Vertical columns of IO from satellite observations - sensitivity studies and latest results -

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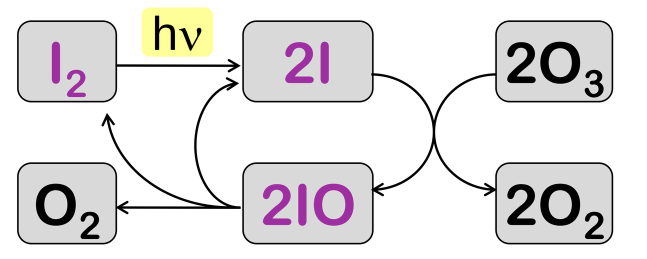
Iodine in the troposphere

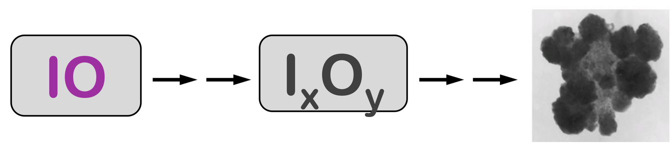
Why is iodine important for tropospheric composition?

- 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 the radiation balance



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



Nucleation procedure

McFiggans et al, 2004.

Sources of atmospheric iodine

Mainly maritime sources have been identified. Release pathways are not yet fully understood.

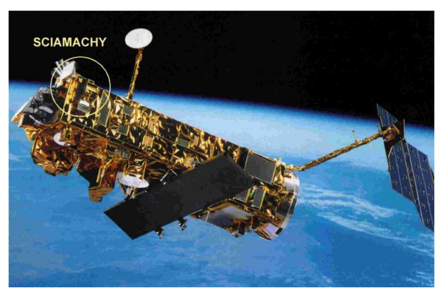
Biogenic release by certain types of algae/phytoplankton: CH_2I_2, CHICl, I_2, etc $\xrightarrow{h\nu}$ I

Inorganic release, e.g. via surface reactions of O_3 with I^-, and/or yet unknown pathways

SCIAMACHY and the IO retrieval

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

- UV-Vis-NIR spectrometer onboard ENVISAT
- spectral range between 214 – 2400 nm
- sun-synchronous orbit at 800 km altitude
- geometries: nadir, limb, occultation
- typical ground pixel size 30 x 60 km²
- launch in 2002, mission assured until 2014
- mission extension strongly recommended



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

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 order polynomial

DOAS
Differential
Optical
Absorption
Spectroscopy

Sensitivity of satellite observations for IO detection – AMF considerations

Radiative transfer

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

- Result from DOAS retrieval: Slant Columns, SC
- More useful quantity: Vertical Columns, VC
- Solution: Application of the Air Mass Factor, AMF

$$VC = SC(\lambda)/AMF(\lambda)$$

(where AMF values are calculated with SCIATRAN)

SC: Trace gas amount integrated along the individual light path and then averaged over all occurring light paths.
VC: Trace gas amount integrated vertically above a 1 cm² ground area through all altitudes
AMF: Light path enhancement/reduction within the absorber layer, i.e. also the ratio between SC and VC.
BAMF: 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 giving the altitude sensitivity of the retrieval.

Calculations of AMF and Block AMF values (BAMF):

1.) Influence of the ground spectral reflectance

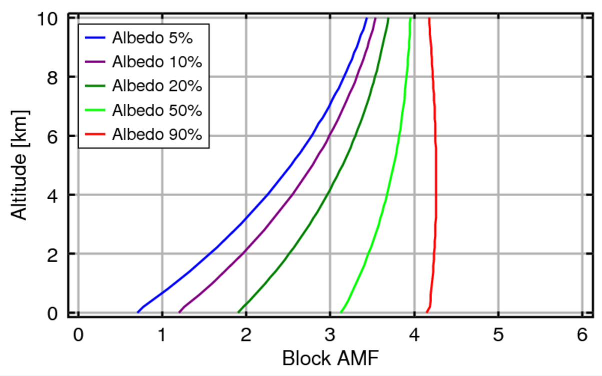


Figure 1: Block AMF values for IO calculated for different ground albedo cases. The higher the albedo, the lower the sensitivity for IO close to the surface. SZA: 70°, Rayleigh atmosphere.

