GOME-2 Observations of Polar Boundary Layer BrO Explosions

A. Richter, M. Begoin, L. Kaleschke*, H. Kirk, F. Wittrock, and J. P. Burrows
Institute of Environmental Physics / Remote Sensing, University of Bremen,
FB 1, P.O. Box 330440, D-28334 Bremen, Germany
Email: Andreas.Richter@iup.physik.uni-bremen.de
*Center for Marine and Atmospheric Research, University of Hamburg, Germany

Polar BrO Explosions

- Each spring, events of strongly reduced boundary layer ozone concentrations are observed in polar regions of both hemispheres.
- Ozone destruction is catalysed by halogens, mainly Br but possibly also I and Cl.
- Low ozone events are accompanied by reduced concentrations of gaseous mercury and increased particulate mercury leading to input of anthropogenic mercury into the polar ecosystem.
- Mercury chemistry is linked to BrO chemistry.
- The ultimate source of halogens is salt in sea water.
- Bromine is released in an autocatalytic process from aerosols or salty surfaces to the gas phase.
- Frost flowers, fresh ice and also snow have been suggested as active surfaces.
- Low temperatures are thought to be needed to facilitate BrO release.
- The atmospheric life time of BrO is short but efficient recycling on aerosols or surfaces can extend the lifetime of BrO events.
- How BrO explosions are initialized is not yet fully understood.

GOME-2 Instrument and BrO Retrieval

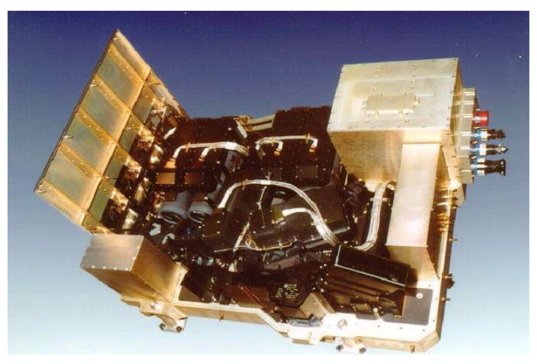

Fig 1: The GOME-2 instrument

GOME-2 Instrument:

- launched on MetOp-A in October 2006, data since March 2007
- 4 channel nadir viewing UV/visible spectrometer
- similar to GOME and SCIAMACHY
- first in a series of three identical instruments
- 80 x 40 km^2 pixel size
- global coverage in 1.5 days
- 09:30 LT equator crossing

Measurement and Retrieval Technique:

- Differential Optical Absorption Spectroscopy on UV/visible sun light scattered back and reflected from the atmosphere and surface
- BrO fitting window: 336 - 347 nm
- application of stratospheric AMF (reasonable approximation over bright surfaces)
- no separation between stratospheric and tropospheric contributions assuming more or less constant stratospheric columns
- no cloud screening

A Large BrO Event in Spring 2007

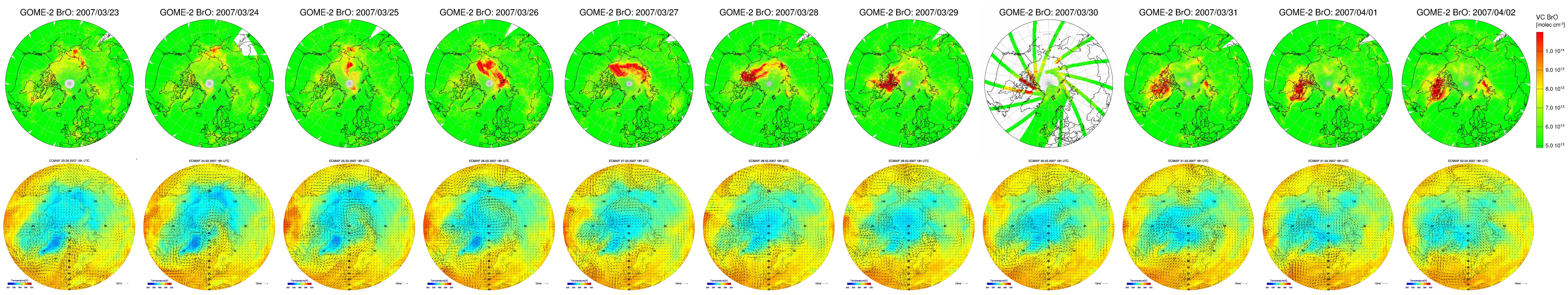

Fig. 2: GOME-2 total BrO columns (upper row) and ECMWF wind and temperature fields at surface (lower row). ECMWF data are shown at 18:00 UT. GOME-2 data gaps on March 30 are due to a special observation mode (narrow swath). The large BrO cloud formes within one day and moves with the low pressure system (see boxes).

