Satellite Remote Sensing of Halogens in the Arctic Troposphere

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Introduction & Motivation

The warming trend in the Arctic is almost twice as large as the global average in recent decades. This is known as **Arctic Amplification**. The warming results in significant changes in various climate parameters. Changes in the extent and type of sea ice influence the inorganic production of **bromine** monoxide via a chemical chain reaction known as **bromine explosion**. Also organo-halogens (especially **iodine**) are released from phytoplankton and dissolved organic matter, which are also affected by the changing amount of ice. The halogen radicals play a key role in the chemistry of the Arctic troposphere, as they cause severe **ozone depletion**. Ozone is a major greenhouse gas and a precursor of hydroxyl radicals. As a result, changes in tropospheric concentrations of halogens will potentially have an impact on the **radiative properties and temperature**, as well as on the **oxidizing capacity** of the Arctic atmosphere.

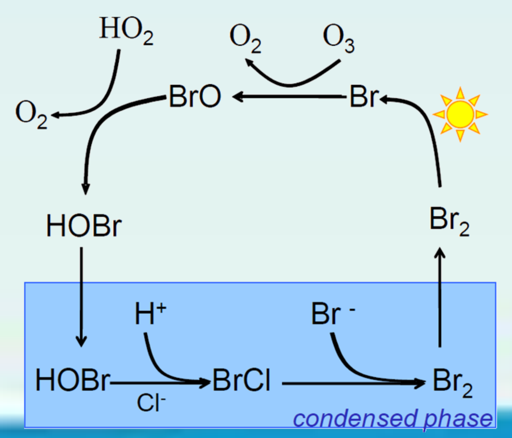

Figure 1: The Bromine Explosion ***(4)***

Objectives

Our objectives can be summarized as follows:

- Investigate if and how Arctic Amplification affected the tropospheric concentrations of halogens during the last 20 years
- Link the changes in concentrations to changes in halogen sources (sea ice coverage and type, phytoplankton)
- Study the relation between halogens and meteorological parameters crucial for their release (temperature, wind speed)

To assess these goals, we will develop a consistent long term halogen dataset from the instruments shown below:

Instrument	Equator Passing Time	Time Period	Footprint
GOME	10.30 AM	1996 – 2003	40X320 km^2
SCIAMACHY	10.00 AM	2002 - 2012	30X60 km^2
GOME-2	09.30 AM	2007 – Present	40X80 km^2
OMI	01.45 PM	2004 – Present	13X24 km^2
TROPOMI	01.30 PM	2017	7X7 km^2

Methodology

In order to obtain meaningful information from the initial satellite data, the well known **DOAS** method **(5)** (Differential Optical Absorption Spectroscopy) is applied, which is based on **Beer – Lambert's absorption law**:

$$I(\lambda,s) = I_o e^{-\sigma(\lambda)\rho s}, \text{ where:}$$

I_o the initial radiance

$\sigma(\lambda)$ the absorption cross section

ρ the number density

s the light path

By applying the DOAS method, we acquire Total **Slant Column Densities** (SCDs). In order to compute **Vertical Column Densities** (VCDs), we divide the Slant Column with an **Air Mass Factor** (AMF):

$$VCD_{total} = SCD_{total} / AMF$$

Results

In the figures below we can see the average evolution of BrO on a daily and a monthly basis for both satellite instruments. The daily averages are presented for the overlapping period of the two instruments (January 2007 - April 2012), while the monthly averages from August 2002 – July 2016.

