Long-term Time-series of Arctic BrO Derived From Satellite Remote Sensing

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1. Introduction & Motivation

• **Bromine** has a crucial role in the arctic atmospheric composition. During **polar spring**, it is released from **young sea ice, blowing snow & frost flowers**, and through an autocatalytic chemical cycle known as **BrO explosion** (Fig.1), it **depletes ozone** by creating bromine oxides and consequently **changes the oxidizing capacity** of the atmosphere.

• BrO explosion events can be effectively studied by **satellite remote sensing** (Fig.2)

• Our goal is to **assess** the changes in the halogen atmospheric composition of the Arctic due to Arctic Amplification, by creating a consistent long-term BrO dataset, which will be used as the basis for evaluating possible **trends and links** to drivers of tropospheric BrO.

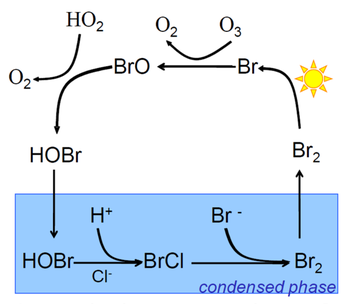

***Fig. 1**: The bromine explosion [1]*

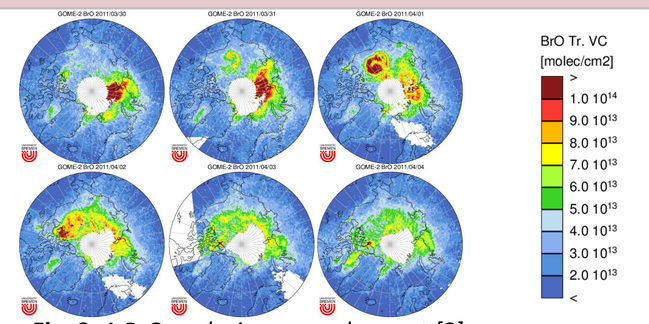

***Fig. 2**: A BrO explosion example event [2]*

2. DOAS Retrieval Method

• In order to study the **evolution** of BrO over the Arctic, we have retrieved BrO columns from **UV – VIS remote sensing** instruments using the DOAS method, which is based on **Beer – Lambert's law**: $I = I_o e^{-\int \sigma(\lambda) \rho ds}$

Instrument	Platform	Time Period	Footprint	Equatorial Overpass	Fit. Window
GOME	ERS-2	1995 – 2003	320X40 km²	10.30	336.8 – 358
SCIAMACHY	Envisat	2002 – 2012	30X60 km²	10.00	336 – 347
GOME-2A GOME-2B	MetOp – A MetOp – B	2007 – Present 2012 - Present	80X40 km²	09.30	337.5 – 357 338 – 360
OMI	EOS - Aura	2005 – Present	13X24 km²	13.30	338.23 – 359

• The RMS of the fit defined as the root mean square difference between the logarithm of I_o / I and σ(λ)ρds, divided by the amount of wavelengths in the fitting window:

