Investigating the Relationship between Arctic Tropospheric BrO retrieved using Satellite Remote Sensing and Sea Ice Age and Meteorological Parameters during Arctic Amplification (D3249)

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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 producing 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 use the consistent long-term BrO satellite dataset we developed ***[4]*** in order to identify changes in tropospheric BrO amounts and the relation to changes in **sea ice age** and meteorology (**air temperature, mean sea level pressure, wind speed and boundary layer height**) due to Arctic Amplification.

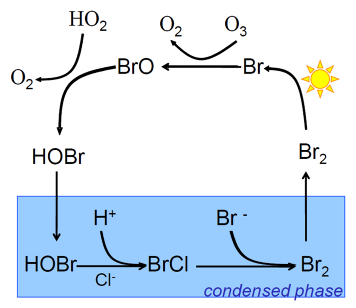

Fig. 1**: The bromine explosion* (Figure from Jones et al., 2009) ***[2]

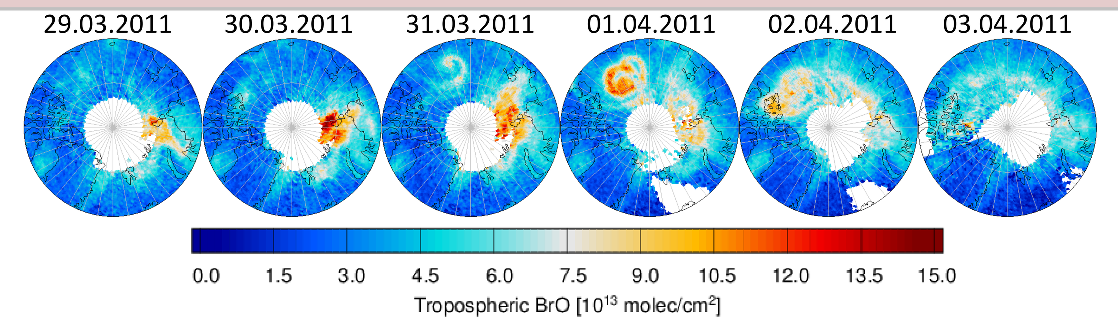

Fig. 2**: A BrO explosion event, as seen by GOME-2A* ***[3]

2. Long-term Time-series of BrO Vertical Columns & a Case Study

- 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**: $I = I_0 e^{-\int \sigma(\lambda) \rho ds}$

Instrument	Platform	Time Period	Footprint	Equatorial Overpass	Swath	Fitting Window
GOME	ERS-2	1996 – 2003	320X40 km²	10.30	960 km	336.8 – 358 nm
SCIAMACHY	Envisat	2002 – 2012	30X60 km²	10.00	960 km	336 – 347 nm
GOME-2A	MetOp – A	2007 – present	80X40 km² (40X40 km²)	09.30	1920 km (960 km)	337.5 – 357 nm
GOME-2B	MetOp – B	2013 – present	80X40 km²	09.30	1920 km	338 – 360 nm

- 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**. The tropospheric BrO column is extracted from the retrievals by using the Theys et al ***[5]*** method:

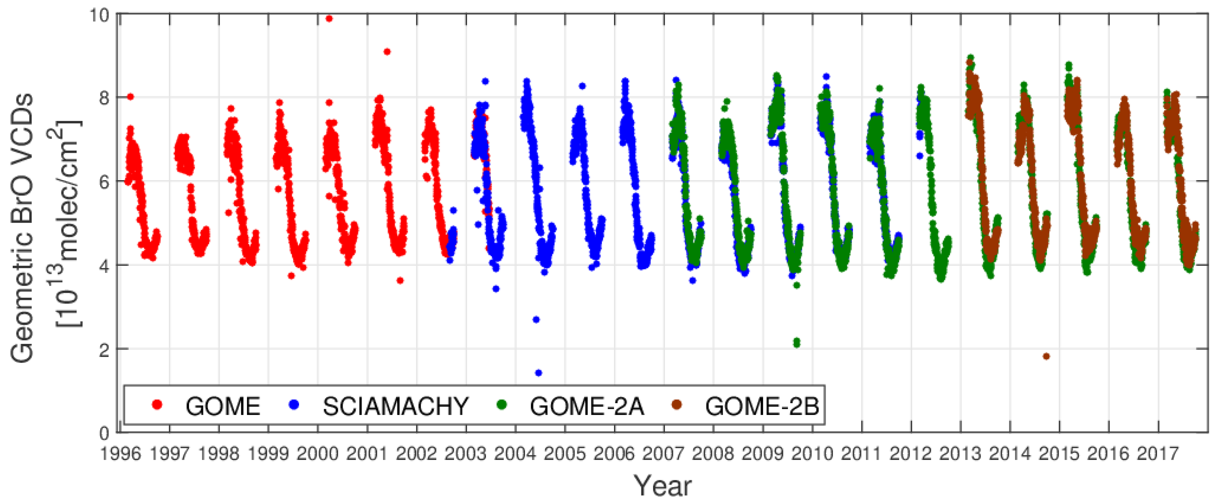

***Fig. 3**: 22 years of daily geometric BrO vertical columns over sea ice from **GOME**, **SCIAMACHY**, **GOME-2A** & **GOME-2B** for the Arctic region (>70° N). Only data over sea ice is regarded.*

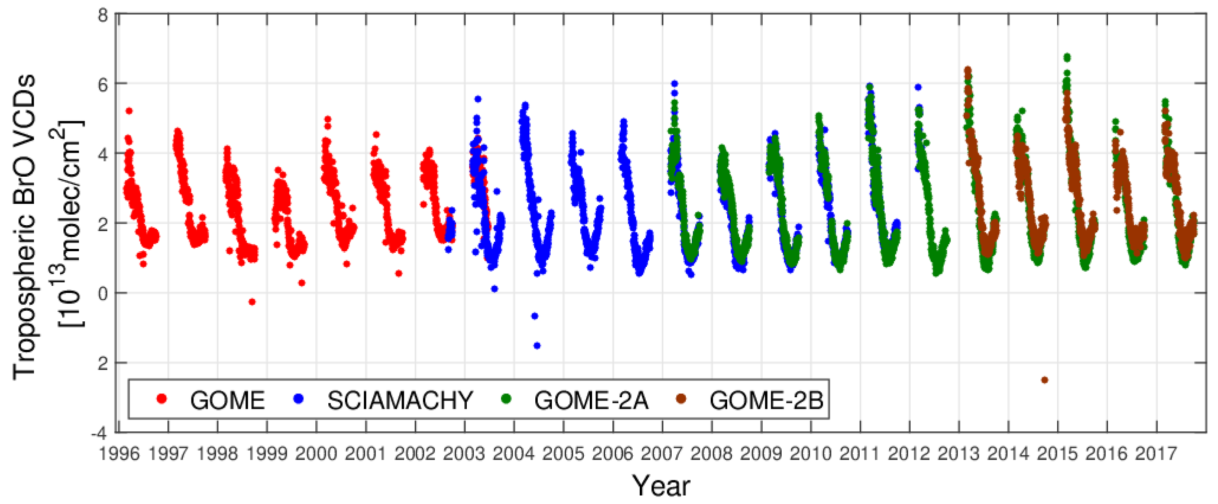

***Fig. 4**: 22 years of daily tropospheric BrO vertical columns over sea ice from **GOME**, **SCIAMACHY**, **GOME-2A** & **GOME-2B** for the Arctic region (>70° N). Only data over sea ice is regarded.*

- The comparison of tropospheric BrO and a **sea ice age dataset *[6]*** and two reanalyses datasets ***[7]*** &***[8]***, including **air temperature, mean sea level pressure, wind speed** and **boundary layer height** for a case study (01.04.2011) follows:

