The use and usability of tropospheric constituents, retrieved from the measurements of GOME and SCIAMACHY and the potential applications of GeoTROPE

J.P. Burrows, H. Bovensmann, M. Buchwitz, S. Noël, A. Richter, V. Rozanov, and F. Wittrock
Institute of Environmental Physics, University of Bremen – P. O. Box 330440, D-28334 Bremen, Germany – burrows@iup.physik.uni-bremen.de
L. Kaleschke
Institute of Oceanography, University of Hamburg, Germany

Introduction

In the last decade, the first demonstration of the ability to retrieve the amounts and distributions of tropospheric trace constituents from space is providing the atmospheric chemistry community with a new wealth of information for research in air quality, transport and transformation of pollution, the carbon budget and climate change. The global and largescale regional views of atmospheric constituents test our current understanding and constrain our models of the physical and chemical behaviour of the atmosphere. The observations of GOME (Global Ozone Monitoring Experiment) and SCIAMACHY (Scanning Imaging Absorption spectrometer for Atmospheric CartographY), two passive remote sounding spectrometers flying in sun synchronised orbits, have provided trail blazing observations. These instruments yield data in the early morning. In the future we require geostationary measurements to provide high spatial and temporal sampling e.g. the proposal GeoTROPE.

Fig 1: ERS-2/ENVISAT tandem flight (from pictures kindly provided by ESA), adapted from NDAAC website.

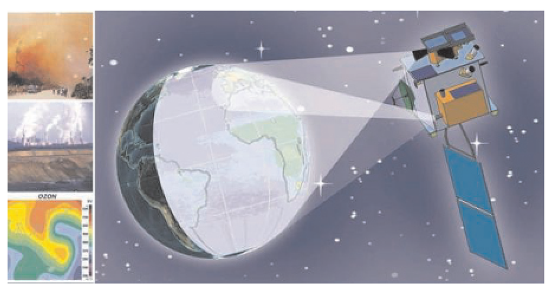


Fig 2: GeoSCIA on GeoTROPE satellite, http://www.iup.uni-bremen.de/geotrope .

Experiments

GOME is a smaller scale version of SCIAMACHY and both measure the up-welling radiation from the top of the atmosphere. GOME flies on board ESA's second European research satellite, ERS-2, and it measures simultaneously the entire spectral region from 230-793 nm at spectral resolutions between 0.2 and 0.4 nm in nadir viewing geometry. SCIAMACHY measures the spectral region contiguously from 214 to 1750 nm at resolutions between 0.2 and 1.4 nm, and two bands 1940-2040 nm and 2265-2380 nm. It measures alternately in limb and nadir viewing during an orbit and solar and lunar occultation. ERS-2 was launched in April 1995 and GOME made global measurements from July 1995 until June 2003, when the tape recorder on ERS-2 failed, it now downlinks 30-40% of its data. ENVISAT was launched on the 28th of February 2002 and SCIAMACHY is making global measurements since the beginning of August 2002.

