Observing iodine monoxide from satellite

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SCIAMACHY

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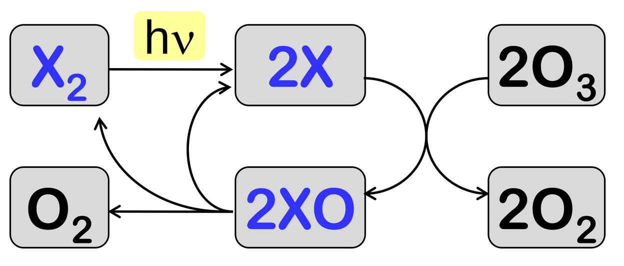
COSPAR 2010
A11-0157-10

Motivation: Importance of iodine in the troposphere

- Iodine belongs to the group of halogens (together with, e.g. chlorine and bromine)
- Iodine is an essential element for vertebrates due to its function within the thyroid hormones

Ozone depletion via catalytic cycles:

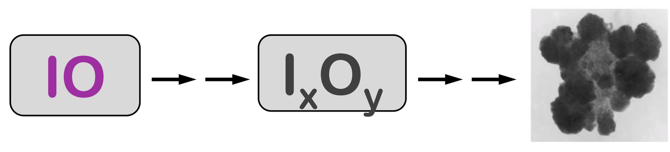


Scheme of catalytic O_3 depletion (X=I,Br)

- Reaction of atomic halogens with O_3
- Halogen oxides are formed, e.g. iodine monoxide: IO
- Ozone depletion events (ODEs) recognized in the 80's

→ Change of oxidation pathways in the troposphere

New Particle Formation:



Nucleation procedure

McFiggans et al, 2004.

- 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

Iodine release pathways: … not fully understood

Evidence for biogenic release by macroalgae and phytoplankton has been revealed.

CH_2I_2, $CHClI_2$, I_2, etc $\xrightarrow{h\nu}$ I

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

Current topics under investigation concerning reactive iodine:

Global importance and full source strength, spatial distribution and spatial-temporal variation, open ocean sources, influence of particulate iodine on Earth's radiation budget

SCIAMACHY satellite instrument

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

- UV-Vis-NIR spectrometer onboard ENVISAT
- spectral range: 214 – 2400 nm
- orbit: sun-synchronous in 800 km altitude
- geometries: nadir, limb, occultation
- ground pixel: typically 30 x 60 km²

ENVISAT Foto: ESA

The DOAS trace gas retrieval

The DOAS equation: based on Lambert-Beer's absorption law

$$\ln\left(\frac{I_0(\lambda)}{I(\lambda)}\right) = \int_S \sum_i \rho_i(s)\sigma_i'(\lambda,s)ds + \sum_k a_k\lambda^k + r(\lambda)$$

Variables:

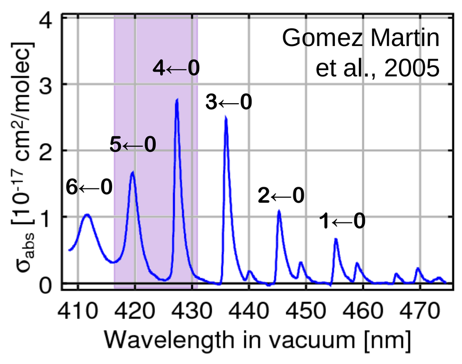
I, I_0	actual intensity and the reference background intensity
λ, s	wavelength and distance along specific light path
ρ, i, σ	concentration ρ of absorber i and absorption cross section σ
a_k, r	polynomial coefficients and residual spectrum

Retrieval method:
DOAS
Differential
Optical
Absorption
Spectroscopy

Retrieval settings

Fitting window:	416 to 430 nm
Trace gases:	NO_2 (223K), O_3 (221K), IO (298K)
Other features:	2nd order polynomial
	stray light, Ring effect
Reference background:	Earthshine spectrum in Pacific

$A^2\Pi^{3/2} \leftarrow X^2\Pi^{3/2}$ transition



Absorption cross section of IO. Shaded: fitting window

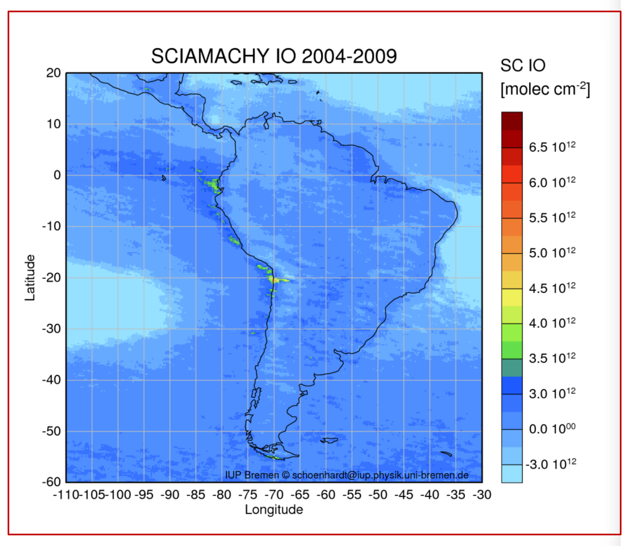
Global view on IO observations from SCIAMACHY