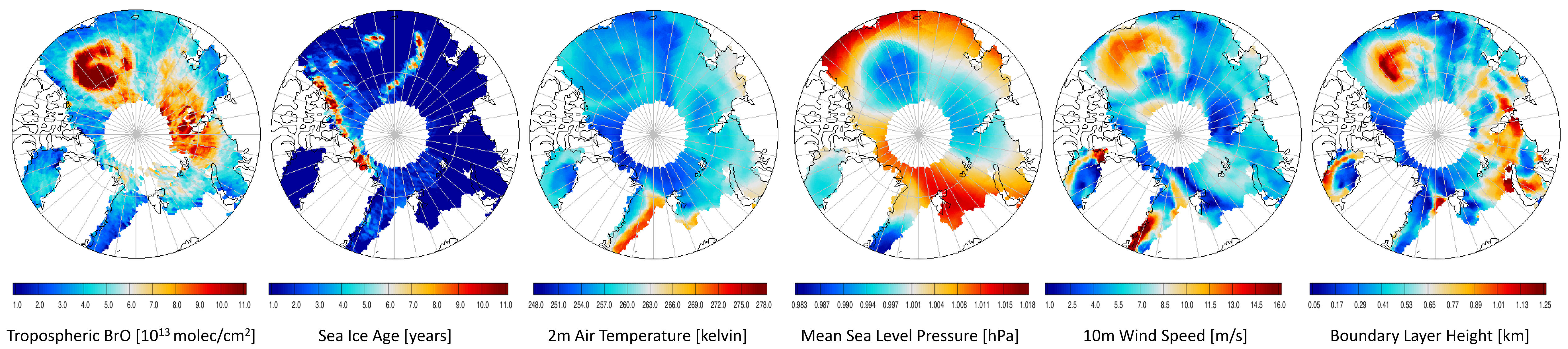

***Fig. 5**: Comparison of tropospheric BrO measurements and driving mechanisms for 01.04.2011. Only data over sea ice is regarded*

3. Long-term Relation of Tropospheric BrO to its Driving Mechanisms

- Time-series and scatter plots of tropospheric BrO and its driving mechanisms, in order to investigate their long-term relation, are shown below:

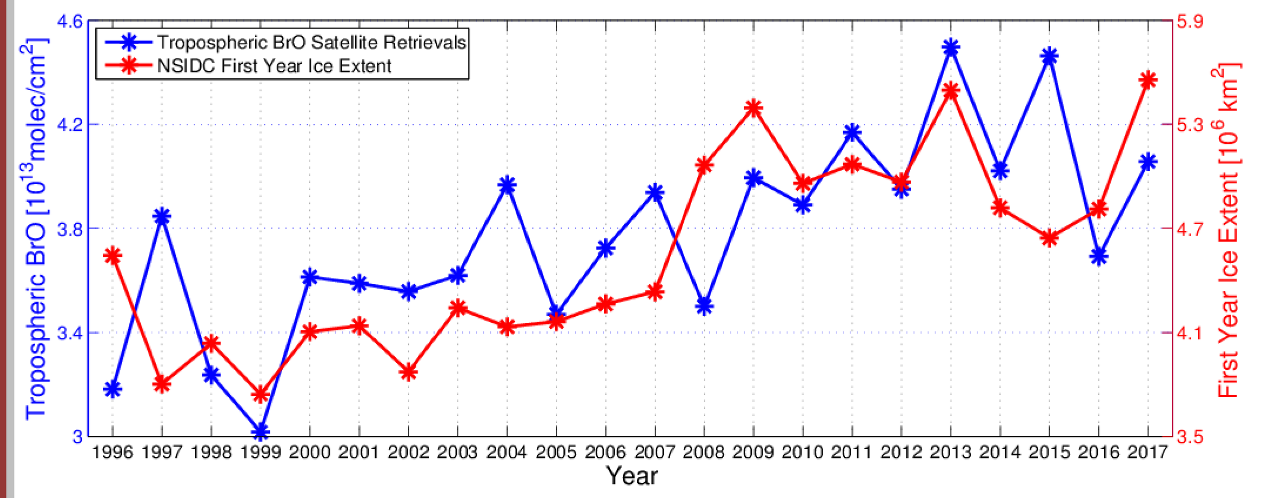

***Fig. 6**: Polar spring (MAM) averaged time-series between tropospheric BrO and first year ice extent. Only data over sea ice is regarded.*