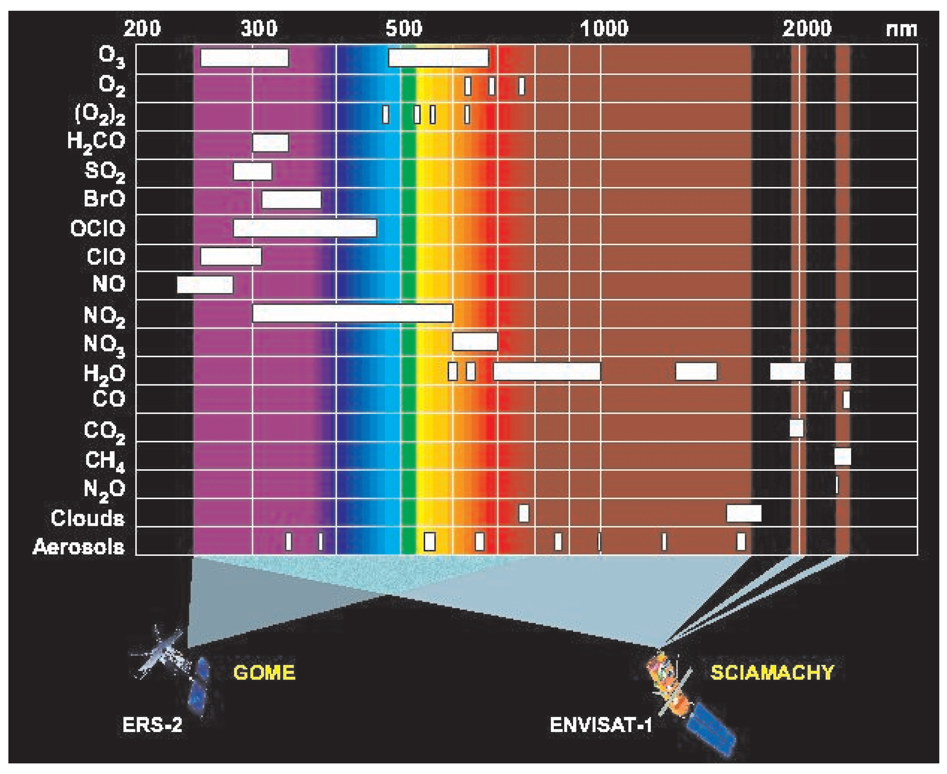


Fig 3: Spectral coverage of instruments used in this study.

Selected Results

Air Pollution

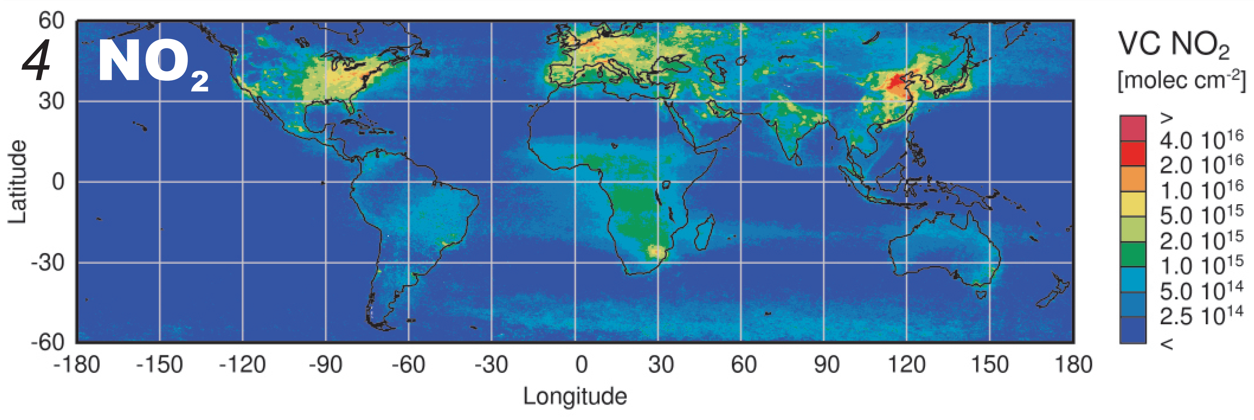


Fig 4: Annual mean of tropospheric NO_2 derived from SCIAMACHY measurements in 2005. The highly variable NO_2 is one key species in the troposphere. It catalyzes ozone production, contributes to acidification and also adds to radiative forcing. The main sources of NO_2 are anthropogenic in origin, e.g. industry, power plants, traffic and forced biomass burning. Other origins comprise natural biomass burning, lightning and microbiological soil activity. With the GOME time series starting in 1995, a first global long-term data set of tropospheric NO_2 has been created. By extending this time series with SCIAMACHY, OMI and GOME-2 data, more than two decades of continuous and consistent measurements will become available.