Is high BrO linked to low T?

- Ground-based measurements often observe good correlation between low T and low ozone (high BrO)
- This could indicate the need of low T for BrO activation or just a link to polar air mass origin
- Here, BrO changes are neither clearly correlated or anti-correlated to T changes
- low T can still be involved in BrO activation as temperatures were low throughout the Arctic

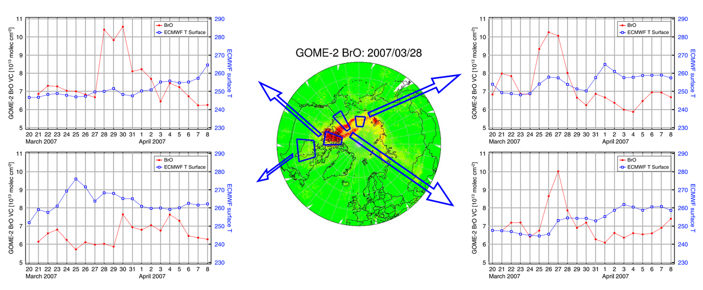

Fig. 3 Time evolution of BrO and ECMWF surface T in 4 selected regions. There is no indication for anti-correlation between T and BrO in these areas.

How fast is Bromine Activation?

- Ground-based observations have shown episodes of rapid increase of BrO, but the effects of transport and local chemistry could not be separated.
- Satellite measurements give full spatial coverage => total amount of BrO can be integrated
- Fig. 4 shows area North of 50°N with BrO columns above 1x10^{14} molec cm^{-2} => full activation happens within 24 hours
- => followed by several days of "transport phase"
- Fig. 5 shows three consecutive overpasses over one region, showing rapid variation of BrO within hours

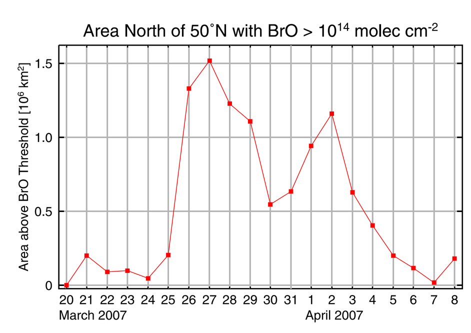

Fig. 4: Time evolution of area North of 50°N covered with BrO columns larger than an arbitrary threshold value of 1x10^{14} molec cm^{-2}. Very rapid increase from basically 0 values to more than 1.5 million square km is observed from March 25 to March 26, indicating rapid activation over a large area.

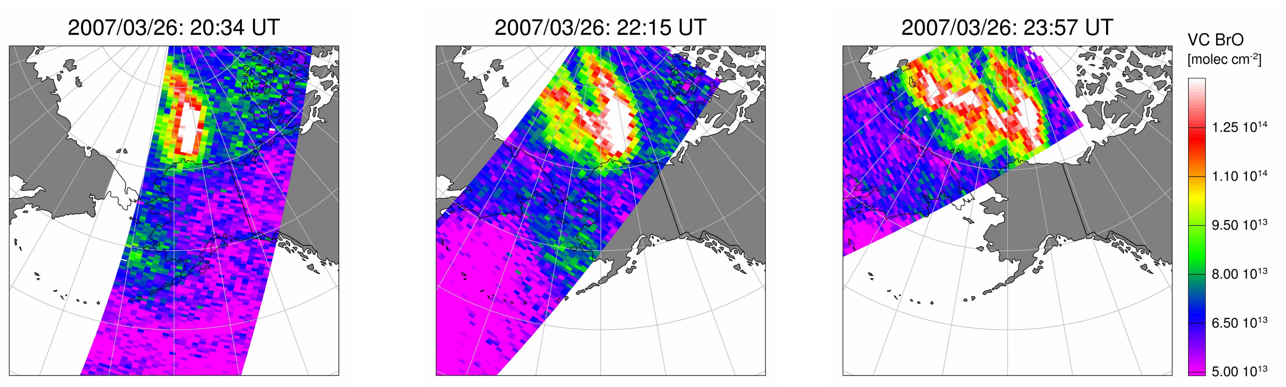

Fig. 5 Three consecutive overpasses of GOME-2 over one of the BrO plumes on March 26. Within the roughly 100 minutes time difference, both shape and total BrO amount observed change, indicating rapid chemistry and transport

Why does the BrO cloud move?