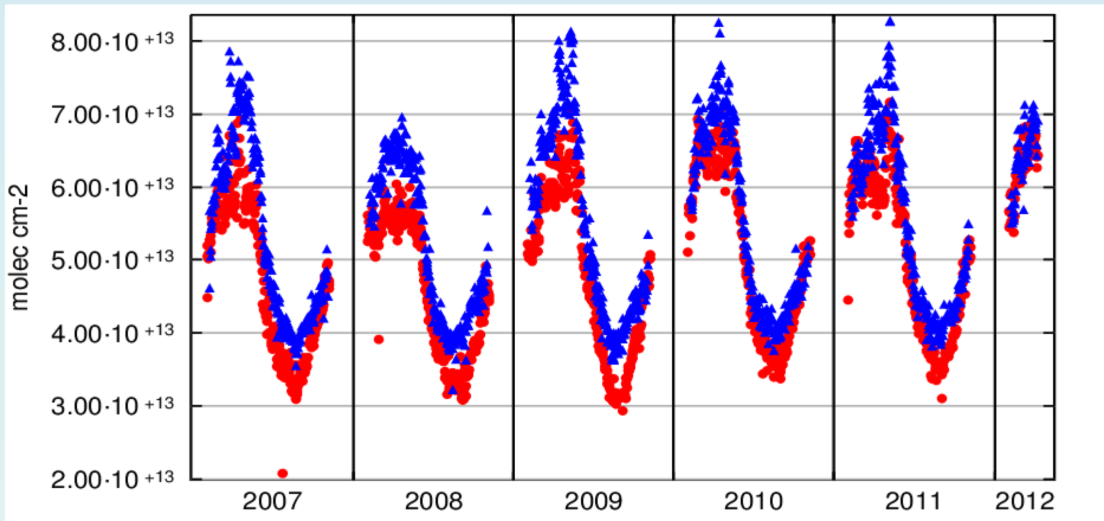

Figure 2: *Average Daily BrO VCDs timeseries for the Arctic region (SCIAMACHY with blue, GOME-2 with red), (molecules/cm^2), (70º – 90º latitude)*

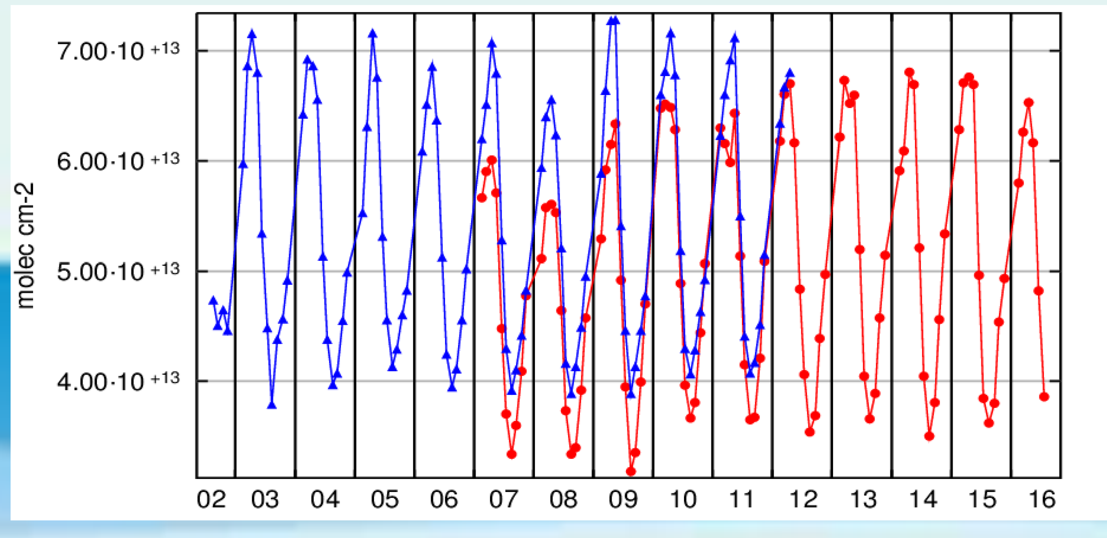

Figure 3: *Average Monthly BrO VCDs timeseries for the Arctic region (SCIAMACHY with blue, GOME-2 with red), (molecules/cm^2), (70º – 90º latitude)*

Also, some comparison maps from the Arctic spring months are presented. In each figure, GOME-2 VCDs are subtracted from SCIAMACHY VCDs.