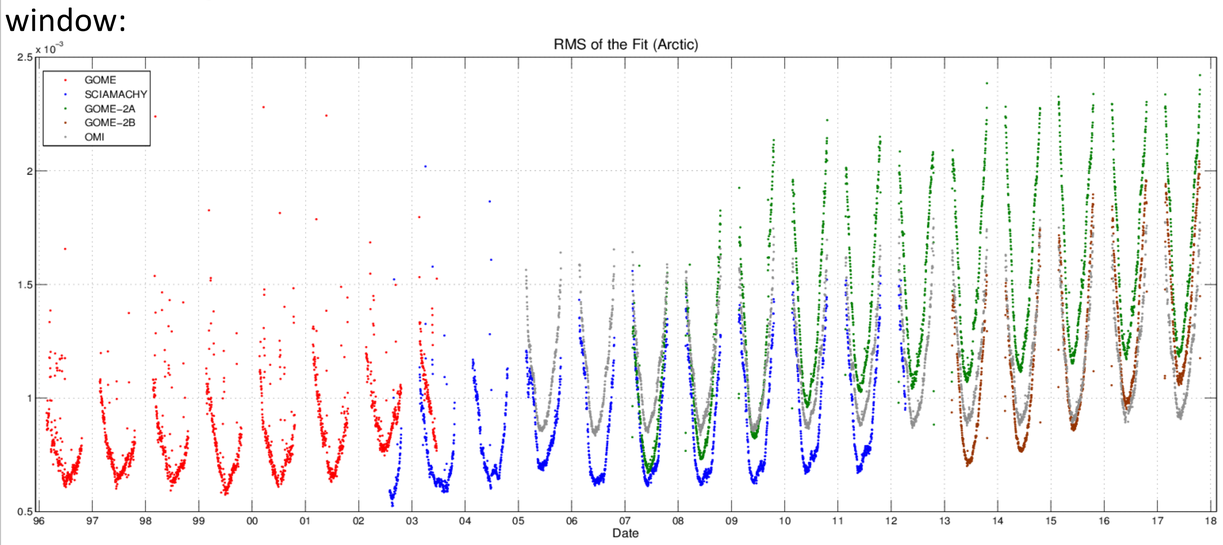

***Fig. 3**: Daily RMS values for our dataset over the Arctic region*

• The BrO geometric vertical column is obtained by dividing the output of the retrieval (**Slant Column**) with a simple geometric Air Mass Factor:

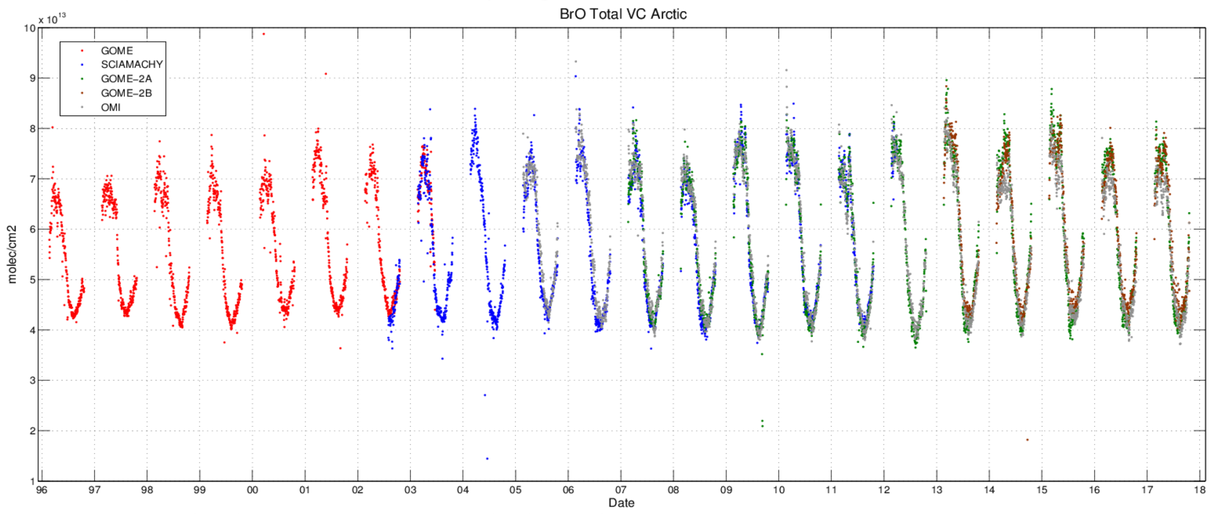

***Fig. 4**: 22 years of daily geometric BrO vertical columns from GOME, SCIAMACHY, GOME-2A , GOME-2B & OMI*

3. BrO Stratospheric Separation – Tropospheric Maps

• In order to extract the tropospheric BrO column from our retrievals, we first obtain the **BrO stratospheric vertical column**; a **model based BrO climatology** is used ***[5]***, which takes as inputs satellite retrievals of **O_3, NO_2 & tropopause height *[3], [4], [6]*** and gives an estimation of vertical columns of stratospheric BrO, **independently of the performed BrO retrievals:**

