Long-term Time-series of Arctic BrO Derived from Satellite Remote Sensing and its Relation to Driving Mechanisms under the Impact of Arctic Amplification

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1. Introduction & Motivation

- Air temperature in the Arctic increases at a double rate compared with the worldwide mean. This phenomenon is called **Arctic Amplification.**
- **Bromine** plays a key 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 act as the basis for evaluating possible **trends and links** to drivers of tropospheric BrO.

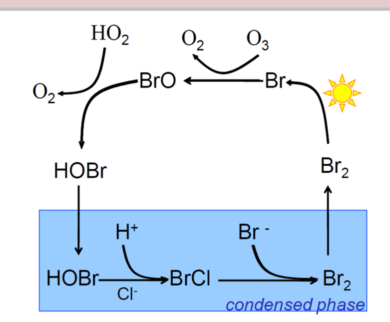

***Fig. 1**: The bromine explosion* (Figure from Jones et al., 2009) *[1]*

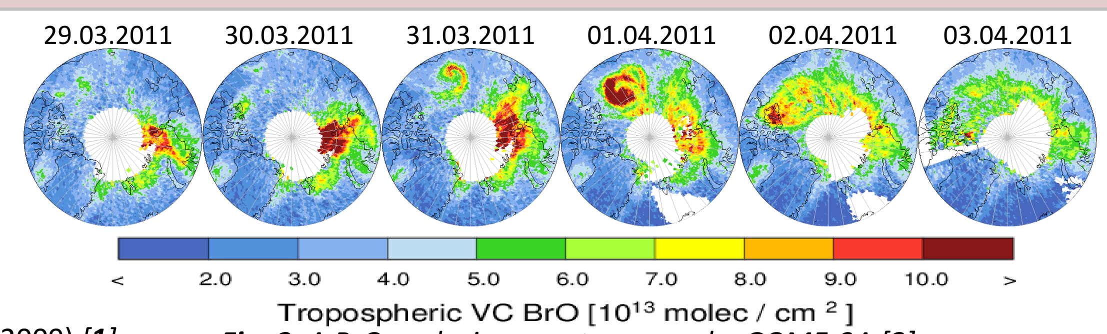

***Fig. 2**: A BrO explosion event, as seen by GOME-2A [2]*

2. DOAS Retrieval Method – Geometric Columns & Stratospheric BrO Separation

- In order to study the **evolution** of BrO over the Arctic, we have retrieved BrO columns from four **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	Swath	Fitting Window
GOME	ERS-2	1995 – 2003	320X40 km^2	10.30	960 km	336.8 – 358
SCIAMACHY	Envisat	2002 – 2012	30X60 km^2	10.00	960 km	336 – 347
GOME-2A	MetOp – A	2007 – Present	80X40 km^2 (40X40 km^2)	09.30	1920 km	337.5 – 357
GOME-2B	MetOp – B	2013 - Present	80X40 km^2	09.30	1920 km	338 – 360

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

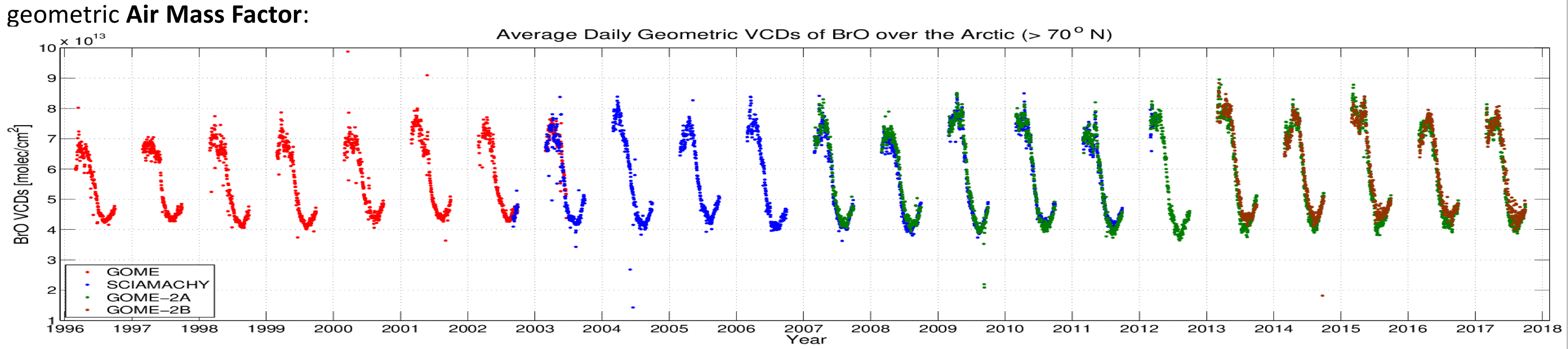

***Fig. 3**: 22 years of daily geometric BrO vertical columns from GOME, SCIAMACHY, GOME-2A & GOME-2B for the Arctic region*

