Satellite observations of enhanced tropospheric BrO plumes around polar coastal polynyas

Sora Seo (Sora.Seo@iup.physik.uni-bremen.de), Andreas Richter, Anne-Marlene Blechschmidt, and John P. Burrows
Institute of Environmental Physics (IUP), University of Bremen, Bremen, Germany

I. Motivation

Bromine radicals play an important role in tropospheric chemistry by destroying ozone catalytically. Especially, strong ozone depletion events are observed in the Arctic and Antarctic boundary layer during polar spring due to rapid releases of bromine from the liquid to the gas phase and an autocatalytic sequence of reactions that is termed Bromine explosion. The spatial extent of these BrO explosion events is varied and the sources and release mechanism of reactive halogen remain still open questions. Satellite observations which have large spatial coverage are useful to answer these open questions by detecting different BrO explosion cases over the Polar Regions. In this study, we analyzed BrO plumes of long and narrow shape found along coastlines using OMI and GOME-2 measurements.

II. DOAS BrO slant column retrieval

To obtain the slant column density from the backscattered earthshine spectrum measured by satellites, **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)

Atmospheric absorbers (BrO) are separated using the characteristic differential structures of their absorption cross-sections determined from laboratory measurements. The retrieved quantity is the integrated BrO concentration along the mean optical light path referred to as the slant column density (SCD).

Table 1. BrO retrieval settings for OMI and GOME-2A

Retrieval settings	OMI	GOME2-A
Fitting window	332- 359 nm	
Solar Reference Spectrum	Kurucz solar spectrum (Fraunhofer calibration)	
Trace gases cross sections	BrO (Wilmouth et al., 1999; 228K) O_3 (Serdyuchenko et al., 2013; 223K, 243K) NO_2 (Vandaele et al., 1998; 220K) OClO (Kromminga et al., 2003; 213K) O_4 (Hermans et al., 298K) HCHO (MellerMoortgat et al., 2000 ;298K)	
Ring cross sections	Cross-section calculated using SCIATRAN model	
Polynomial degree	5th order	
Background	Daily Earthshine, Pacific (30°S-30°N, 150-240°E)	
Offset correction	Slope (2 parameters)	

III. Derivation of tropospheric BrO vertical column density

- **Local stratospheric background correction**

- An empirical model based on the linear regression analysis between BrO SCD and various viewing geometry to estimate background stratospheric BrO SCD

$$BrO\ SCD_{strat} = a_0 + a_{lon}{*}lon + a_{lat}{*}lat + a_{sza}{*}cos(SZA) + a_{los}{*}cos(LOS)$$

$$BrO\ SCD_{trop} = BrO\ SCD_{total} - BrO\ SCD_{strat}$$

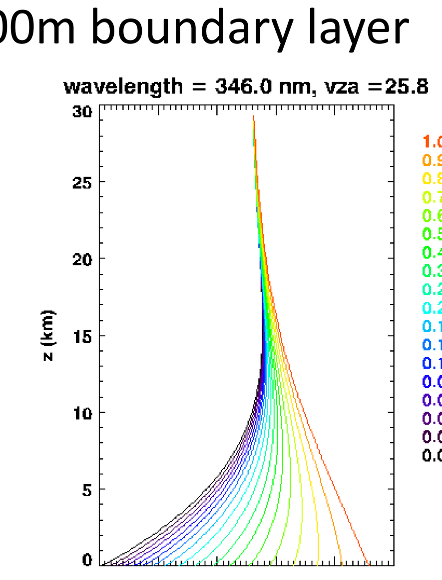
- To avoid the influence of locally enhanced tropospheric BrO over the study area, total BrO VCDs within 3 sigma of the study area are used as dataset.

- **Tropospheric air mass factor (AMF) calculation**

- Pre-calculated Box AMF LUT using the SCIATRAN radiative transfer model
- f(z, sfh, alb, raa, vza, sza, λ)
- Homogenous vertical distribution of BrO within 200m boundary layer

