Combination of different satellite observations of BrO over Antarctica

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1. Introduction

Reactive halogen species are known as one of the important components in atmospheric chemistry. They are responsible for ozone depletion through catalytic reaction cycles, changes in the OH/HO_2 and NO/NO_2 ratios, and oxidation of compounds such as gaseous elemental mercury and dimethyl sulphide. Thus, monitoring of their spatial and temporal distribution is necessary to understand accurately their impact on the chemistry of both troposphere and stratosphere. Data from the GOME-2 and OMI instruments has been successfully used to monitor the daily global distribution of bromine monoxide (BrO) vertical column densities.

Large amounts of reactive BrO are found in polar regions during spring due to a phenomenon known as bromine explosion, the release of bromine originating from sea salt to the gas phase through an autocatalytic process. In this study, we used BrO column densities from the OMI and GOME-2 satellite instruments to investigate the transport pattern and shape variations during Antarctic bromine explosion events that occurred over a large area for consecutive days.

2. BrO satellite retrieval

- Satellite instruments

- **OMI** (Ozone Monitoring Instrument) and **GOME-2A** (Global Ozone Monitoring Experiment–2A)
- UV/VIS nadir viewing spectrometers
- Spatial resolution: 13 x 24 km^2 (OMI), 40 x 80 km^2 (GOME-2A)
- Overpass time: ~1:30 p.m. (OMI), ~9:30 a.m. local time (GOME-2A)

- Theoretical background

To obtain the slant column density from the backscattered earthshine spectrum measured by the satellite, the **DOAS** method (Differential Optical Absorption Spectroscopy) is applied:

$$I(\lambda, s) = I_0 exp(-\sigma(\lambda)\rho s)$$

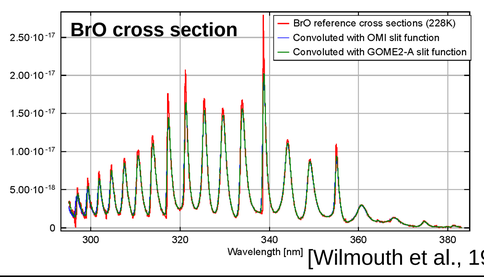
(the initial intensity: I_0, the length of light path: s,
the absorption cross-section: σ , the absorber number density: ρ)

The retrieved slant column can be converted into a vertical column using the air mass factor (AMF)

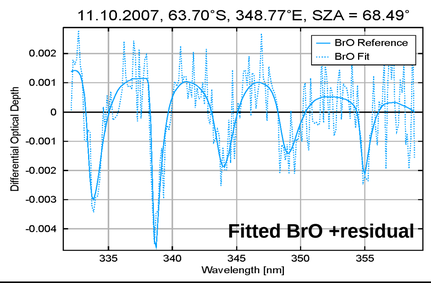
$$VCD_{total} = SCD_{total} / AMF$$

- **Retrieval settings for BrO from OMI and GOME-2A**

Retrieval settings	OMI	GOME-2A
Fitting window	332 - 359 nm	332–359 nm
Polynomial degree	5th order	5th order
Trace gases cross sections	O3 (218K and 295K), NO2 (220K), BrO (228K), HCHO (298K), OClO (213K), O4 (298K)	O3 (223K and 273K), NO2 (223K), BrO (228K), HCHO (298K), OClO (213K), O4 (203K)
Background	Daily Earthshine, Pacific (30°S-30°N, 180-220°E)	Daily Earthshine, Pacific (30°S-30°N, 180-220°E)
Offset correction	Done	Done