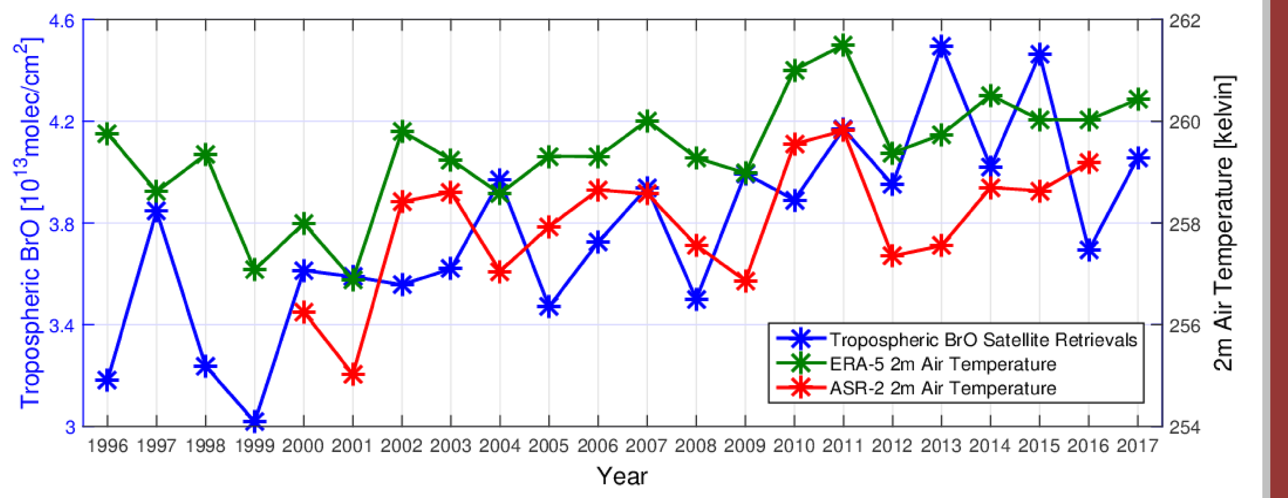

***Fig. 7**: Polar spring (MAM) averaged time-series between tropospheric BrO and 2m air temperature. Only data over sea ice is regarded.*