2.) Influence of the Solar Zenith Angle

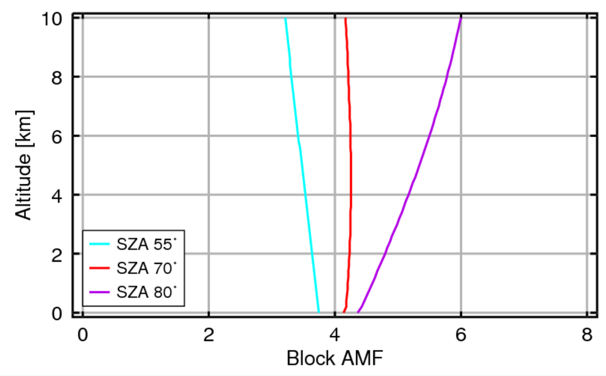


Figure 2: Block AMF values for IO calculated for different SZA at constant albedo (90%, e.g. over snow and ice). Over bright surfaces, the SZA has no major influence on the surface sensitivity, but larger influence at higher altitudes.

3.) Influence of aerosols

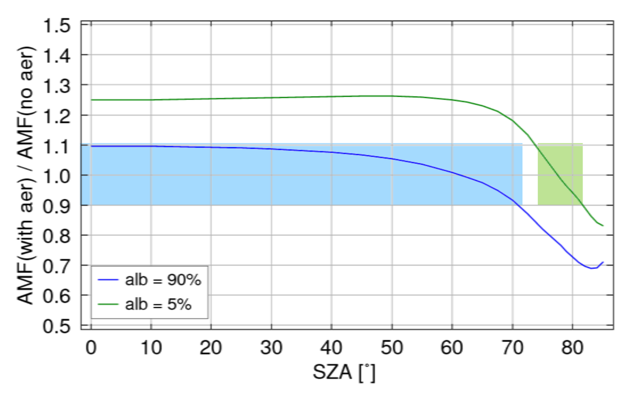


Figure 3: Ratio of AMF values for IO with respect to varying SZA at 90% albedo (blue) and 5% albedo (green), showing the ratio of AMF with aerosol to the AMF without aerosol influence. The scenario assumed here is maritime aerosol at a visibility of 10km. Over dark surfaces, the influence of aerosol is stronger, as long as SZA<75°. Shaded areas show where deviation is below 10% (ratio = 0.9...1.1).

4.) Influence of IO profile

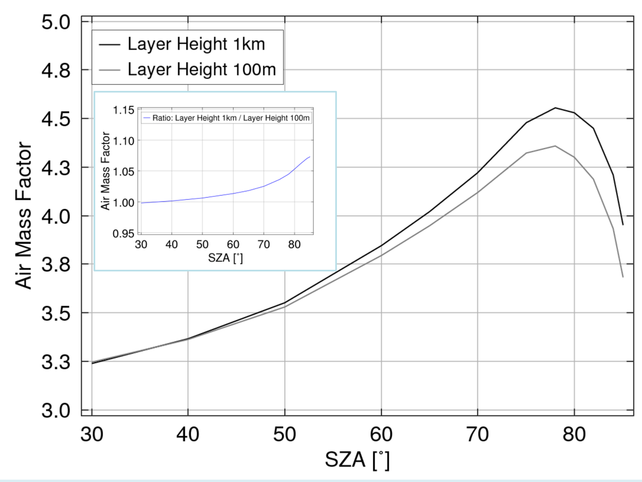


Figure 4: AMF values for IO with respect to varying SZA at 90% albedo calculated for two different box profile heights, constant volume mixing ratio (VMR) up to 1km (black) and up to 100m (grey). Over bright surfaces, the exact IO profile has no major influence on the AMF amount, differences remain below 7%. Over dark surfaces, this influence is stronger (nearly a factor of 2, also compare Figure 1.).