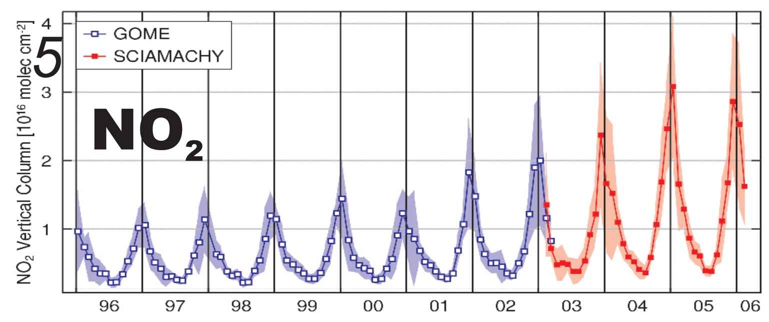
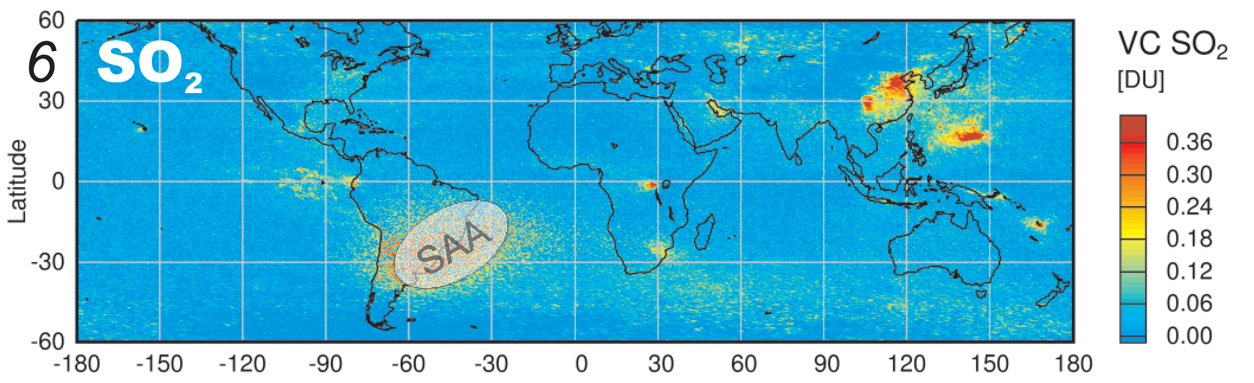


Fig 5: GOME and SCIAMACHY NO_2 above East Central China. The increase in NO_2 columns over China is related to the rapid economic development and increasing use of fossil fules (Richter et al., 2005).

SO_2 is another pollutant that can be observed using GOME and SCIAMACHY spectra. **Fig 6** shows the retrieved annual mean for 2005. Sources of SO_2 are combustion of sulfur rich coal and other fossil fuels or volcanic eruptions including degassing. Although SO_2 emissions have been reduced significantly over the last decades, clear signals can be detected in particular over the polluted areas in China. As in the case for NO_2, the improved spatial resolution of new-generation satellite instruments such as SCIAMACHY facilitates source identification and makes the data set an interesting new data source for air quality measurements.