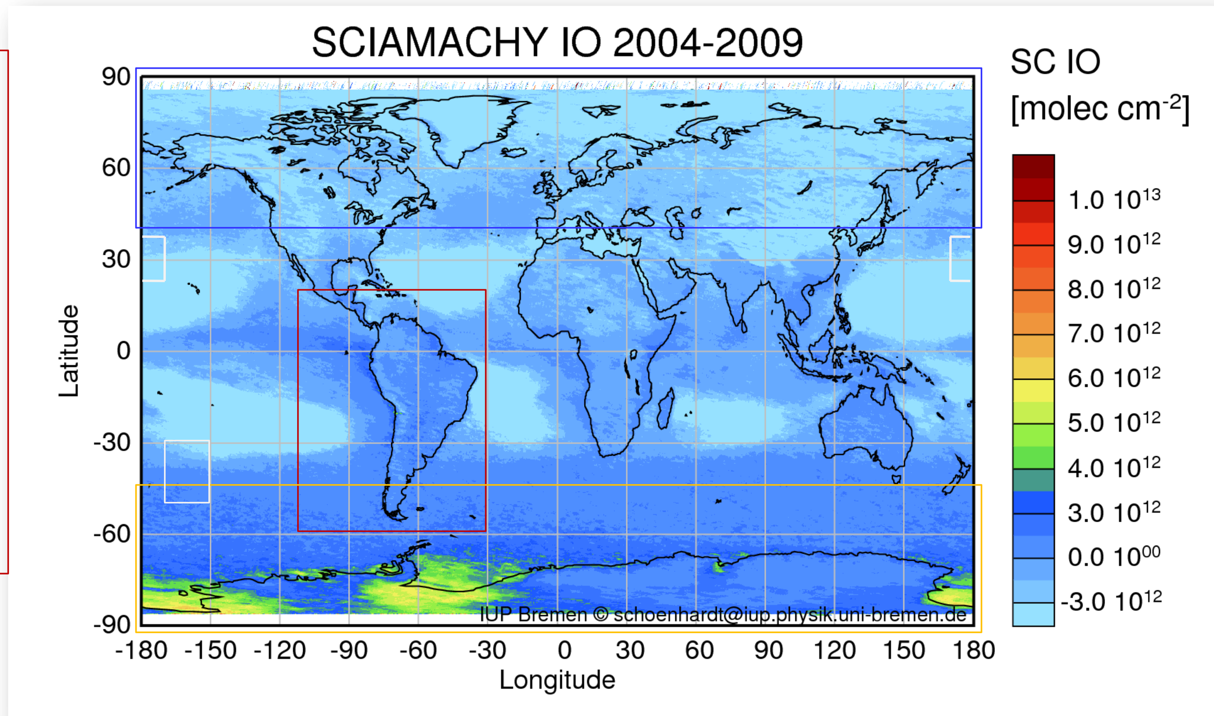
Satellite maps of IO slant columns

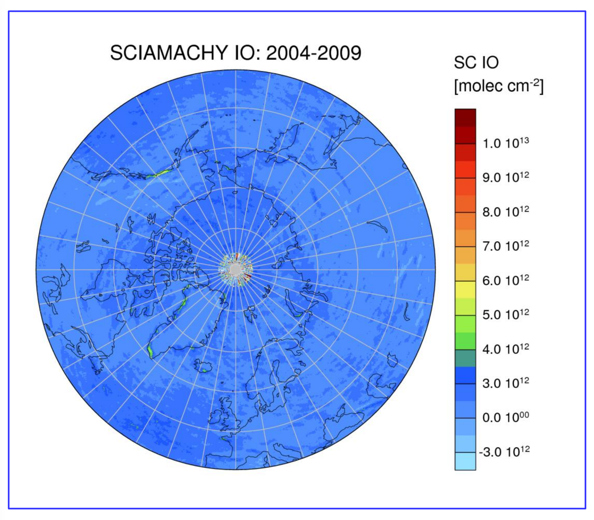
Time period: 2004-2009

The global map shows a multi-year average over 6 years of observations. Background Ref. (white boxes): South Pacific

IO in the East Pacific upwelling region: possible connection to the biologically active ecosystem (Humboldt current)? IO amounts above oceans need to be treated with caution, absolute values are not stable with changing retrieval settings. The connection between iodine species, the biosphere, short-lived biogenic trace gases and atmospheric particles is a field of ongoing research.

