing time** in the ascending node . On the Earth surface, the OMI swath covers an area of **~2600 km across-track**, divided into 60 ground pixels of **spatial resolution between 13×24 km² at nadir and 28×160km²** at the swath edges. OMI **covers the globe in one day**.

Retrieval Approach

Absorption of light by trace gases in the Earth's atmosphere **introduces characteristic absorption structures** in the solar irradiance, I_0, on its path through the atmosphere to the satellite sensor, where it is detected as earthshine radiance, I. The information content is extracted from the spectra by **non-linear least-squares fitting.** Radiance R is fitted directly ("BOAS fitting") as:

$$R = A(\lambda) F e^{-\sum \tau_n} + Ring + closure(\lambda)$$

Additional manipulation for Beer's Law fitting provides:

$$\ln\frac{R}{F} = -A(\lambda)\sum \tau_n + \frac{Ring}{F} + higher-order - Ring + closure(\lambda)$$

Since it is a nonlinear fitting problem "DOAS fitting" adds high-pass filtering ("H") to give:

$$H\left(\ln\frac{R}{F}\right) = -A(\lambda)\sum H(\tau_n) + H\left(\frac{Ring}{F}\right) + closure(\lambda)$$

The **results from the fitting are slant column densities** (SCDs), *i.e.*, integrated number of molecules per cm² along the line of sight of the instrument through the atmosphere. SCDs are **converted to vertical column densities (VCDs) with a so-called air mass factor** (AMF), defined as AMF = SCD/VCD. AMF are derived from GEOS-Chem shape factors and the LIDORT radiative transfer model. The AMF is a function of viewing geometry, surface properties, atmospheric absorption (other gases, absorbing aerosols) and scattering (Rayleigh, clouds, aerosols), and the vertical profile of the retrieved gas [Palmer *et al*., 2001]. **AMFs are pre-computed and compiled as look-up tables**, and are usually applied post-fitting to the SCDs (**H_2CO and $C_2H_2O_2$ case**). **Alternatively**, if the AMF is a strong function of wavelength over the fitting window, it **is applied pre-fit to the molecular absorption cross-sections of the target gas**, and VCDs are retrieved directly **(BrO case)**. Corrections for wavelength calibration, ring effect, spectral undersampling (not Nyquist sampled) and instrument transfer (slit) function are also applied.

Row Anomaly

More information is available at
http://knmi.nl/omi/research/product/rowanomaly-background.php

The row anomaly affects all wavelengths at a number of viewing directions/cross track positions/rows.

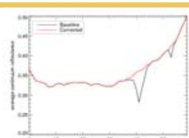
The currently the following rows are affected by the anomaly:

- **Anomaly 1 Since 06/25/2007 Rows 54—55**
- **Anomaly 2 Since 05/11/2008 Rows 38—45**
- **Anomaly 3 Since 01/24/2009 Rows 28—45**
- **Anomaly 4 Since 07/05/2011 Rows 42—45 †**

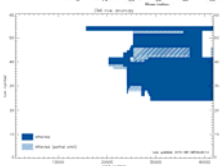
† (previously for partial orbits, now for complete orbits)

Flagging of BrO and OClO L1b data is done and has been implemented in the operational product.

Flagging of row anomaly for formaldehyde (HCHO) and glyoxal (CHOCHO) is currently in process and will be undergoing testing soon.



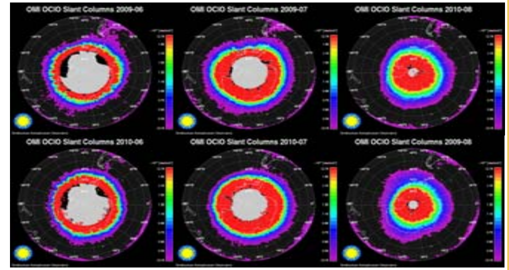
Average continuum reflectance at 475 nm over the southern part of several orbits for each row index. The averages are taken for January 12, 2009 with and without the blockage correction applied to Level 1B. (Maarten Sneep, see link above).



Graphical representation of the affected rows over time.

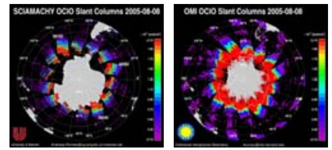
The rows in the UV2 and VIS channels that are affected are colored in this graphical representation of the OMI row anomaly. The orbit numbers are listed on the horizontal axis, the row number is listed on the vertical axis. Not shown here are the changes during an orbit as a function of the orbit phase, because not all effects reported here are seen along the entire orbit. Note that there are minor differences between UV2 and VIS that are ignored here. (Remco Braak, see link above).