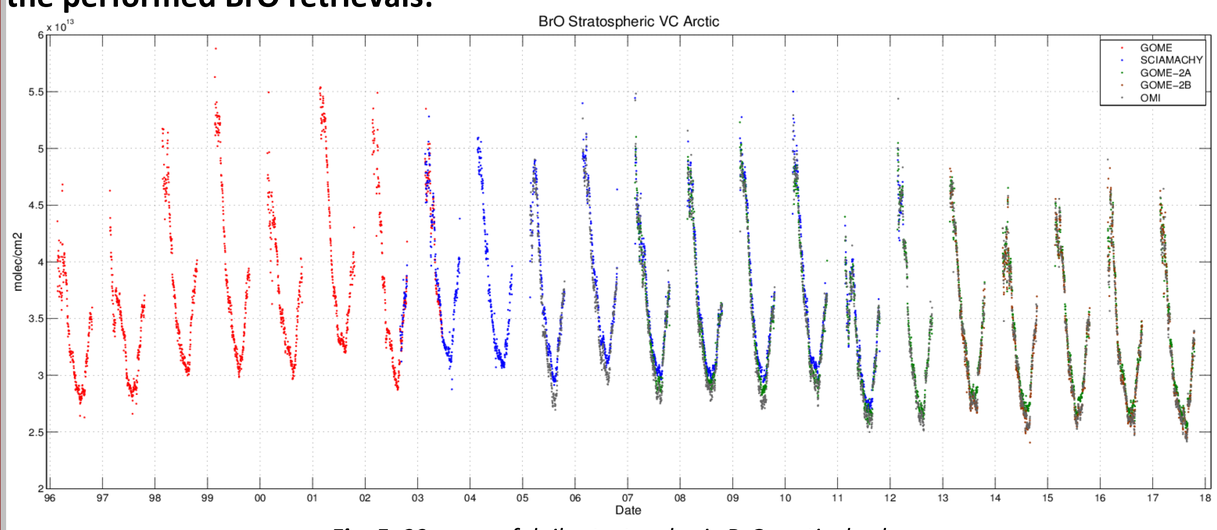

***Fig. 5**: 22 years of daily stratospheric BrO vertical columns*

• The formula that is used for the calculation of the **BrO tropospheric vertical column** is: $VCD_{tropo} = (SCD_{total} - VCD_{strato} \times AMF_{strato}) / AMF_{tropo}$ ***[5]***