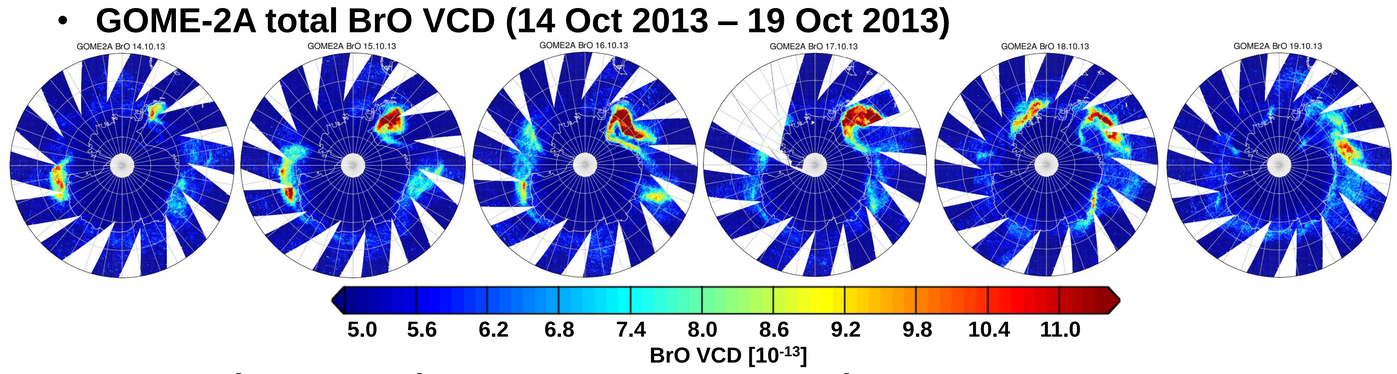


[Wilmouth et al., 1999]

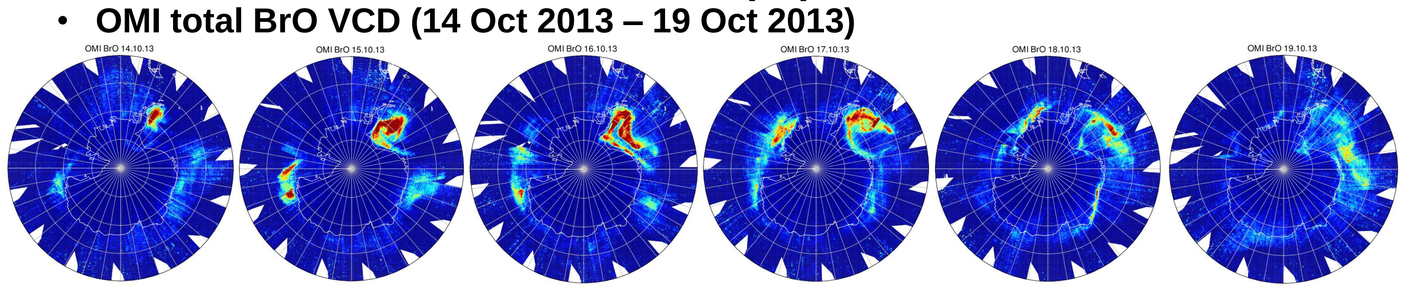


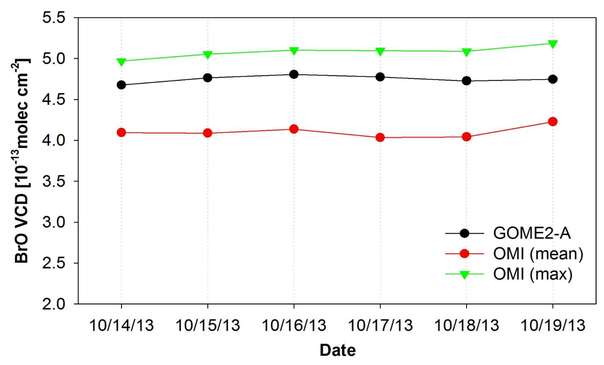
3. Comparison of OMI and GOME-2 BrO in Antarctica

- **GOME-2A total BrO VCD (14 Oct 2013 – 19 Oct 2013)**



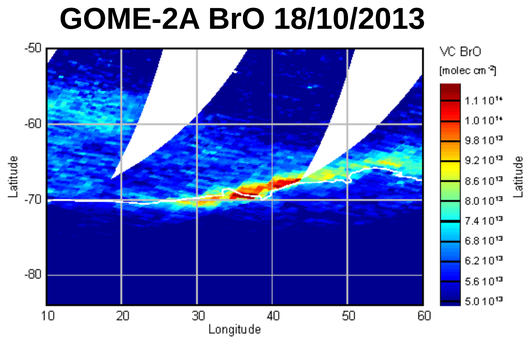
- **OMI total BrO VCD (14 Oct 2013 – 19 Oct 2013)**