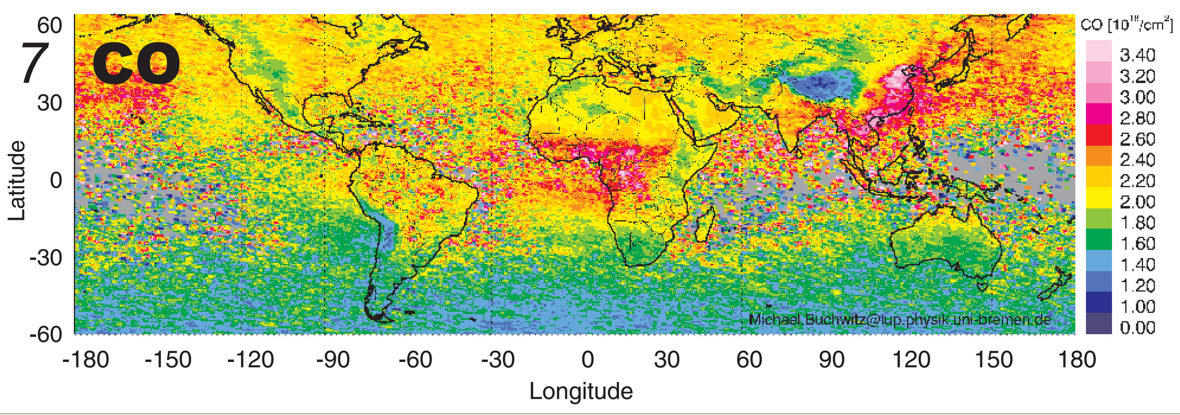
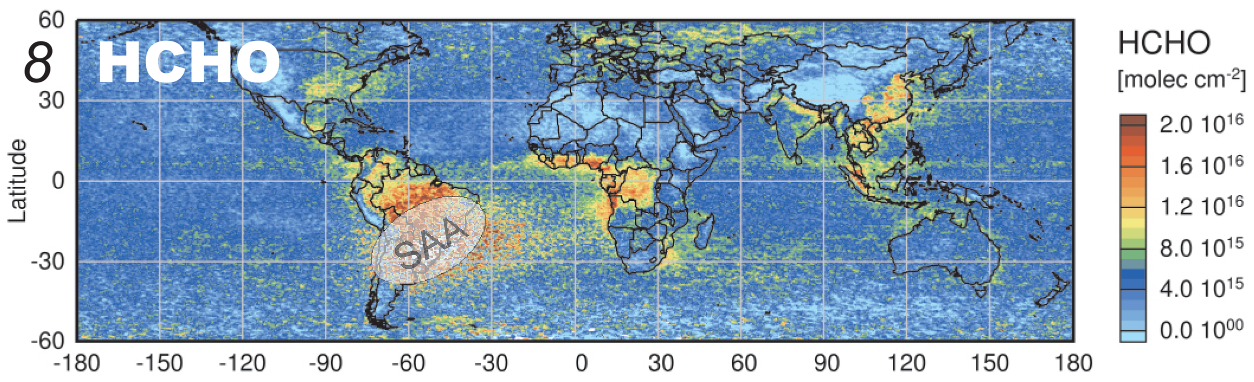


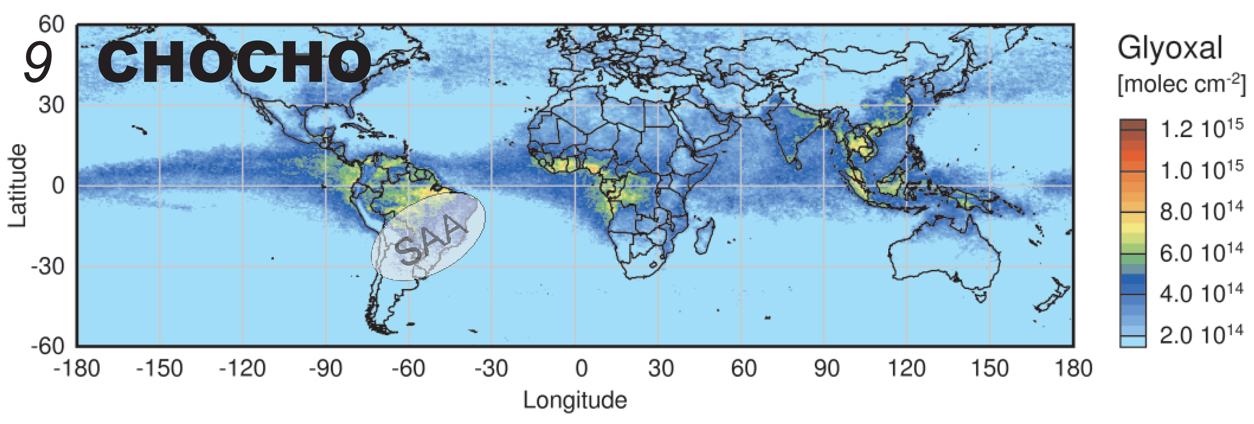
Fig 7 shows a global map of the year 2004 **CO** columns. Clearly visible are major source regions located e.g. in central Africa and south-east Asia. CO plays a central role in tropospheric chemistry. It is of prime importance for the troposphere's self-cleansing efficiency and also has a large air quality impact because it is a precursor of tropospheric ozone.

