Bromine oxide in the polar boundary layer: Analysis of long-range transport processes

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Introduction

On many days in polar springtime, a nearly complete removal of ozone from the polar boundary layer can be observed in widespread parts of Arctic and Antarctic. Responsible for these so called **O**zone **D**epletion **E**vents (ODE) is the catalytic destruction of ozone by halogens. These can be released from sea salt to the gas phase by heterogeneous reactions on surfaces like newly formed sea ice, frost flowers, sea salt enriched snow or sea salt aerosols.

Bromine has been identified as the key halogen in the destruction cycle and reacts with ozone to bromine oxide (BrO). Due to autocatalytic processes, bromine release and ozone destruction are strongly increased (”Bromine Explosions”).

BrO can be detected in-situ or by absorption spectroscopy from the ground or from satellites. It also has a large impact on the deposition of gaseous mercury in the sensitive polar ecosystem.

The exact mechanism, which leads to an initial bromine release and the influence of transport and chemical processes on BrO is still not completely understood.

In this study we use BrO measurements of the satellite instrument GOME-2 together with model calculations of the dispersion model FLEXPART and Potential Frost Flowers (PFF) maps to interpret a very special arctic BrO event in March/April 2007, which could be observed over many days and large areas to get new information about source regions of BrO and the influence of transport on the evolution of these event.

Instrument and Retrieval

GOME-2(Global Ozone Monitoring Experiment 2)

- Four channel UV/VIS grating spectrometer
- Nadir viewing observation geometry
- Launched on MetOp-A in October 2006
- Data available since January 2007
- Equatorial Crossing Time: 9.30h local time
- Spatial resolution: 40 x 80 km²
- Scan width: 1920 km
- Global coverage within one day
- Spectral resolution: 0.2 – 0.4 nm
- Spectral range: 240 – 790 nm
- Comparable to SCIAMACHY and GOME
- Mission duration: 5 years
- Identical instruments on MetOp-B/C (2010/15)

Fig. 1: MetOp-A satellite

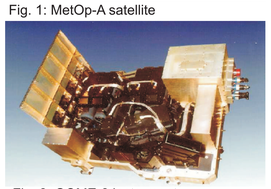
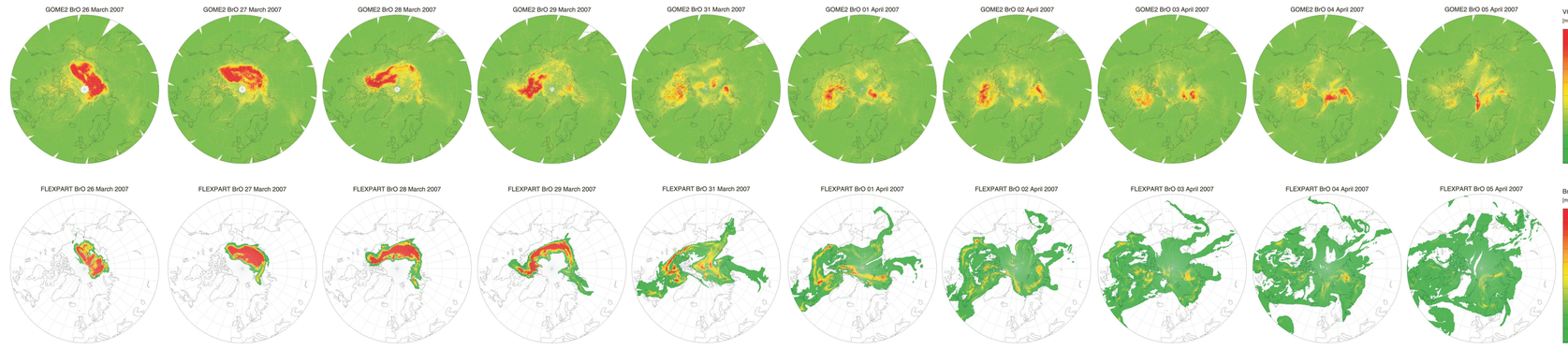


