Long-term Time-series of Tropospheric BrO over the Arctic Derived From Satellite Remote Sensing and its Relation to Driving Mechanisms under the Impact of Arctic Amplification (A51H-2766)

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1. Introduction & Motivation

- Air temperature in the Arctic increases twice the rate of the worldwide mean. This phenomenon is called **Arctic Amplification** ***[1]***.
- **Bromine** plays a key role in the **atmospheric composition** of the Arctic. 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), **depletes ozone** by production of bromine monoxides 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 derive a consistent long-term BrO satellite dataset in order to identify changes in tropospheric BrO amounts and the relation to changes in **sea ice** and meteorology (**air temperature, mean sea level pressure, wind speed and boundary layer height**) due to Arctic Amplification

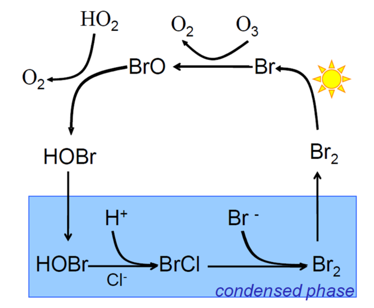

Fig. 1**: The bromine explosion (Figure from Jones et al., 2009)* ***[2]

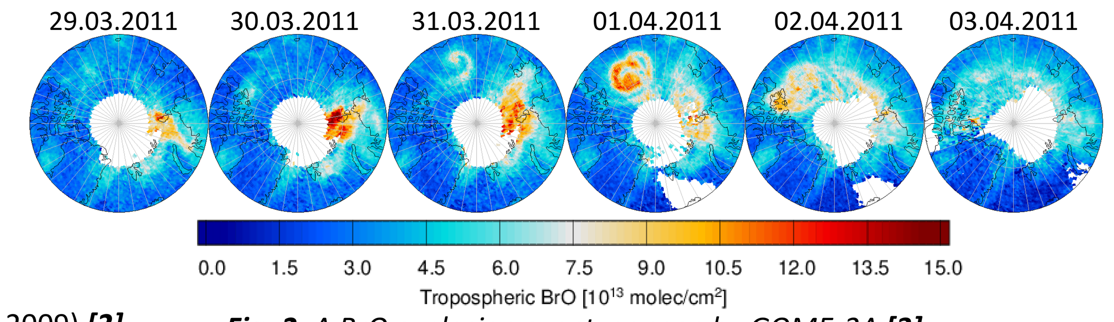

Fig. 2**: A BrO explosion event, as seen by GOME-2A* ***[3]

2. Long-term Time-series of Geometric & Tropospheric BrO Vertical Columns

- 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 km²	10.30	960 km	336.8 – 358
SCIAMACHY	Envisat	2002 – 2012	30X60 km²	10.00	960 km	336 – 347
GOME-2A	MetOp – A	2007 – present	80X40 km² (40X40 km²)	09.30	1920 km	337.5 – 357
GOME-2B	MetOp – B	2013 – present	80X40 km²	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**:

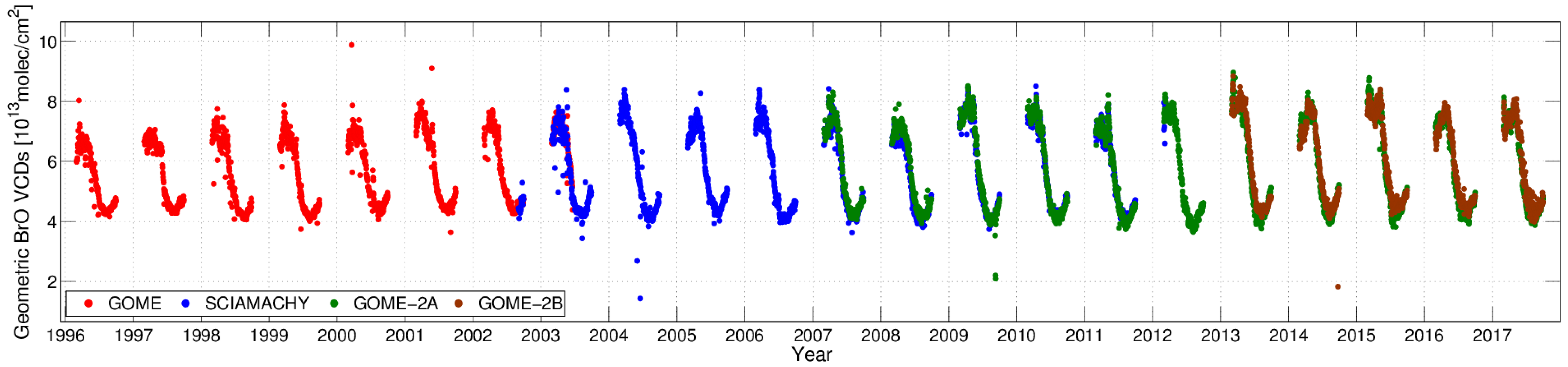

***Fig. 3**: 22 years of daily geometric BrO vertical columns over sea ice from GOME, SCIAMACHY, GOME-2A & GOME-2B for the Arctic region (>70°)*

- To extract the tropospheric BrO column from our retrievals, the method by Theys et al ***[4]*** is used, which takes as inputs satellite retrievals of **NO_2, O_3 & tropopause height, *[5], [6], [7]*** and gives an estimation of vertical columns of stratospheric BrO from a model BrO climatology. The formula to calculate the **BrO tropospheric vertical column** is: $VCD_{tropo} = (SCD_{total} - VCD_{strato} \times AMF_{strato}) / AMF_{tropo}$ ***[4]***:

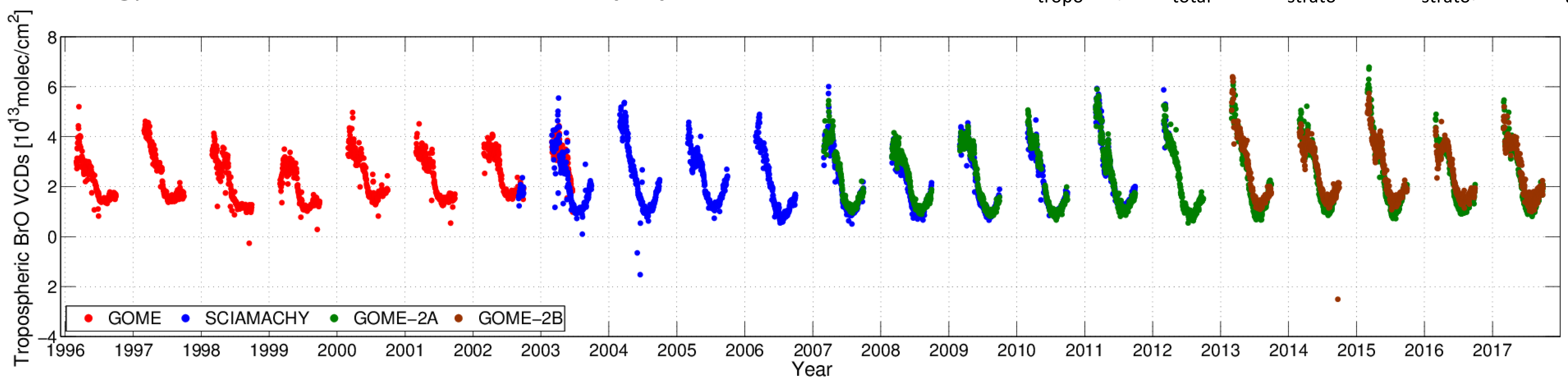

***Fig. 4**: 22 years of daily tropospheric BrO vertical columns over sea ice from GOME, SCIAMACHY, GOME-2A & GOME-2B for the Arctic region (>70°)*

3. Relation of Tropospheric BrO to its Driving Mechanisms

- In order to compare Arctic tropospheric BrO with its driving mechanisms, a **sea ice age dataset *[7]*** and two reanalyses datasets ***[8]*** & ***[9]***, including **air temperature, mean sea level pressure, wind speed** and **boundary layer height** were obtained and evaluated:

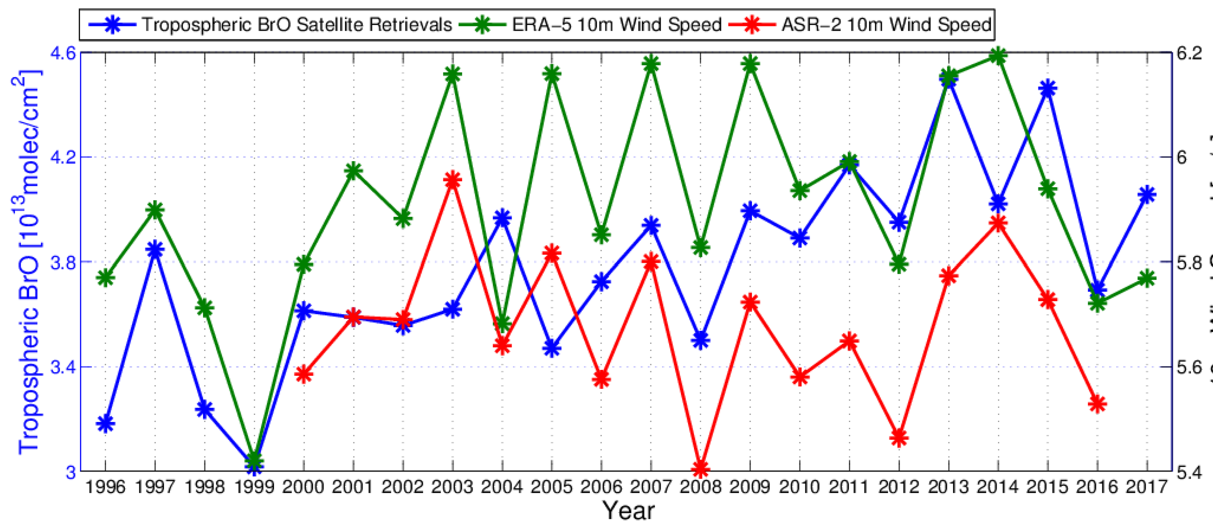

***Fig. 5**: Polar spring (MAM) averaged time-series between tropospheric BrO and 10m wind speed. Only data over sea ice is regarded.*

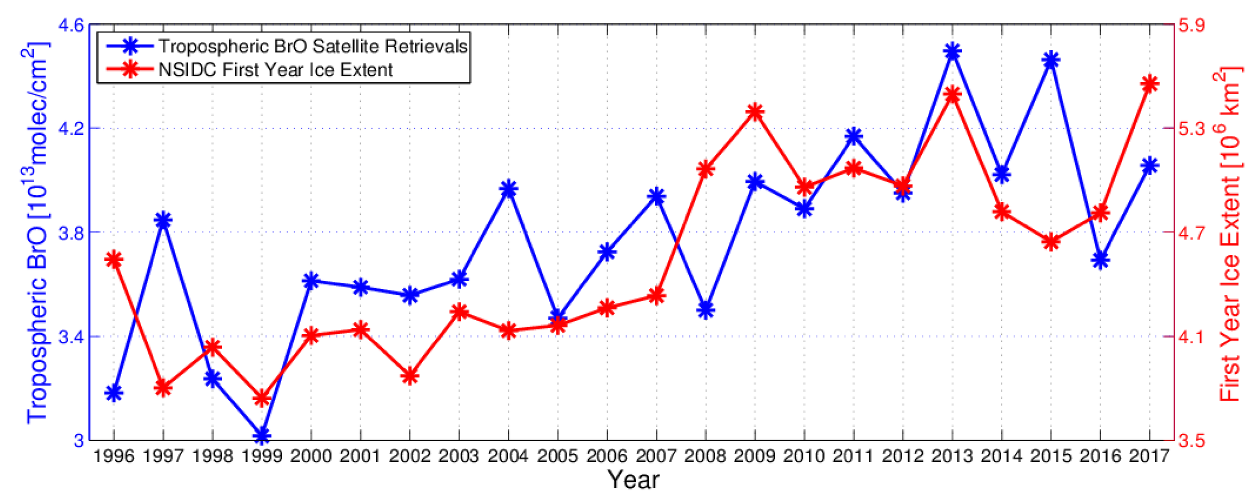

***Fig. 6**: Polar spring (MAM) averaged time-series between tropospheric BrO and first year ice extent. Only data over sea ice is regarded.*