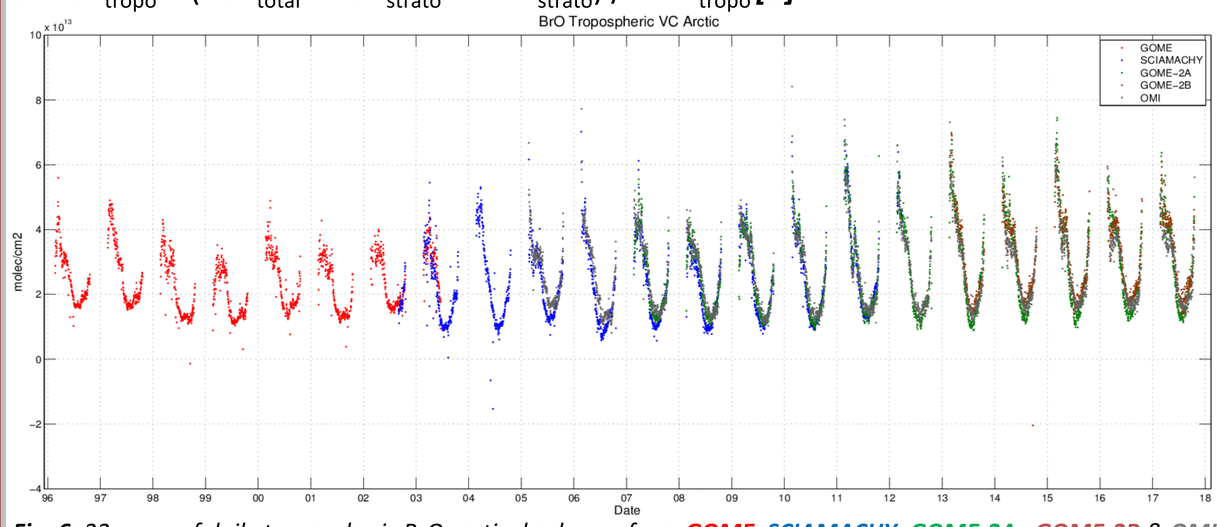

***Fig. 6**: 22 years of daily tropospheric BrO vertical columns from GOME, SCIAMACHY, GOME-2A , GOME-2B & OMI*

• The consistency between different instruments can be verified by plotting **monthly tropospheric BrO maps**; we see below March BrO maps, as observed by SCIAMACHY (1st row), GOME-2A (2nd row), GOME-2B (3rd row):

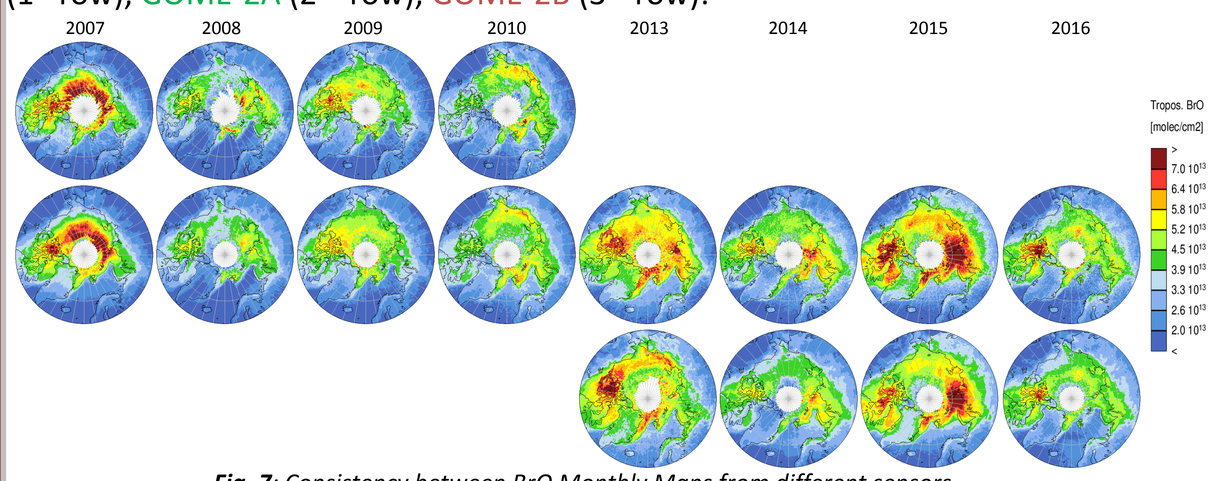

***Fig. 7**: Consistency between BrO Monthly Maps from different sensors*

4. Conclusions & Outlook

• A consistent long-term BrO dataset was developed, by using five UV-VIS satellite instruments (to our knowledge, this is the first one of its kind)

• Our dataset demonstrates high quality on the evaluation criteria we applied

• Regardless of the different instrumental attributes (e.g. spatial resolution), we see a satisfactory agreement between the sensors for the overlapping years

• Also, this agreement of both the magnitude of BrO columns and the areas where they appear can be validated by BrO maps

Future Work:

• Compare the trends of all three time-series: total geometric, stratospheric and tropospheric BrO

• Link the trends of tropospheric BrO time-series to first year ice evolution

• Study the relationship of tropospheric BrO to meteorological drivers

5. References & Acknowledgements

1. *A. E. Jones et al: BrO, blizzards, and drivers of polar tropospheric ozone depletion events, (2009)*
2. *A.-M. Blechschmidt et al: An exemplary case of a bromine explosion event linked to cyclone development in the Arctic, (2016)*
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4. *M. Weber et al: Stratospheric Ozone [in State of Climate in 2012], (2013)*
5. *N. Theys et al: Global observations of tropospheric BrO columns using GOME-2 satellite data, (2011)*
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