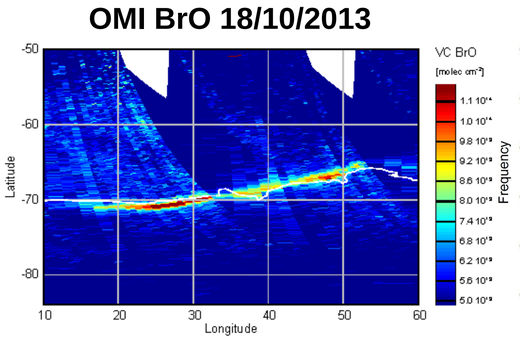


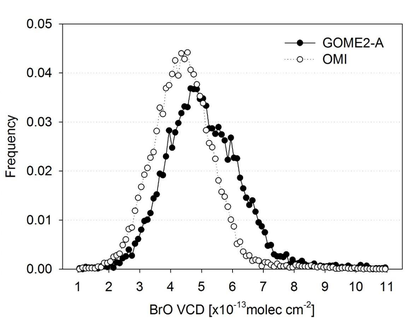
- In the Antarctic region, the shape and concentration of BrO plumes are similar between GOME-2 and OMI in general. However, due to the different local overpass time and spatial resolution between the two instruments, differences in spatial distribution are observed.
- BrO VCDs of OMI are slightly lower than those of GOME-2.

GOME-2A BrO 18/10/2013



OMI BrO 18/10/2013

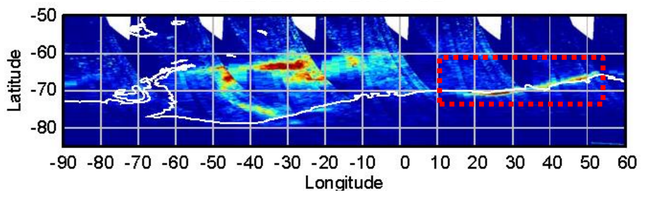




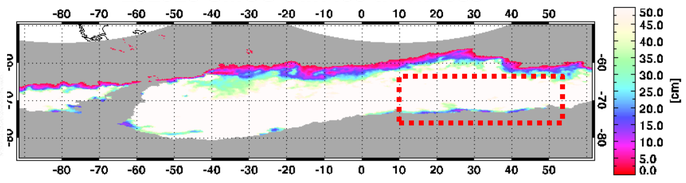
4. BrO explosion event case study

- Meteorological and sea ice conditions

131018OMI BrO VCD

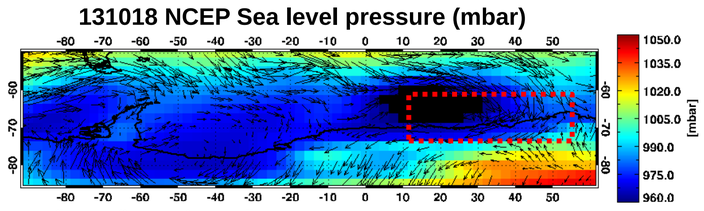


131018 SMOS thin ice thickness

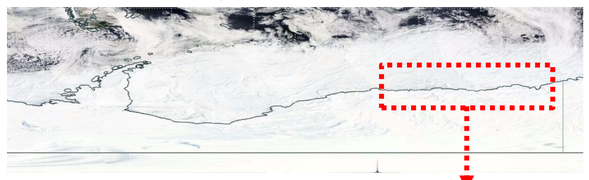


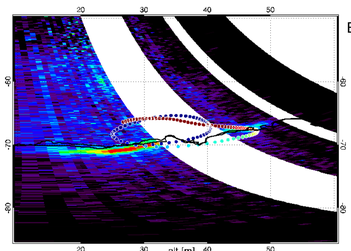
[https://seaice.uni-bremen.de/data//smos/]