Biogenic Emissions

Fig 8 shows the 2005 annual mean of **HCHO**. Formaldehyde is mainly produced from the oxidation of methane and other hydrocarbons and has an average lifetime of a few hours. The highest values occur above regions with evergreen broadleaf forests near to the equator due to the oxidation of biogenic VOC emissions, mainly isoprene. Other areas with enhanced values of HCHO are those with strong air pollution, e.g. the Red Basin in China, or with regular biomass burning, e.g. woodland and wooded grassland in Africa.



SCIAMACHY is the first instrument which provides a global picture of the glyoxal (**CHOCHO**) distribution. **Fig. 9** shows again the 2005 annual mean. CHOCHO is another representative of VOC and is known to be formed during the oxidation of a variety of biogenic emissions, e.g. isoprene, and of aromatic hydrocarbons. Global observations of glyoxal, coupled with those of NO_2 and HCHO, will help to identify photochemical hot spots in the Earth's atmosphere (Wittrock et al., 2006).



Climate

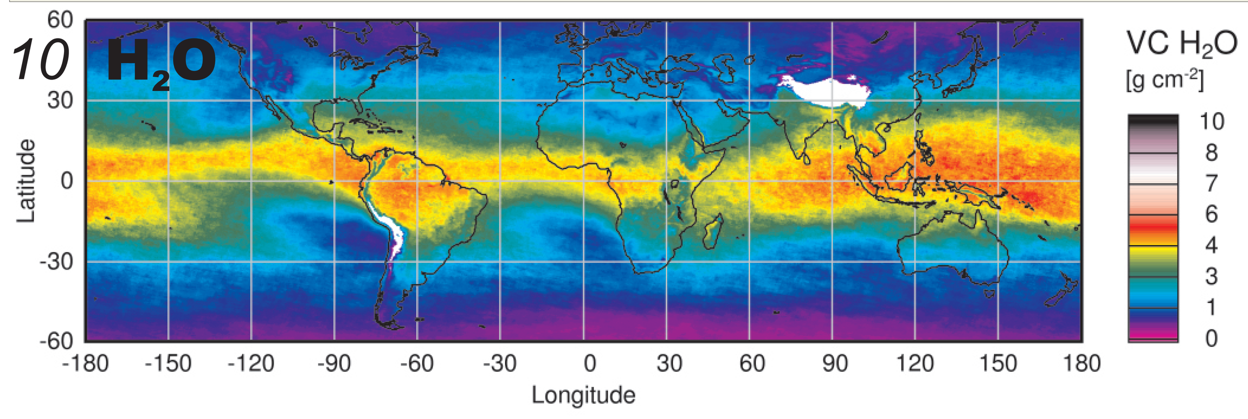
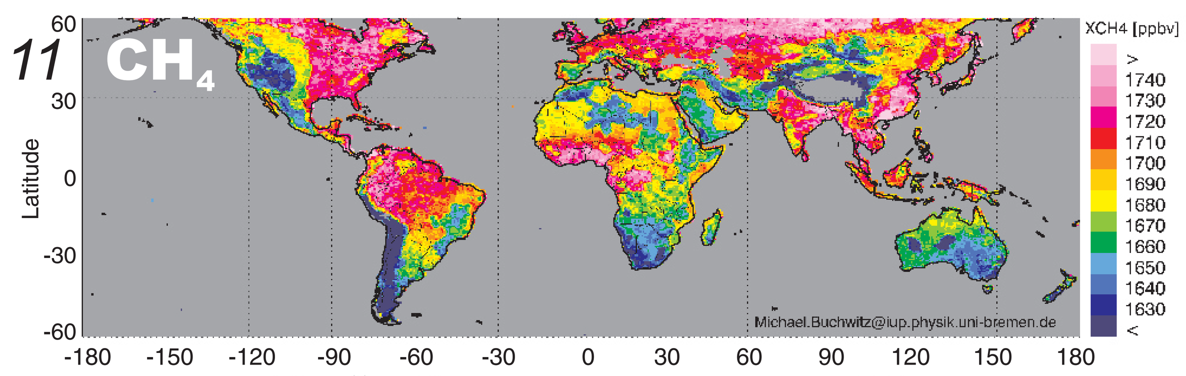


Fig 10: Annual global mean of H_2O in 2004 retrieved from SCIAMACHY measurements. Water vapour is one of the most abundant atmospheric constituents and in fact the most important greenhouse gas. More than 99% of water vapour is located in the troposphere where it significantly contributes to atmospheric chemistry, weather, and climate. Its large spatial and temporal variability makes water vapour a tracer for tropospheric changes and especially important for global models which aim to predict climate. The high relevance of water vapour has generated the need for global water vapour data of high quality (Noël et al., 2004).