Fig. 2: GOME-2 instrument

Retrieval and measurement method

- **D**ifferential **O**ptical **A**bsorption **S**pectroscopy (DOAS) on back scattered sun light
- BrO fitting window: 336-347 nm
- Subtracting constant value of 4.5E13 molec/cm² VC stratospheric BrO
- Application of tropospheric AMF (Assumption: BrO located in the lowest 400 m)
- Surface albedo 0.9
- No cloud screening applied

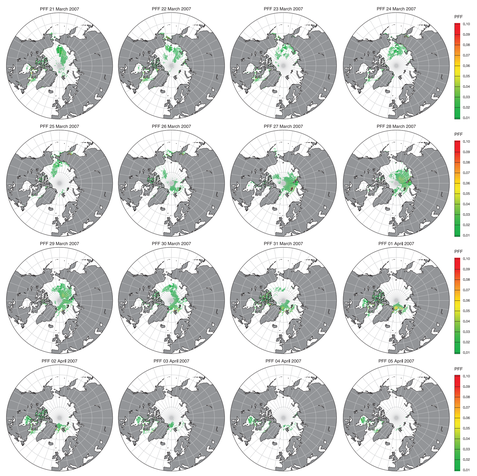
Comparison of FLEXPART model results with GOME-2 BrO data



- GOME-2 observations of the BrO event indicate a fast transport within 3 days towards Hudson Bay and the west coast of Greenland
- Enhanced BrO values can be detected until 5th April, where several new BrO events can be observed in Kara and Greenland Sea
- Fast transport towards Hudson Bay and over the pole seen in GOME-2 Bro data can be well described by modeled FLEXPART data
- FLEXPART model data show very high values in Laptev and East Siberian Sea, which can't be identified in the according GOME-2 data
- BrO could have been deactivated or can’t be seen due to clouds

Fig. 3: The upper line of figures shows tropospheric BrO from GOME-2. Below the daily averaged FLEXPART model results are shown. As model input, three seperate GOME-2 orbits were choosen to cover the complete probable source region of the BrO event using only values above 6.0E13 molec/cm² and a passive tracer without any chemistry. BrO data of 30th March were excluded, because on this day GOME-2 was operated in narrow swath mode.

Influence of frost flowers



- Frost flowers are a possible source of released bromine
- They show a large surface and a high salinity up to three times higher than sea water
- They grow on a thin brine layer on top of newly forming sea ice and are a source of sea salt aerosol
- Enhanced PFF values in the BrO source region can be observed a few days before the BrO event starts
- Enhanced values can also be seen near the north eastern coast of Greenland, where an additional BrO event is initialized on 4th April
- A direct correlation between high PFF and enhanced BrO can’t be found, but high values a few days before BrO events

Fig.4: Potential Frost Flowers (PFF) Maps, showing enhanced values above 0.01 up to 0.1. They are created by using ECMWF meteorological data and AMSR-E sea ice maps in combination with a thermodynamic model to simulate areas, where frost flowers potentially grow

Conclusions

- In March/April 2007 a large arctic BrO event could be observed in GOME-2 BrO data over many days and large areas
- A FLEXPART model run has been initialized, using GOME-2 BrO values above 6.0E13 molec/cm², a passive tracer and no chemistry
- Observed BrO values can be partly well explained by transport processes
- Some high modeled BrO values can’t be identidied in GOME-2 data, because BrO has been deactivated or can’t be seen due to clouds
- Due to the short lifetime of BrO, highly efficient recycling processes have to be involved within the transported air masses
- Additional released BrO in Kara and Greenland Sea can be explained by reactivation of transported bromine compounds and the initialization of a new bromine explosion process
- A direct correlation between high BrO values and enhanced values of PFF has not been found
- High PFF values has been located a few days before the initial BrO event, which could be an indication to the life time of frost flowers
- Observed long range transport of BrO provides additional information of source regions and the initial release of BrO, which is important for the analysis of in-situ measurements and interpretation of ice cores

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