Vertical column amounts of IO above Antarctica

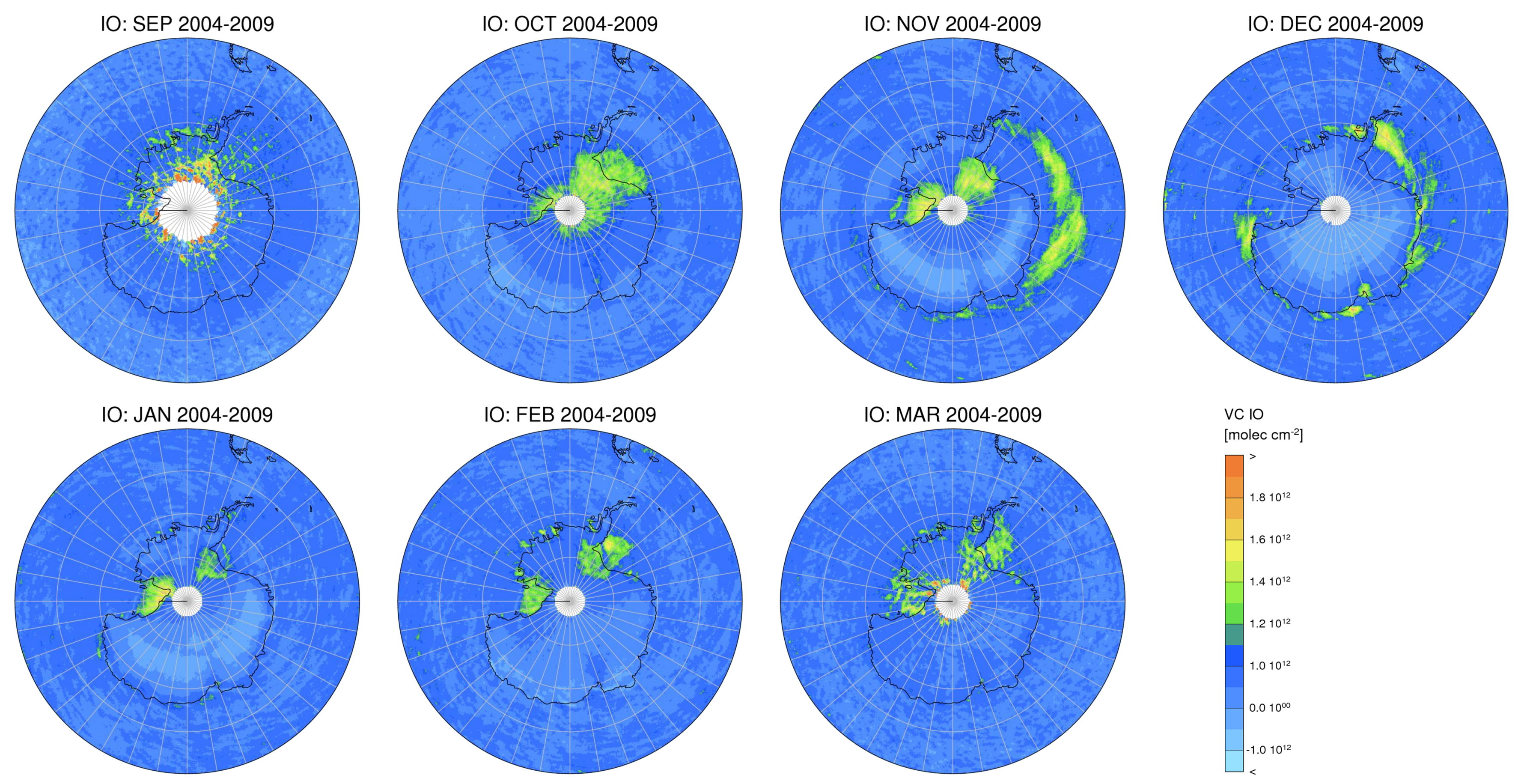


Figure 5: Vertical columns of IO above the Antarctic region. Monthly means are additionally averaged over six years (2004-2009) each. An SZA dependent AMF for a 1km box profile of IO and 90% surface albedo has been applied (cp. Fig. 4). The maps show several details on the spatial and temporal variation in the IO distributions.

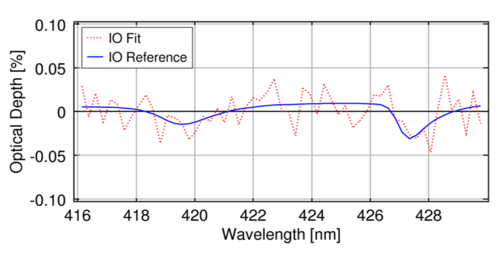


Figure 6: Example fit result at 71°S, 54°W. Detection of $2x10^{13}$molec/cm² IO slant column.

Vertical columns of IO above Antarctica:

- Maximum average amounts in the range of $1.7x10^{12}$ molec/cm²
- Strong variation in space & time: enhanced IO in different areas at individual times
- Areas affected include sea ice areas, coast lines, parts of the continent and ice shelves
- Assuming box profiles of IO, vertical columns 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 fully developed November
- Enhancement on sea ice is present for about 2 months with varying pattern
- Later and temporally shorter occurrence of IO as compared to BrO
- IO emergence possibly due to emissions by ice algae from below sea ice after the ice gets more porous and full of open leads

Challenge of retrieving IO – a "small" absorber

- Atmospheric IO optical depths are quite small
- Careful selection of retrieval settings needed
- For IO, choice of the fitting window is crucial
- Fitting windows including wavelengths larger than 430nm apparently produce artifacts