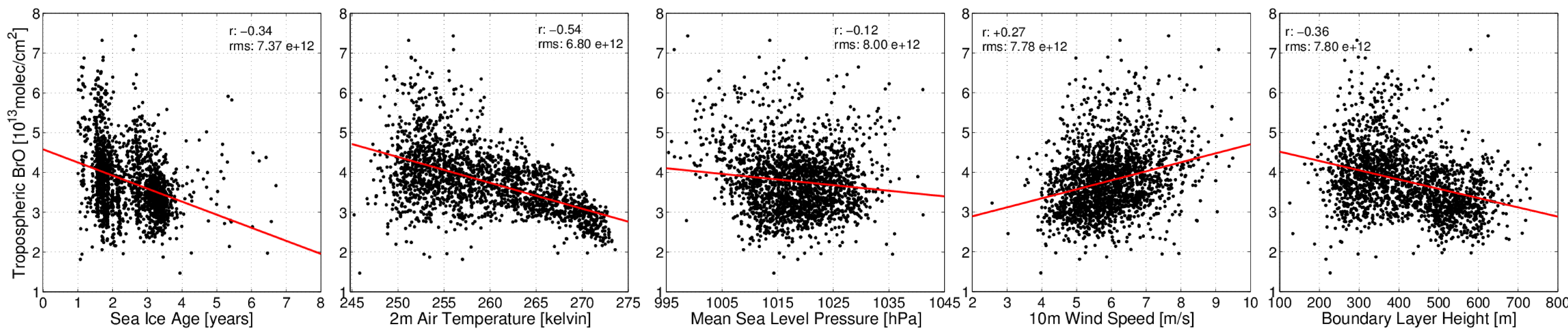

***Fig. 7**: Scatter plots between tropospheric BrO and its driving mechanisms, during polar spring period. Only data over sea ice is regarded*

- To further investigate the correlation between tropospheric BrO and its driving mechanisms, we have calculated the trend of every pixel for each one of them, during the 22 years of our study:

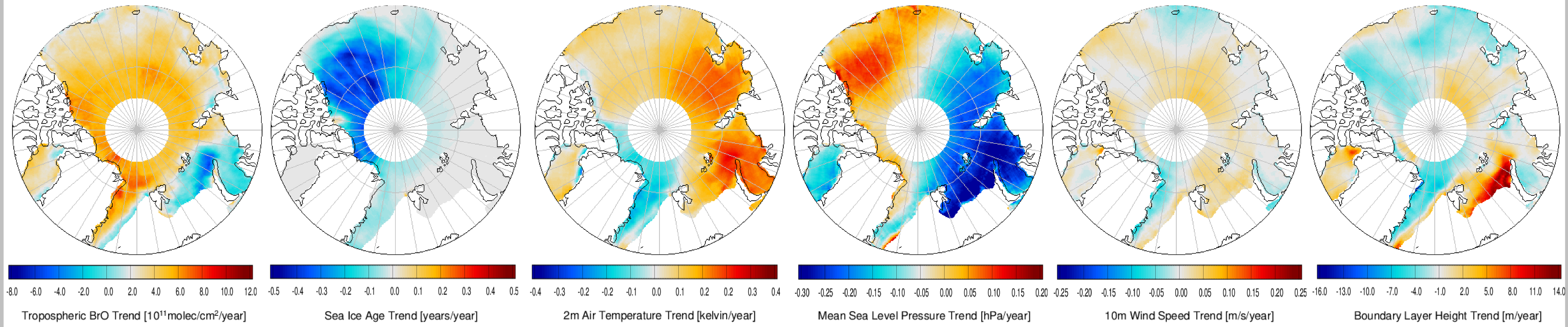

***Fig. 8**: Pixel-wise trend analysis of tropospheric BrO and its driving mechanisms, during polar spring period. Only data over sea ice is regarded*

4. Summary & Conclusions

- 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
- Our tropospheric BrO time-series indicates that there is an increase of BrO explosion events over the latest years (during polar springs)
- A similar increase can be observed for the first year ice extent
- The relation to wind speed is more complicated (it is known that BrO explosions appear in specific low and high wind speed weather conditions
- Air temperature shows the largest correlation to tropospheric BrO, but this does not necessarily mean it is the most important parameter
- The area east of Greenland, where tropospheric BrO has increased , shows good agreement with the evolution of its driving mechanisms
- Detailed case studies should follow to better understand the observed spatial and temporal changes

5. References & Acknowledgements

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