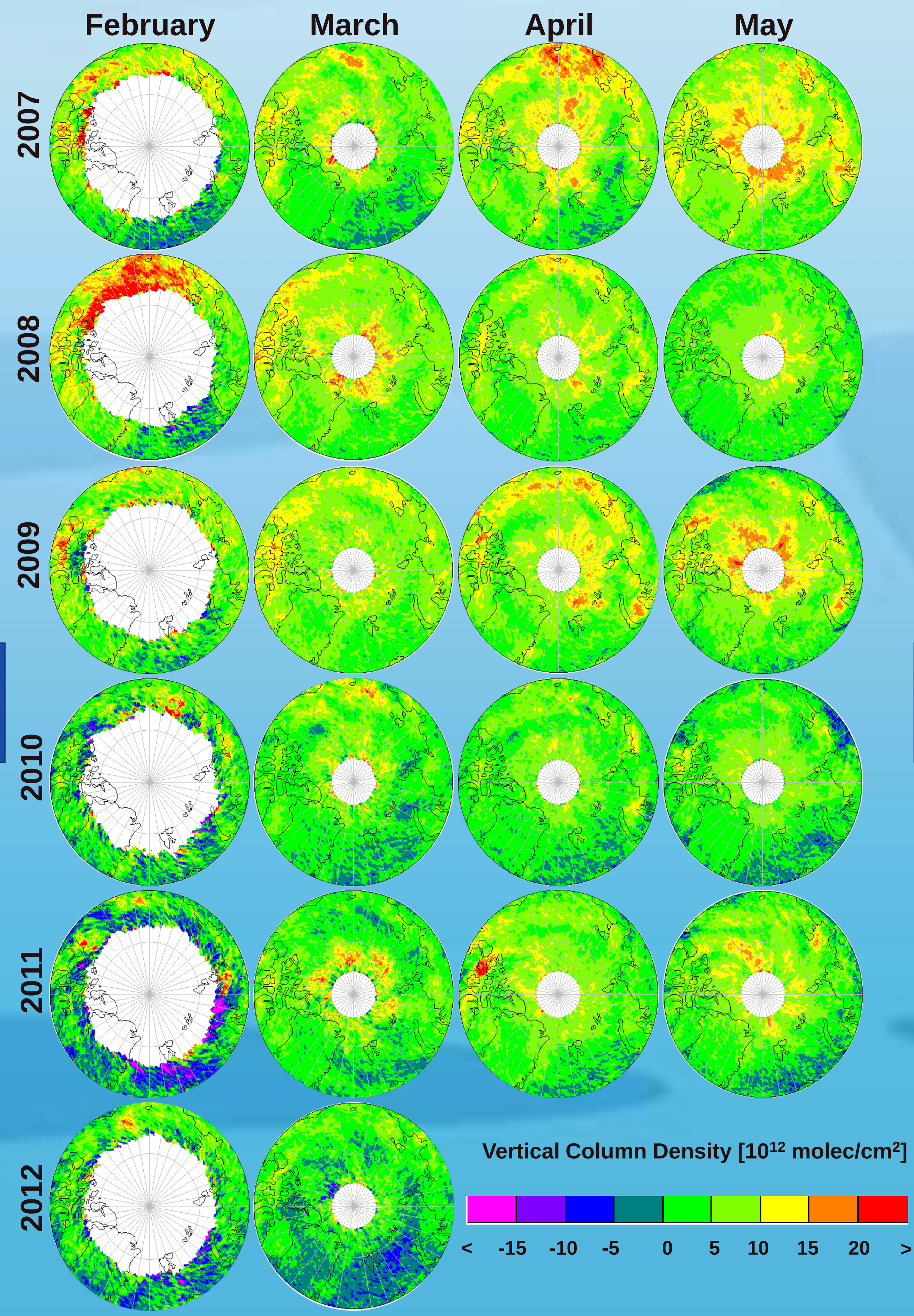

Figure 4: *SCIAMACHY – GOME-2 subtraction VCDs of BrO in the Arctic region (70º – 90º latitude)*

Conclusion & Future Goals

Through the intercomparison of the two instruments' columns we can come to the following conclusions:

- We observe inconsistencies between the two instruments, not only in the values, but also in the changes from year to year; SCIAMACHY maximum spring time monthly values tend to increase from 2009 to 2012, while the GOME-2 corresponding values show a different trend
- The SCIAMACHY based columns are higher in most cases than those of GOME-2. This is unexpected in the SCDs, because GOME-2 has a wider swath than SCIAMACHY. This effect is corrected by applying the AMF to the SCDs. As a result, we believe that the higher values of SCIAMACHY in the VCDs are due to the already higher values in the SCDs