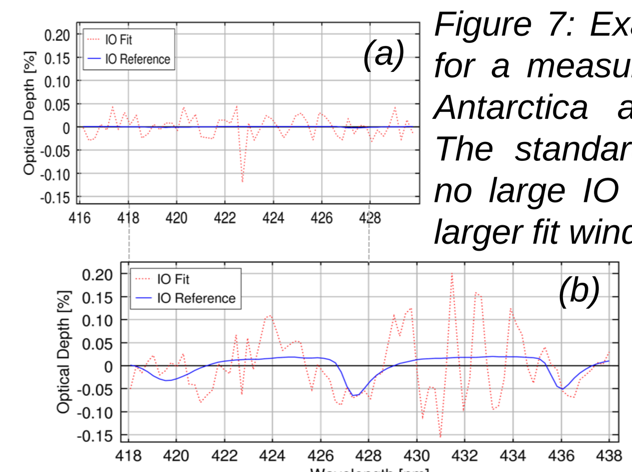


Figure 7: Example fit results for a measurement close to Antarctica at 60°S, 35°W. The standard fit (a) shows no large IO occurrence, the larger fit window (b) leads to artifacts.

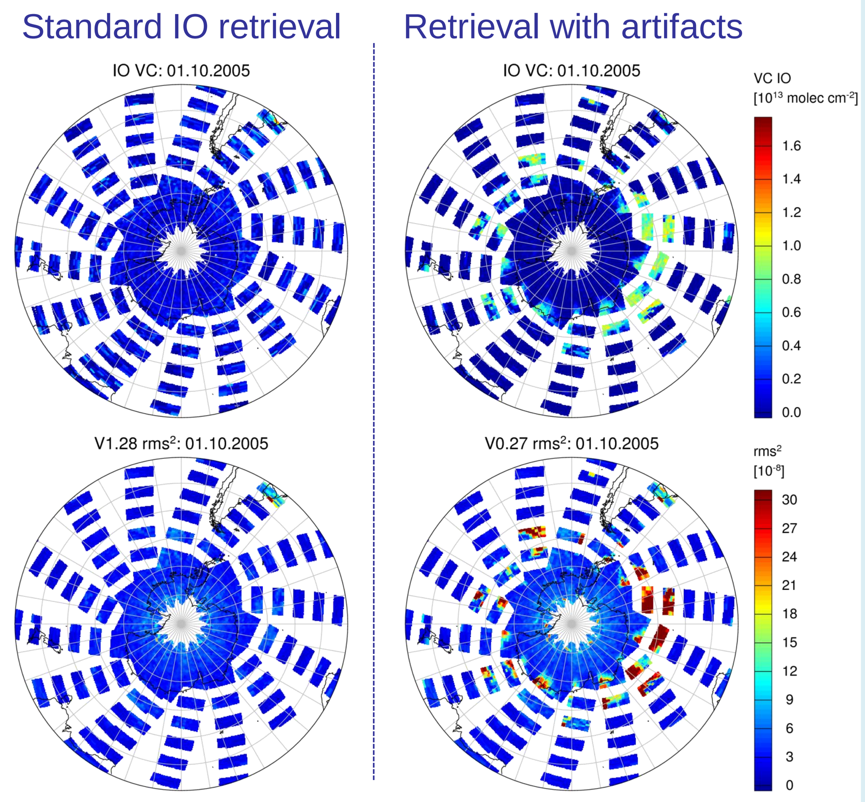


Figure 8: Demonstration of retrieval challenges. Left: Standard retrieval, actual IO amounts are below this colour scale. Right: Retrieval showing artifacts of IO detection in correlation with strongly reduced retrieval quality, i.e. large rms (root-mean-square) values.

Conclusions and future work

Retrieval of IO vertical columns above bright surfaces

- Better detectability of IO over bright than over dark surfaces, highest sensitivity to low layers
- Weak dependency on the IO profile enables AMF determination in spite of uncertain profile
- Applying current AMF calculations, vertical columns of IO are determined
- Vertical columns of IO show detailed spatial and temporal variations
- Interpretation of the observations is ongoing work

Future activities directly concerning the retrieval of IO

- Future refinement of AMF over Antarctica: use high resolution measured ground albedo, consideration of aerosol, when aerosol measurements over Antarctica become available.
- Future treatment of IO above dark surfaces, especially oceans: make use of local IO profile measurements if available, inclusion of aerosol (maritime regions), further sensitivity studies of initial IO retrieval, identification of source regions in comparison with biological conditions.

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