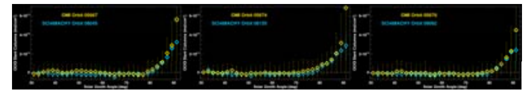
OClO



OClO is a qualitative indicator for chlorine activation in the polar vortex and, hence, a tracer for polar ozone depletion. It is observed in the polar stratospheric winter (October-March in the northern hemisphere, April-September in the southern hemisphere; see figures below right). The OClO products currently have the proper flagging for the row anomaly. OMI OClO retrievals are performed in the spectral range 358.5-392.0 nm, producing slant column densities. Column uncertainties are 40-100% for single measurements. SCDs are not converted to VCDs due to the high solar zenith angles (SZAs, ~90º) at which OClO is observed.

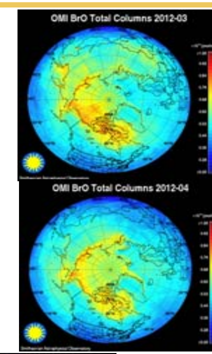
Validation: Comparative measurements of OClO are sparse and are mostly limited to other satellite instruments. Comparison of OClO SCDs from OMI and SCIAMACHY on Envisat shows excellent agreement for SZAs up to around 88º-89º, as shown by the examples from selected orbits on 8 August 2005.





Issues: Row anomaly effects aside, no product-specific issues are currently known to affect the operational OMI OClO slant column densities.

BrO

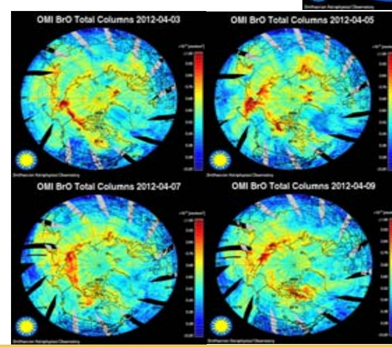


BrO is present in both the stratosphere, where it catalytically destroys O_3 with higher efficiency than ClO, and in the lower troposphere, where it is released by salt lakes, volcanos, and at fresh ice surfaces hit by ocean water. The latter effect is thought to give rise to so-called bromine explosions that have long been observed by satellites. OMI BrO is retrieved in the spectral region 319-375.5 nm, using a wavelength-dependent AMF that is applied pre-fit to the BrO cross-sections to yield BrO VCDs. A subsequent fit for BrO SCDs provides AMF values in the product.

The ARCTAS 2008 campaign (http://www.espo.nasa.gov/arctas) called into question the tropospheric origin of bromine explosions, when airplane-based observations failed to detect elevated boundary layer BrO where satellite instruments placed hot-spots. Since then, a "new interpretation" [Salawitch *et.al.*, 2010] for some (but not all) of these elevated BrO features has been derived, using the UMCP stratospheric bromine model which includes 5 -10 ppt of very-short-lived (VSL) stratospheric bromine and low tropopause heights.

The current state of knowledge of the polar BrO vertical distribution can be summarized as follows: While a significant number of day-to-day hot-spot variations, formerly thought to be located in the boundary layer, are, in fact, of stratospheric origin, longer temporal averaging reveals persistently elevated BrO in areas of thin sea ice, consistent with the release of BrO in the interaction of ocean water with fresh ice surfaces. (see figures on top right for March and April 2011).

Issues: Results shown here are derived with the current version 5.0 of the operational BrO retrieval algorithm. Improvements are achieved by a change of fitting window and the omission of O_2-O_2 interference in the fit which, when included, improves RMS but degrades VCD quality. Reprocessing of the entire OMI data record has been completed. BrO columns, particularly at high latitudes after 2008, are affected by the instrument row anomaly. BrO products will require additional reprocessing to correct for improper implementation of the HITRAN recommended H_2CO cross sections.



Validation: OMI BrO has been compared extensively against ground-based and satellite-based measurements. It shows excellent agreement with VCDs derived from ground-based zenith-sky instruments and GOME-2.

Comparison between OMI and Harestua for the period of February 1, 2011 to April 15, 2011.

There is an agreement between OMI and Harestua and it appears to follow the same pattern as that of the comparison prior to the row anomaly.