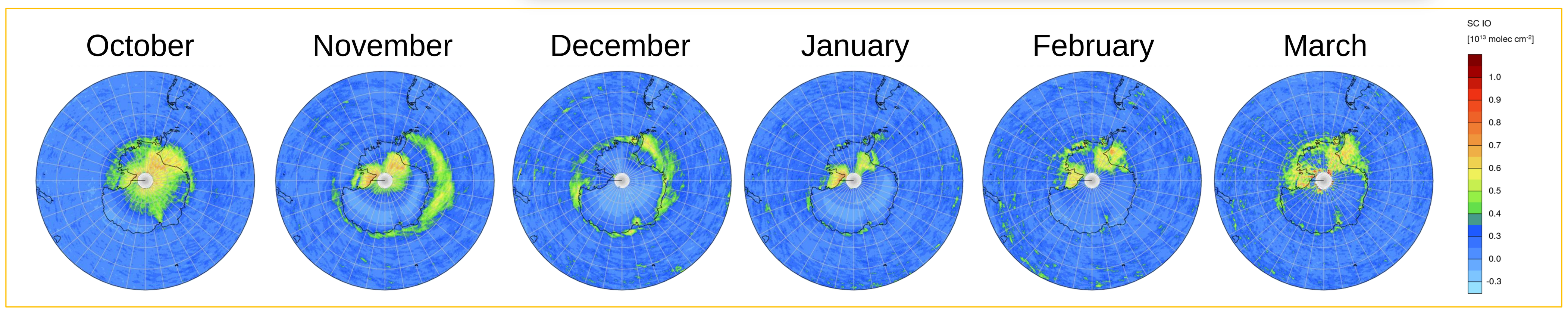






On the Northern Hemisphere, unlike the South, IO is not widespread and enhanced in Spring time. The multi-year average shows enhanced IO at certain coast lines. Differences between the two Hemispheres point at biological origin of iodine species and different biospheres. Background Ref.: North Pacific

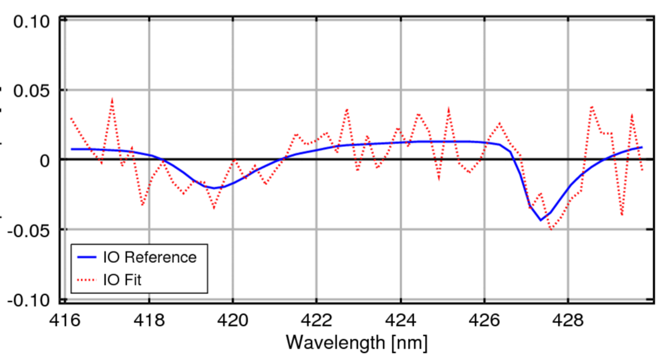
Enhanced IO above Antarctica reaches a maximum during Southern Spring. Affected regions include the ice shelves, the continent, coast lines, and the sea ice. The spatial and temporal variations show many details. (continued on the right)



In late spring (November), enhanced IO is detected on the sea ice around the continent. At this time, the sea ice becomes more porous and contact between ice algae below the ice sheets and the atmosphere above is facilitated. Enhanced IO abobe shelf ice regions and the continent might be caused by transport in combination with recycling on snow and aerosol particles. Further research is needed here.

Retrieval of minor trace gases

The detection limit is determined by the achievable residual RMS of the optical depth.



Typical residual RMS for the SCIAMACHY measurements used here lies around ~ $2 \cdot 10^{-4}$
→ detectable IO slant column: $7 \cdot 10^{12}$ molec/cm²
→ ground VMR: between 0.7 and 35 ppt

Example IO fit showing the scaled reference cross section (blue) and the measurement (red). The difference between both curves is the residual and determines the quality of the fit. RMS = $1.7 \cdot 10^{-4}$.

Notes related to the small amounts of IO:

- Different background reference regions need to be applied for the Northern and Southern Hemispheres (accounting for an interhemispheric gradient).
- Negative IO amounts above clear ocean areas indicate retrieval interferences.
- The tidal signal at mid-latitude coastal locations (e.g. Mace Head) can not be resolved by current satellite observations.

Summary and discussion

Summary

- SCIAMACHY is currently the only satellite instrument for which the retrieval of IO has been demonstrated.
- The single measurement detection limit is challenging, but in long-term averages, enhancements of IO are observed.
- Detailed spatial and temporal variations, e.g. in the Antarctic area yield new insight into possible source processes
- Maximum IO columns in seasonal/annual averages reach to about $7 \cdot 10^{12}$ molec/cm², i.e. an OD of around $2 \cdot 10^{-4}$.

Points of discussion

- Release processes are one main interest - biogenic origin may be supported by satellite observations – the Antarctic region is a highly productive biosphere with high concentrations of ice algae and diatoms.
- Occurence of IO on Antarctic continent is puzzling; transport/recycling might play a role; requires further investigation.
- Enhanced IO in the Eastern Pacific might also be connected to biogenic release. Active biology and diatom abundances there may support this idea. Laboratory studies show that diatoms emit organic iodine compounds.
- A reason for the differences between the Northern and Southern Hemispheres might be the diverse biospheres.

References

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Acknowledgements

The authors gratefully acknowledge financial support by the University of Bremen, the DFG (through the SALT project), and the ACCENT network. ESA/ESRIN has provided the level-1 SCIAMACHY data.

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