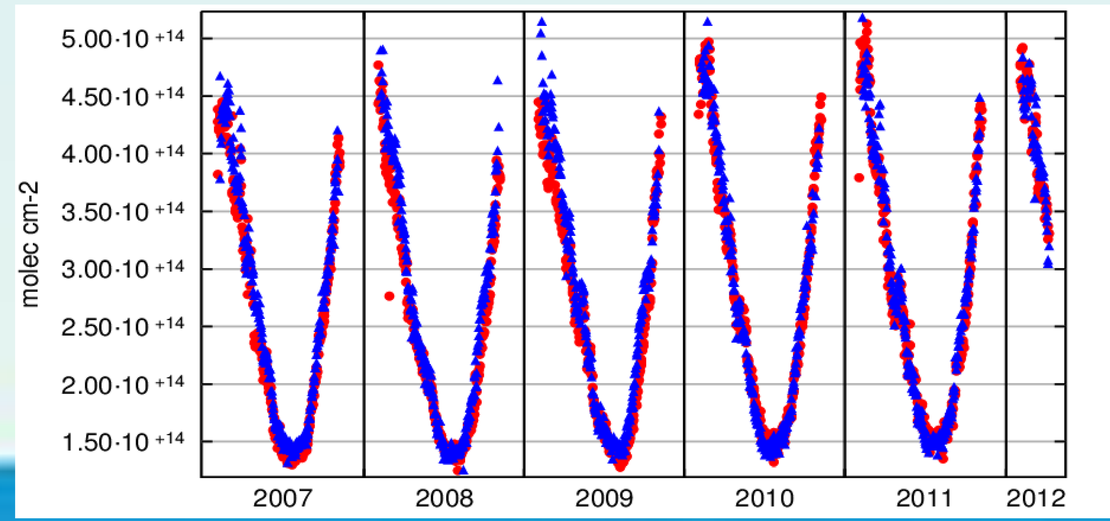

Figure 5: *Average Daily BrO SCDs timeseries for the Arctic region (SCIAMACHY with blue, GOME-2 with red), (molecules/cm^2), (70º – 90º latitude)*

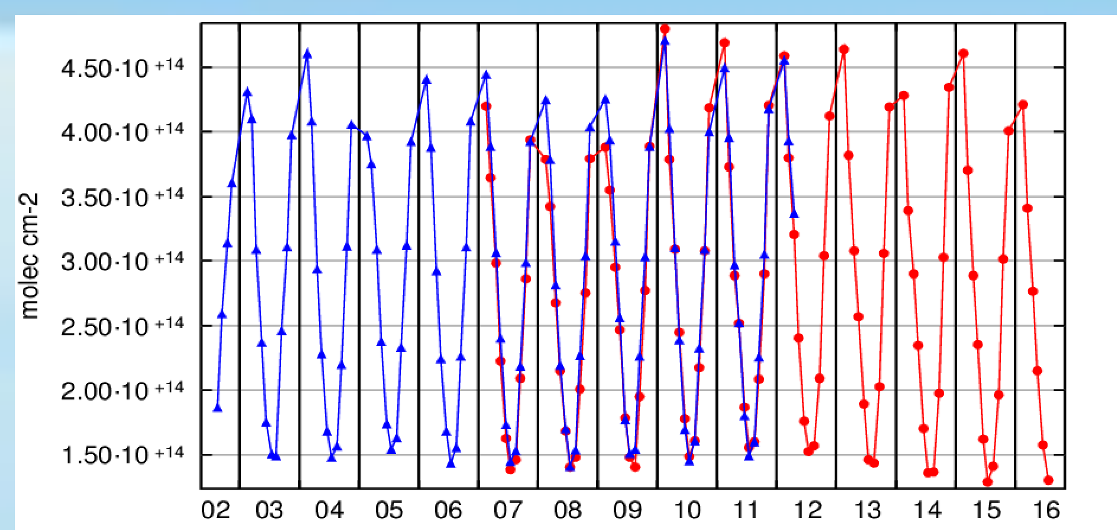

Figure 6: *Average Monthly BrO SCDs timeseries for the Arctic region (SCIAMACHY with blue, GOME-2 with red), (molecules/cm^2), (70º – 90º latitude)*

Our future goals can be summarized as follows:

- The retrieval of the SCDs should be re-performed for both instruments (currently working task); different parameters (e.g. absorption cross sections, fitting windows) and settings should be tested in order to obtain consistent datasets
- The AMF calculation needs improvement (better BrO profiles, better Albedo, better viewing angle correction)

Selected References & Acknowledgement

(1) A.-M. Blechschmidt et al: An exemplary case of a bromine explosion event linked to cyclone development in the Arctic (2016)

(2) John P. Burrows et al: The Remote Sensing of Tropospheric Composition from Space, Chapter 1

(3) A. Richter et al: GOME measurements of stratospheric and tropospheric BrO

(4) A. E. Jones et al: BrO, blizzards, and drivers of polar tropospheric ozone depletion events

(5) U. Platt et al: Measurements of Atmospheric Trace Gases by Long Path Differential UV/Visible Absorption Spectroscopy

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