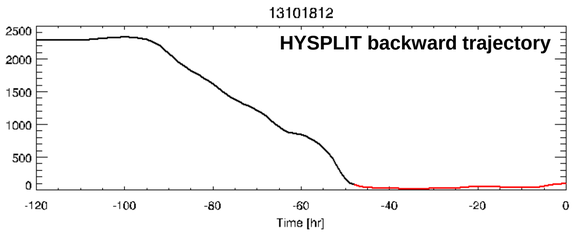
131018 NCEP Sea level pressure (mbar)



MODIS Aqua corrected reflectance

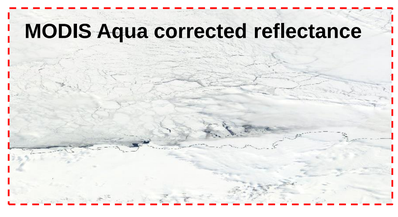






[http://ready.arl.noaa.gov/HYSPLIT.php]

MODIS Aqua corrected reflectance

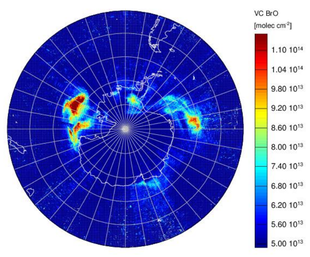


[https://worldview.earthdata.nasa.gov/]

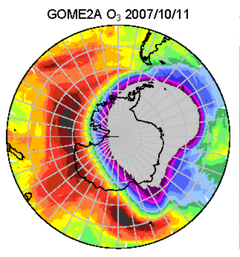
- Enhanced BrO plume is detected along the Antarctic coast line by OMI and GOME2-A.
- NCEP meteorological model data show that the region of interest is located at the edge of a low pressure system.
- SMOS sea ice thickness retrievals indicate thin sea ice in the area where bromine explosion occurred.
- MODIS Aqua reflectance also shows cracks in the sea ice shelf and thin ice.
- Backward trajectories show that air mass contacted and stayed over the thin first-year sea ice region.

5. Stratospheric correction

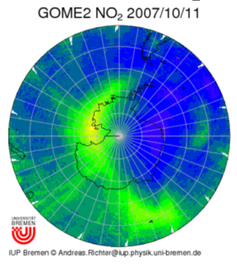
Total BrO VCD



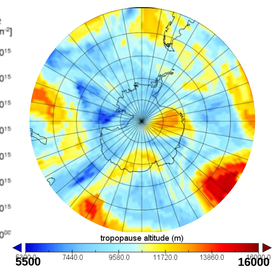
Total O_3 VCD



Stratospheric NO_2 VCD



Tropopause altitude



- O_3 and NO_2 column density can be used as a parameter for tropopause dynamics and stratospheric chemistry [Sihler et al., 2012]
- This assumptions are not applicable to the chemistry inside the polar vortex and ozone hole
- Separation of stratospheric and tropospheric columns of BrO is still challenging in springtime Antarctica

6. Summary and Outlook

- BrO maps from the GOME-2A and OMI satellite instrument show huge areas of elevated BrO above the sea ice around Antarctica.
- BrO retrievals from GOME-2A and OMI generally agree with some differences as expected from the difference in spatial resolution and overpass time.
- Satellite data sometimes detect enhanced BrO along the Antarctic coast. Overall, BrO enhancements often occur on thin first-year ice when the large-scale meteorological situation is associated with cyclonic activity and relatively high wind speeds.
- Backward trajectories indicate that BrO plumes are related to air masses previously in contact with sea ice surfaces.
- An estimation of the stratospheric BrO within the polar vortex occurring in springtime Antarctica is challenging.

7. Acknowledgement & Selected References

- Sihler, H., et al. "Tropospheric BrO column densities in the Arctic derived from satellite: retrieval and comparison to ground-based measurements." (2012).
- Blechschmidt, A. M., et al. "An exemplary case of a bromine explosion event linked to cyclone development in the Arctic." *Atmos. Chem. Phys* 16 (2016): 1773-1788.
- Theys, N., et al. "Global observations of tropospheric BrO columns using GOME-2 satellite data." *Atmospheric Chemistry and Physics* 11.4 (2011): 1791.
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