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

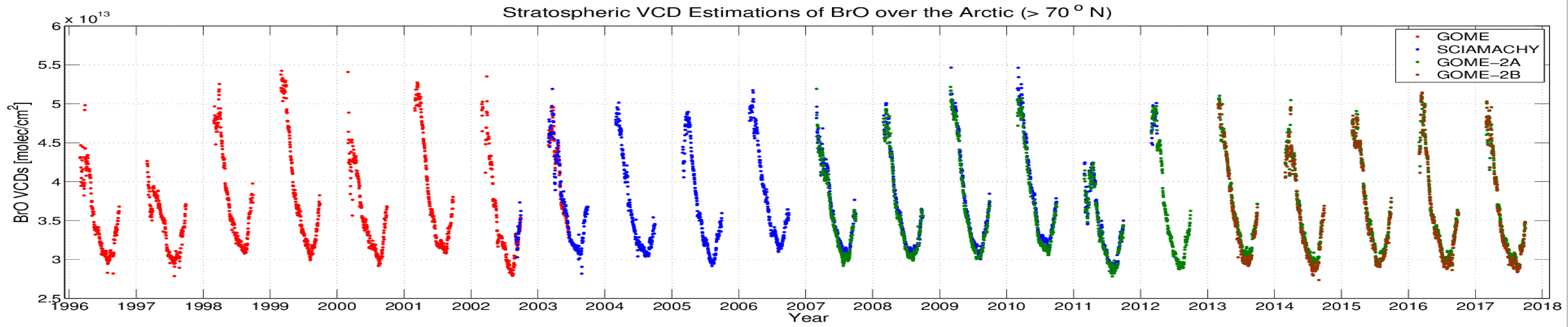

***Fig. 4**: 22 years of daily stratospheric BrO vertical column estimations, based on a BrO climatology model*

3. Tropospheric BrO in the Arctic & Relation to Sea Ice

- The formula that is used for the calculation of the **BrO tropospheric vertical column** is: $VCD_{tropo} = (SCD_{total} - VCD_{strato} \times AMF_{strato}) / AMF_{tropo}$ ***[3]***

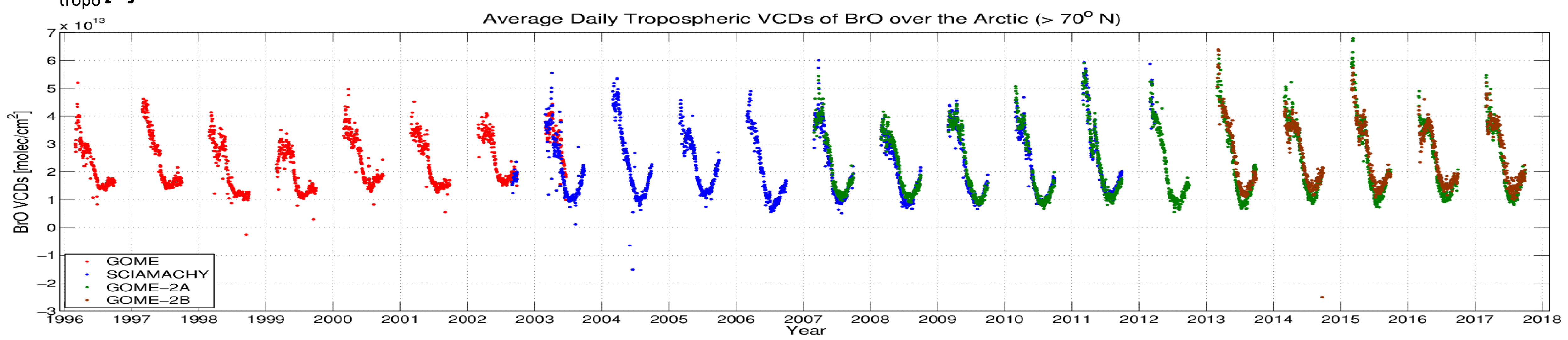

***Fig. 5**: 22 years of daily tropospheric BrO vertical columns from GOME, SCIAMACHY, GOME-2A & GOME-2B for the Arctic region*

- Tropospheric BrO maps provide additional information regarding the spatial distributions of BrO plumes; In the figure below, we see **polar spring (March, April & May, MAM)** mean BrO maps (merged between instruments, when we had an overlapping year) in the 1st row and the corresponding mean **MAM sea ice age maps *[7], [8], [9]*** (2nd row) for every year (columns):