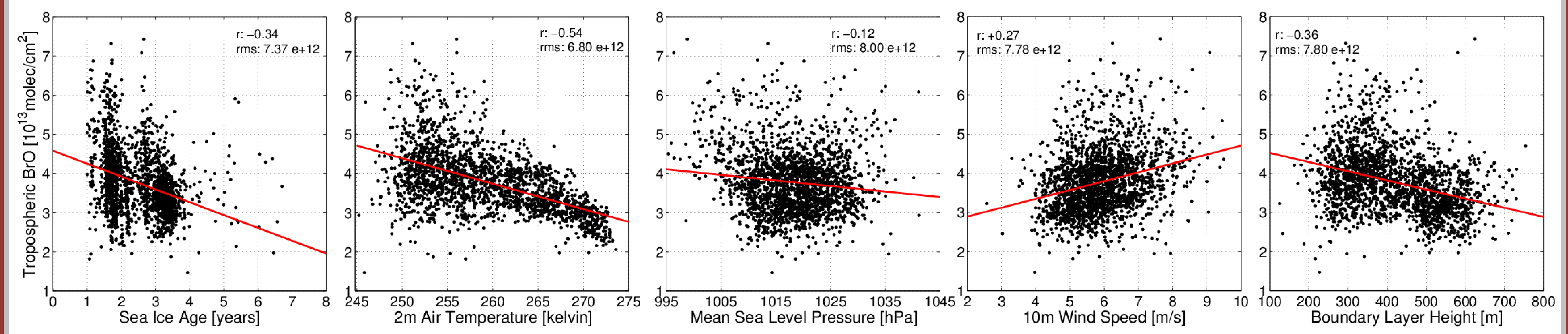

***Fig. 8**: Scatter plots between tropospheric BrO and its driving mechanisms, during polar spring period. Only data over sea ice is regarded*

- 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:

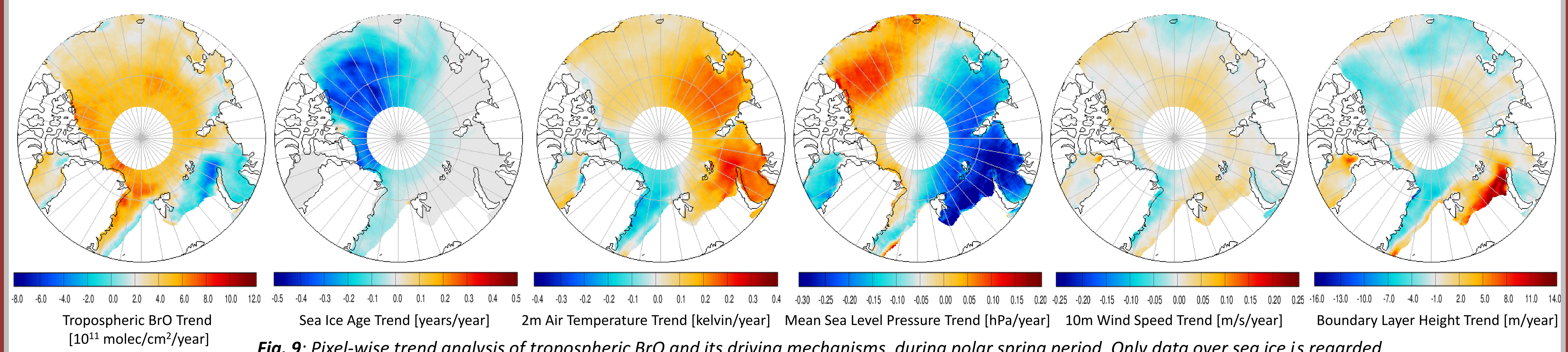

***Fig. 9**: Pixel-wise trend analysis of tropospheric BrO and its driving mechanisms, during polar spring period. Only data over sea ice is regarded*

4. Summary & Conclusions

- 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 case study investigation indicates strong relation of the **tropospheric BrO plume** with **low temperature**, **low pressure**, **high (and low) wind speeds** and **high boundary layer height**
- Air temperature shows the largest correlation to tropospheric BrO, but this does not necessarily mean it is the most important parameter
- The relation to wind speed is more complicated (it is known that BrO explosions appear in specific low and high wind speed weather conditions), showing a weak positive correlation
- The increase of BrO east of Greenland comes in agreement with the evolution of its driving mechanisms in the same area
- Further case studies should be investigated to identify the conditions under which BrO plumes are formed

5. References & Acknowledgements

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2. *A. E. Jones et al: BrO, blizzards, and drivers of polar tropospheric ozone depletion events (2009)*
3. *A.-M. Blechschmidt et al: An exemplary case of a bromine explosion event linked to cyclone development in the Arctic (2016)*
4. *I. Bougoudis et al:* Long-term Time-series of Arctic Tropospheric BrO derived from UV-VIS Satellite Remote Sensing and its Relation to First Year Sea Ice (2020)
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6. *M. Tschudi et al:* EASE-Grid Sea Ice Age, Version 4 (2019)
7. ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate (2017)
8. D. Bromwich: The Arctic System Reanalysis, Version 2 (2018)

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