- The BrO event is linked to a low pressure cyclone
- forward trajectories indicate that most of the BrO is circulating within the low pressure system (see Figs 2 and 6).
- Forward movement is with the cyclone or with air masses pushed ahead of the system
- On March 30, BrO is directed towards the Hudson Bay by the overall wind pattern. It remains there for several days, not following the wind direction anymore.
- As life time of BrO is short, efficient recycling is needed to sustain BrO for more than 10 days as in this event
- The rapid movement over large distances (more than 4000 km in 4 days) is linked to the specific

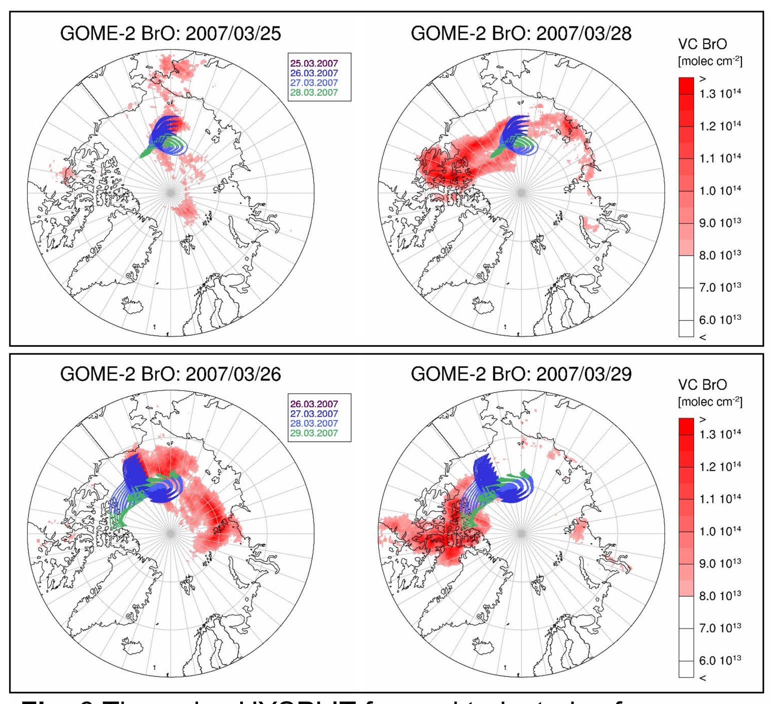

Fig. 6 Three day HYSPLIT forward trajectories from the surface plotted over BrO from the starting day and three days later.

Conclusions

- in March / April 2007, a large BrO plume could be observed in GOME-2 satellite data over the Arctic region
- the BrO plume was linked to a low pressure system and rapidly moved over more than 4000 km within a few days, only partly following trajectories
- BrO activation over a large area (more than 1.5 million km^2) happened within one day
- there is no clear link between BrO changes and ECMWF surface temperature changes

Acknowledgements

- GOME-2 radiances and irradiances have been provided by EUMETSAT
- Meteorological data has been provided by ECMWF
- The authors gratefully acknowledge the NOAA Air Resources Laboratory (ARL) for the provision of the HYSPLIT model
- Parts of this project have been funded by the DFG SALT project, the University of Bremen, and the European Community through the ACCENT network.

Universität Bremen

Selected References

Simpson, W. R. et al., Halogens and their role in polar boundary-layer ozone depletion, *Atmos. Chem. Phys.*, **7**, 4375-4418, 200
Ridley, B. et al., An ozone depletion event in the sub-arctic surface layer over Hudson Bay, Canada, *Journal of Atmospheric Chemistry*, **57(3)**, 255-280, 2007
Jacobi, H. et al., Observation of a fast ozone loss in the marginal ice zone of the Arctic Ocean, *J. Geophys. Res.*, **111**, D15309, doi:10.1029/2005JD006715, 2006
Kaleschke, L.et al., Frost Flowers on Sea Ice as a Source of Sea Salt and their, Influence on Tropospheric Halogen Chemistry, GRL , 31, L16114, doi:10.1029/2004GL020655, 2004.
Richter, A. et al., GOME measurements of stratospheric and tropospheric BrO, *Adv. Space Res.*, **29(11)**, 1667-1672, 2002
Richter, A. et al., GOME observations of tropospheric BrO in Northern Hemisphere spring and summer 1997, *Geophys. Res. Lett.*, No. **25**, pp. 2683-2686, 1998.

see also: www.iup.physik.uni-bremen.de/doas