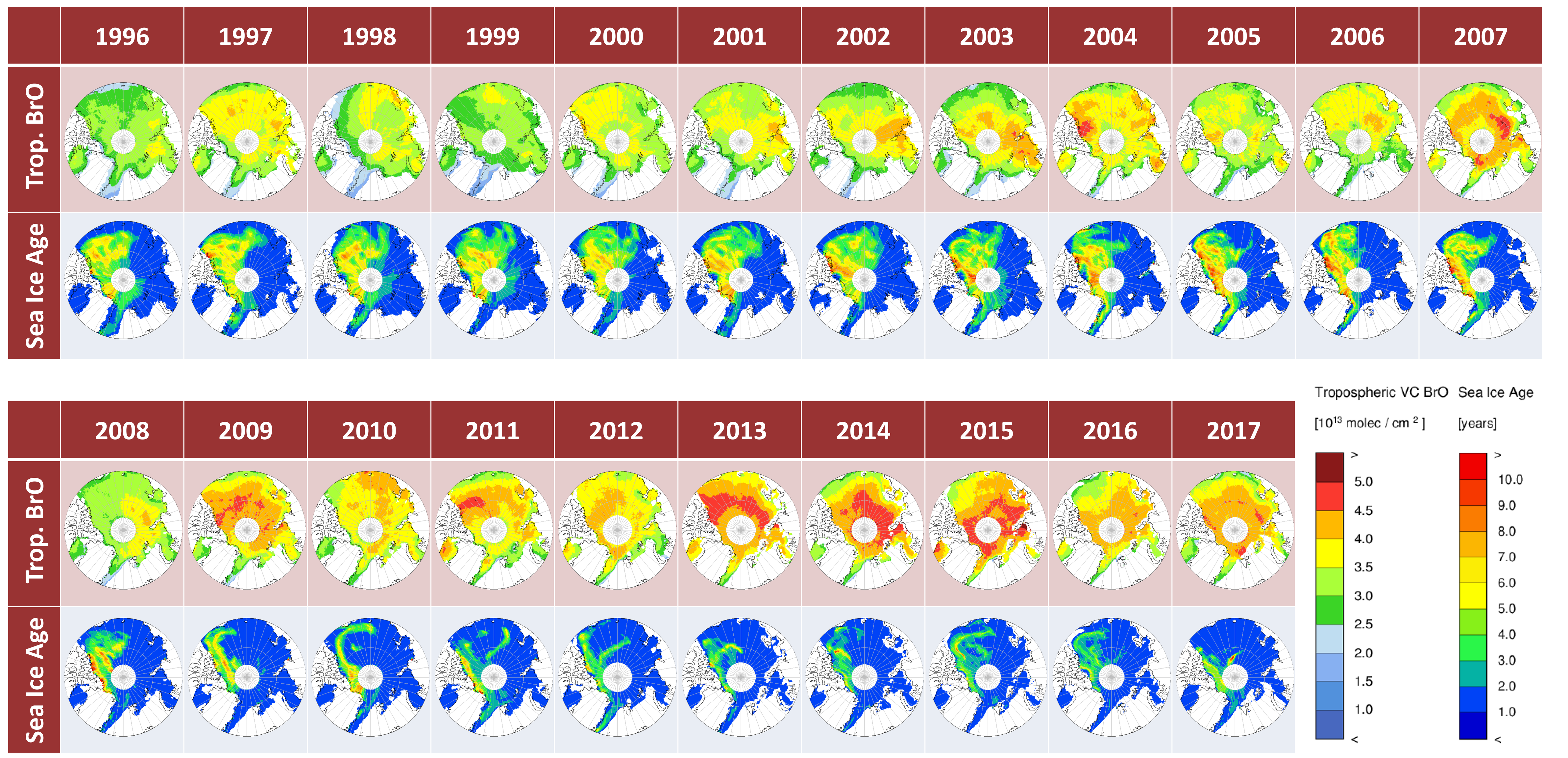

***Fig. 6**: Year to year evolution of tropospheric BrO and sea ice age in the Arctic region*

4. Conclusions & Outlook

- A consistent long-term Arctic BrO dataset was developed, by using four UV-VIS satellite instruments
- Our dataset demonstrates high agreement for the overlapping periods between the sensors
- By applying the stratospheric separation method, we extracted the first to our knowledge long-term tropospheric BrO dataset for the Arctic region
- Our tropospheric BrO time-series indicate that there is an increase of BrO explosion events over the latest years
- Furthermore, we see that the increase of first year ice covered regions may favor the increase of tropospheric BrO (also regarding the areas where it appears)

Future Work:

- Compare and evaluate the trends of our time-series
- Study the relationship of tropospheric BrO to meteorological drivers

5. References & Acknowledgements

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