Table 2. Parameters for Box AMF Look-up table

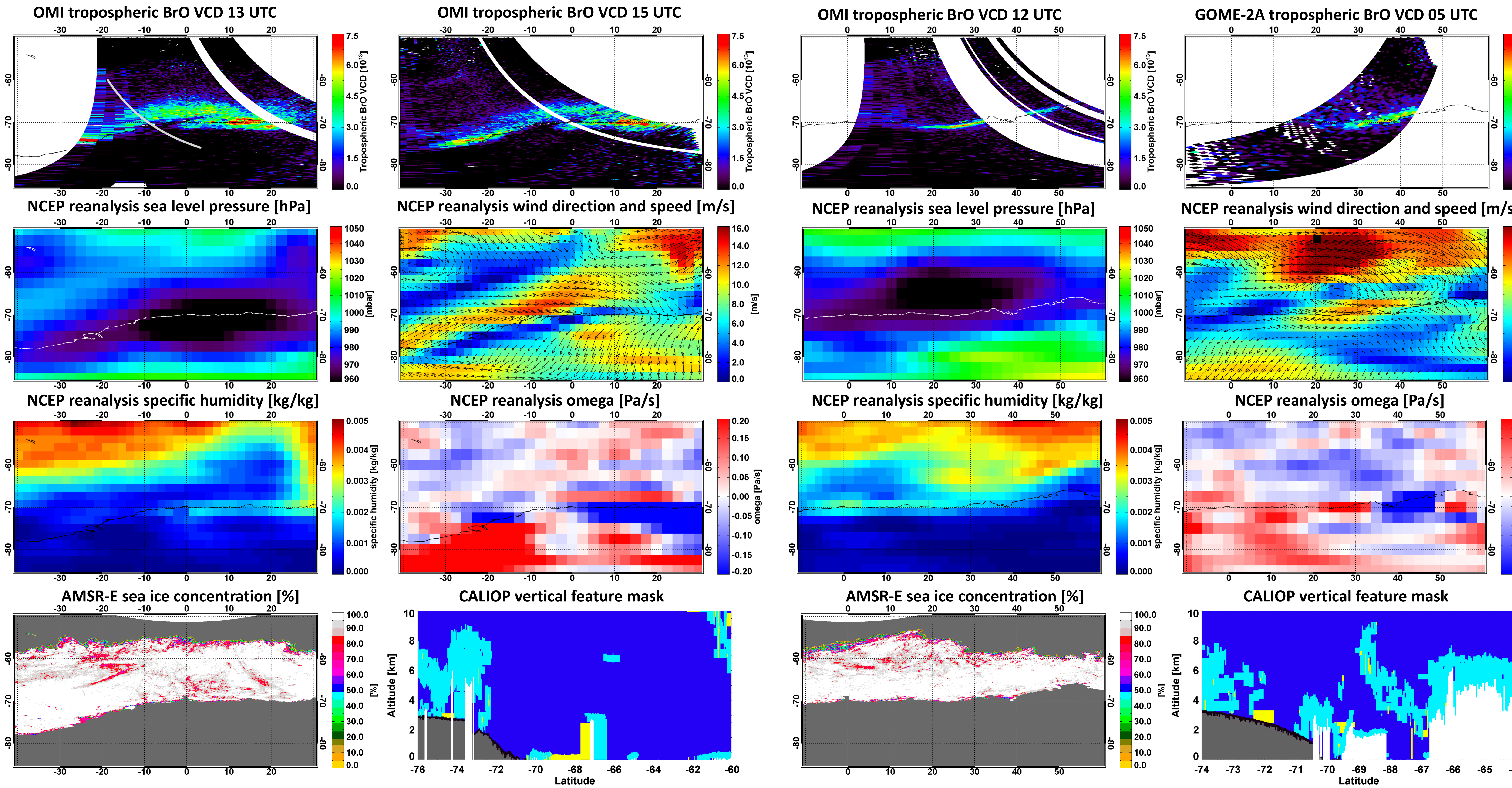
Parameter	Number of grid points
AMF wavelength (nm)	6 (346 nm for tropospheric AMFs in this study)
Solar zenith angle (°)	19
Viewing zenith angle (°)	9
Rel azimuth angle (°)	7
Surface albedo	18
Surface altitude	10
Altitude	201 0..10km (100m), 10..60km (1km), 60..100km (2km)



Box AMFs at 346 nm for various surface albedo

IV. Tropospheric BrO explosion events around polar coastal polynyas

- **Case study I – Oct 8 2006**
- **Case study II – Oct 18 2013**



- Cyclonic circulation induced by the low pressure system forces offshore winds along the ice shelf.
- Strong surface winds along the coastal lines reaching up to 14 m s^{-1} push the pack ice away from the coastal edge, leading to opening of coastal polynya.
- Relatively high specific humidity values and negative omega velocities representing upward air movement appear simultaneously around these open water surfaces, suggesting that evaporation occurred. This vertical uplift can derive a transport of ions contained in the brine into the air and more reactive bromine in the gas phase.
- As shown in CALIOP vertical feature masks, marine type aerosol layers (yellow) are observed over open leads.

V. Conclusions

- Enhanced tropospheric BrO plumes close to Antarctic coastal polynyas were observed by OMI and GOME-2.
- Residual method was used to retrieve the tropospheric BrO column and stratospheric background correction was done by using an empirical multiple linear regression model.
- These tropospheric BrO explosion events are linked to thin sea ice, high surface wind speeds, and upward air movement. When new sea ice grows within coastal polynyas, sea salt aerosols or frost flowers which can act as bromine source can enter the polar boundary layer.
- The high spatial resolution of TROPOMI data (3.5x7 km^2) is expected to improve understanding of the release mechanisms and spatial variation of BrO close to leads and polynyas.

VI. References and Acknowledgements

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." Atmospheric Chemistry & Physics 16.3 (2016).
This work was funded by the University of Bremen and DLR Bonn under contract 50 EE 1618.

Universität Bremen