Methane is considered to be the second most important anthropogenic greenhouse gas after carbon dioxide and is also regulated by the Kyoto protocol. **Fig 11** shows dry-air column averaged mixing ratios of methane for the year 2003. Major source regions of methane are clearly visible, e.g., northern hemispheric wetland regions, India and south-east Asia, and over large parts of the tropics. Here retrieved CH_4 columns are much higher than expected. The retrieval quality is currently only reliable over land since low reflectivity complicates analysis over oceans.

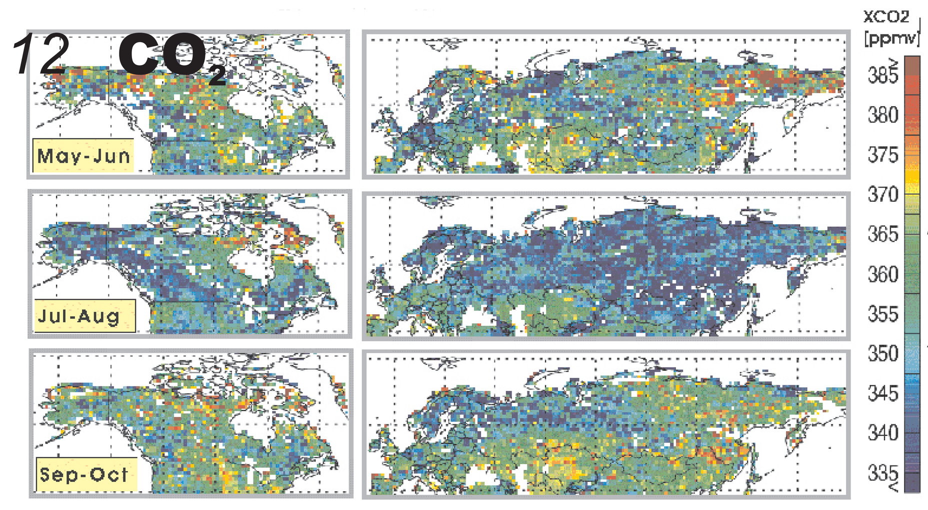
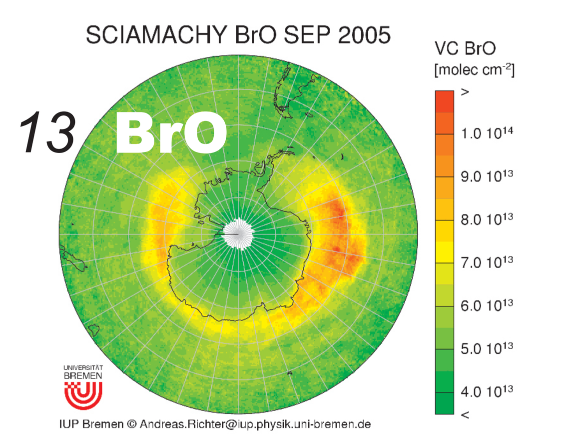
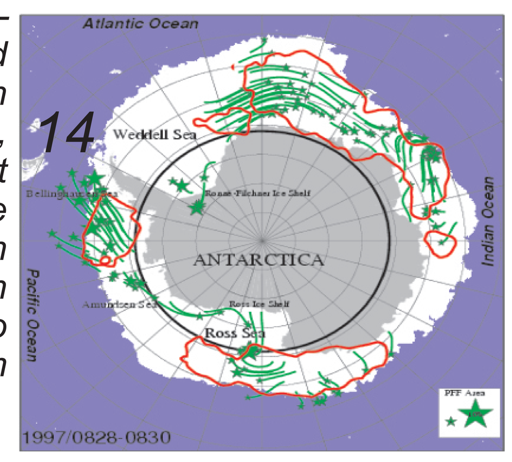


Fig 12 shows averaged mixing ratios of CO_2, the most important anthropogenic greenhouse gas, over the northern hemisphere. The mixing ratios of CO_2 are typically lower in July-August compared to May-June and September-August mainly due to uptake of atmospheric CO_2 by growing vegetation. The measured variability is significantly higher than corresponding model simulations emphasising the need for high quality observations to understand the global carbon cycle (Buchwitz et al., 2005 and 2006).

