Analysing satellite data for IO vertical columns in polar and tropical regions

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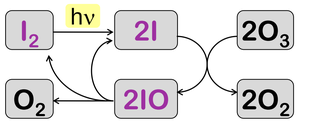
Anja Schönhardt*, A. Richter, M. Begoin, F. Wittrock, J. P. Burrows

Institute of Environmental Physics, University of Bremen, Germany
*Email: anja.schoenhardt@iup.physik.uni-bremen.de

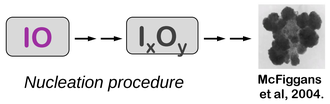
1) Motivation – iodine species in the troposphere

Why is iodine important for tropospheric composition?

- Strong ozone depletion potential via catalytic cycles
- Change of oxidation pathways
- Nucleation of higher iodine oxides I_xO_y (e.g. I_2O_5, I_2O_4)
- Possible growth to cloud condensation nuclei → Impact on radiation balance



Example of catalytic O_3 depletion (X=I,Br)



Nucleation procedure

McFiggans et al, 2004.

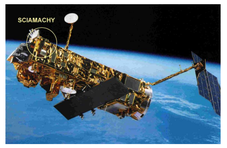
Sources of atmospheric iodine

- Mainly maritime sources identified, release pathways not yet fully understood
- Biogenic release by certain types of algae/phytoplankton: I_2, CH_2I_2, CHICl, etc
- Inorganic release: e.g. surface reactions of O_3 with I^-, yet unknown pathways

2) The SCIAMACHY instrument

SCanning **I**maging **A**bsorption spectro**M**eter for **A**tmospheric **CH**artograph**Y**

- UV-Vis-NIR spectrometer onboard ENVISAT
- spectral range within 214 – 2400 nm
- sun-synchronous orbit at 800 km altitude
- observation geometries nadir, limb, occultation
- ground pixel size typically 30 x 60 km²
- launch in 2002, mission assured until 2014
- mission might be further extended



SCIAMACHY onboard ENVISAT, Monitoring the Changing Earth's Atmosphere, published by DLR, 2006. (ESA, artist's impression)

3) The IO retrieval by DOAS

DOAS retrieval settings for IO

Fitting window:	416 to 430 nm (2 absorption bands)
Trace gases:	NO_2 (223K), O_3 (221K), IO (298K)
Other features:	Ring effect, stray light, 2nd ord. polynomial
Result:	Slant column amounts (SC) of the trace gases

Differential **O**ptical **A**bsorption **S**pectroscopy

Relevant definitions

SC (slant column): Trace gas amount integrated along the individual light path and then averaged over all occurring light paths.
VC (vertical column): Trace gas amount integrated over all altitudes vertically above a ground area of 1 cm².
AMF (air mass factor): Light path enhancement/reduction within the absorber layer, i.e. also equivalent to the ratio between SC and VC.
BAMF (block air mass factor): Discrete change in the retrieved quantity (here SC), if the actual vertical column changes by a discrete amount at a certain altitude interval of the discrete altitude grid, hence representing the altitude sensitivity of the retrieval.

4) AMF considerations

Radiative transfer : Applied code: SCIATRAN (Rozanov, et al. 2005)

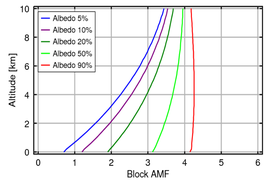


Figure 1: Block AMF values for IO calculated for a Rayleigh atmosphere (no aerosol) and for different cases of surface albedo. SZA: 70°

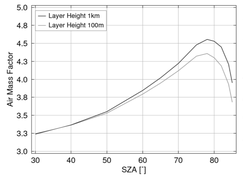


Figure 2: AMF values for IO with respect to varying SZA at 90% albedo for two different box profile heights: constant volume mixing ratio (VMR) up to 1km (black) and up to 100m (grey).

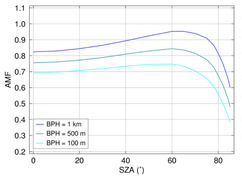


Figure 3: AMF values for IO with respect to varying SZA at 5% albedo for box profile heights (BPH) of 1km (blue), 500m (turqouise, used in Fig. 6) and 100m (light blue).

- The lower the albedo, the lower the sensitivity for IO at the surface, i.e. IO above snow/ice is better visible than over ocean.
- Over bright surfaces, the IO box profile height (e.g. 100m or 1km) has no major influence on the AMF, differences remain below 7%. Over dark surfaces, typical deviations are 20-40%.

5) IO vertical columns above Antarctica

Time series of IO vertical columns above Antarctica from SCIAMACHY observations: Monthly means within 2004-2009

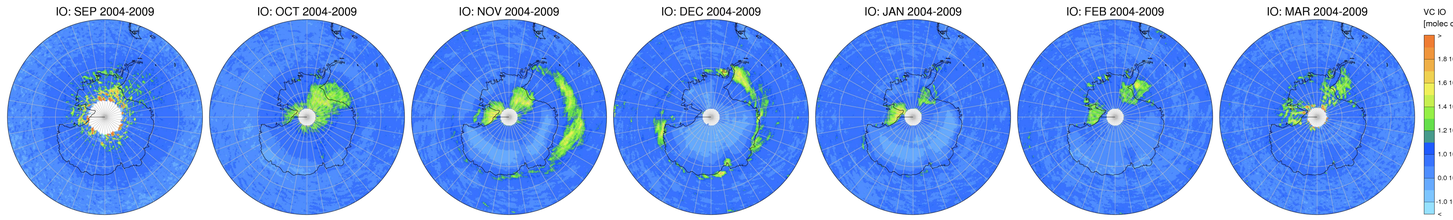


Figure 4: Vertical columns of IO above the Antarctic region. Monthly means are additionally averaged over six years (2004-2009) each. An SZA dependent AMF for a 1km box profile of IO and 90% surface albedo has been applied (cp. Fig. 2). The maps show several details on the spatial and temporal variation in the IO distributions.

- Strong variation in space & time: enhanced IO is observed in different areas at individual times
- Areas affected include sea ice, coast lines, parts of the continent and ice shelves
- Assuming box profiles of IO, vertical column amounts can be directly converted to mixing ratios

Striking feature of IO occurrence above Antarctic sea ice:

- Occurrence is confined to late spring, typical ring like shape is fully developed in November
- Later and temporally shorter occurrence of IO as compared to BrO (present from August for many months)
- Possible link to emissions by ice algae from below sea ice when ice gets more porous in late spring (cp. Figure 5)

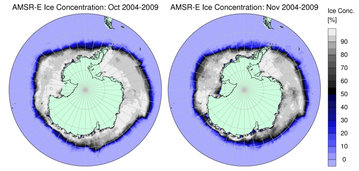
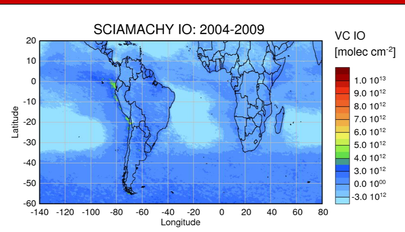


Figure 5: Sea ice concentration around the Antarctic continent within same time period as above (2004-2009) for October (left) and November (right), where concentrations are decreasing. Daily ice concentration data provided by L.Kaleschke and G. Spreen, Institute of Oceanography, University of Hamburg, Germany (ftp-projects.zmaw.de/seaice)

6) IO vertical columns over the ocean



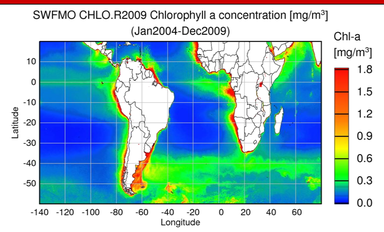
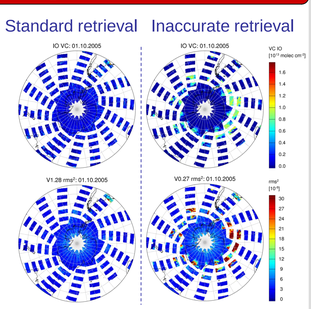


Figure 6: IO vertical columns (left) and Chlorophyll-a concentrations (right) above the Southern Pacific and Atlantic oceans. The Humboldt upwelling region in the Eastern Pacific shows enhanced IO amounts, IO in other upwelling regions (African coast) is lower. Chl-a data are based on SeaWIFS and MODIS observations obtained from the Giovanni online data system, developed and maintained by the NASA GES DISC (Acker and Leptoukh, 2007).

- Retrieval of IO above dark ocean scenes depends more on the retrieval settings than above the Antarctic, caution is necessary.
- Occurrence of positive IO amounts in Eastern Pacific possibly linked to biological productivity.
- No general, clear correlation of IO and Chl-a, but some relation seems to be present.

7) Challenge: retrieving "small" absorbers

Figure 7: Demonstration of retrieval challenges. Left: Standard retrieval, actual IO amounts are below this colour scale. Right: Retrieval with alternative settings (larger fit window up to 438nm) showing artifacts of IO detection in correlation with strongly reduced retrieval quality, i.e. large rms (root-mean-square) values. A cause for inaccuracies are fit difficulties at the 430nm Fraunhofer line.



8) Summary and conclusions

- Retrievals of absorbers with small optical depth such as IO need to be treated with great care.
- IO vertical columns are deduced from SCIAMACHY satellite measurements by using a DOAS retrieval and by applying a Rayleigh atmosphere AMF for a box shaped IO profile.
- Radiative transfer calculations show that the satellite sensitivity for IO is largest above bright surfaces such as snow and ice. In this case, the AMF depends only weakly on the IO profile.
- Six years of IO observations show many details of spatial and temporal variation above th Antarctic.
- Occurence of IO above sea ice in late spring may be linked to biogenic emissions from below the ice.
- Observations of IO above the tropical oceans are subject to larger noise and uncertainties than over snow and ice.
- Enhancements of tropical IO might be linked to biological activity in upwelling regions of the ocean.

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see also: www.iup.physik.uni-bremen.de/doas