Tropospheric Halogens

During polar spring, strong increases of BrO-concentrations, the so called bromine explosions, are frequently observed by the GOME and SCIAMACHY satellite instruments (e.g. **Fig 13**). The elevated levels of bromine are correlated with the sudden depletion of ozone. Up to now, the mechanism of bromine release is not yet understood in detail. However, the conditions under which such events are observed coincide with those, where frost flowers grow (on fresh sea ice at very low air temperatures). This lead to the hypothesis of bromine release by frost flowers in an autocatalytic cycle [Kaleschke, 2004], and in fact areas of high BrO are highly correlated to regions where frost flowers can potentially form (PFF - **Fig 14**)





Further Reading

Bovensmann, H., J. P. Burrows, M. Buchwitz, J. Frerick, S. Noël, V. V. Rozanov, K. V. Chance, A. P. H. Goede 1999, "SCIAMACHY- Mission Objectives and Measurement Modes", Atmospheric Sciences 56 127-150.

Burrows, J.P., M. Weber, M. Buchwitz, V. V. Rozanov, A. Ladstätter, Weißenmayer, A. Richter, R. DeBeek, R. Hoogen, K. Bramstedt and K.U. Eichmann 1999, "The Global Ozone Monitoring Experiment (GOME): Mission Concept and First Scientific Results", J. Atmospheric Sciences 56 pp 151-175.

Richter, A., Burrows, J. P., Nüß, H., Granier, C., Niemeier, U., Increase in tropospheric nitrogen dioxide over China observed from space, Nature, 437, 129-132, doi: 10.1038/Nature04092, 2005.

Kaleschke, L., A. Richter, J. P. Burrows, O. Afe, G. Heygster, J. Notholt, A. M. Rankin, H. K. Roscoe, J. Hollwedel, T. Wagner, H.-W. Jacobi, Frost flowers on sea ice as a source of sea salt and their influence on tropospheric halogen chemistry, Geophys. Res. Lett., 31, L16114, doi:10.1029/2004GL020655, 2004.

Wittrock, F., A. Richter, H. Oetjen, J. P. Burrows, M. Kanakidou, S. Myriokefalitakis, R. Volkamer, S. Beirle, U. Platt, and T. Wagner (2006), Simultaneous global observations of glyoxal and formaldehyde from space, Geophys. Res. Lett., 33, L16804, doi:10.1029/2006GL026310.

Buchwitz, M. , de Beek, R., Noël, S., Burrows, J. P., Bovensmann, H., Schneising, O., Khlystova, I., Bruns, M., Bremer, H., Bergamaschi, P., Körner, S. and Heimann, M., Atmospheric carbon gases retrieved from SCIAMACHY by WFM-DOAS: version 0.5 CO and CH4 and impact of calibration improvements on CO2 retrieval, Atmospheric Chemistry and Physics, Vol. 6, pp 2727-2751, 6-7-2006.

Buchwitz, M., R. de Beek, S. Noël, J. P. Burrows, H. Bovensmann, H. Bremer, P. Bergamaschi, S. Körner, M. Heimann, Carbon monoxide, methane and carbon dioxide columns retrieved from SCIAMACHY by WFM-DOAS: year 2003 initial data set, Atmos. Chem. Phys., 5, 3313-3329, 2005.

Noël, S., M. Buchwitz, J. P. Burrows, First retrieval of global water vapour column amounts from SCIAMACHY measurements, Atmos. Chem. Phys., 4, 111-125, 2004.

Universität Bremen

www.iup.uni-bremen.de