Satellite observations of iodine monoxide and its relation to biospheric variables

Anja Schönhardt[1]*, A. Richter[1], F. Wittrock[1], T. Dinter[1,2], A. Bracher[1,2], and J. P. Burrows[1]

[1] Institute of Environmental Physics, University of Bremen, Germany

[2] Alfred-Wegener Institute, Bremerhaven, Germany

***Email: anja.schoenhardt@iup.physik.uni-bremen.de**

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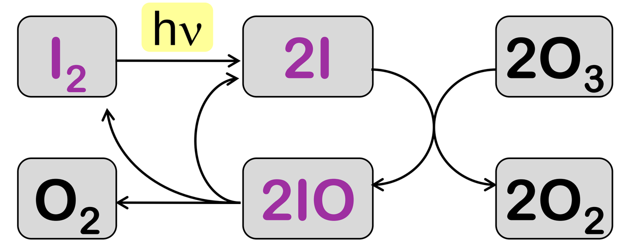
Iodine in the troposphere

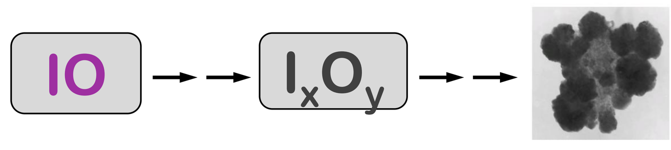
Why is iodine important for tropospheric composition?

- Strong ozone depletion potential via catalytic cycles
- Change of oxidation pathways, impact on OH levels
- 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

Abiotic source: e.g. via surface reactions of O_3, HOI with I^-, DOM; and/or yet unknown pathways

SCIAMACHY and the IO retrieval

SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY

- 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 interrupted since 04/2012

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

DOAS retrieval settings for IO

Fitting window: 416-430 nm (2 absorption bands)

Trace gases: NO_2 (223K), O_3 (221K), IO (298K)

Other features: Ring effect, stray light, 2nd order polynomial

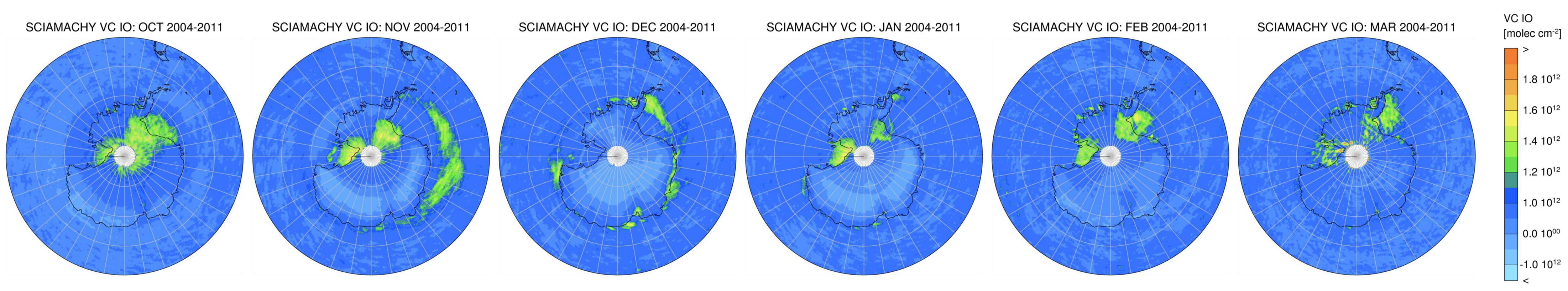
Resulting quantity: Slant column amount (integrated concentration along the light path)

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

IO above the Antarctic Region

Vertical columns of IO above Antarctica

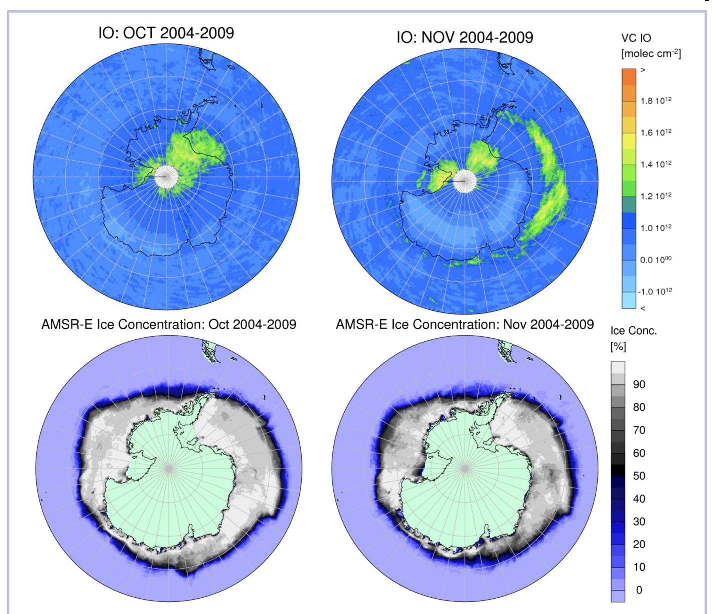
- Average amounts of IO vertical columns over widespread areas lie between 1.0 and 1.5x10^{12} molec/cm²
- Vertical columns are derived from slant columns assuming 0.9 ground reflectance (SCIATRAN calculations)
- Different areas exhibit enhanced IO: sea ice, ice shelves, continent and coast lines
- Detailed spatial and temporal variation is visible in monthly averages (here: averaged over eight years)
- IO appears above the sea ice only in late spring time, when the ice gets more porous and, e.g., the contact between organic species in the water below and the air is facilitated



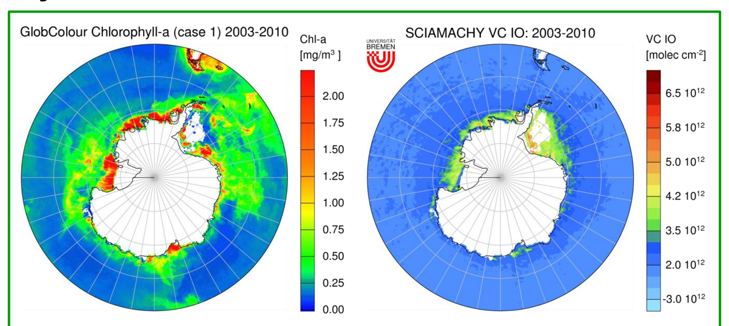
Vertical columns of IO above the Antarctic region using an AMF with 90% ground reflectance. Monthly means are additionally averaged over eight years from 2004 to 2011. Different regions show enhanced IO columns in different time periods.

IO occurrence in Antarctica and biological activity

- IO above sea ice in late spring might be related to melting sea ice
- Antarctic waters are rich in chlorophyll-a

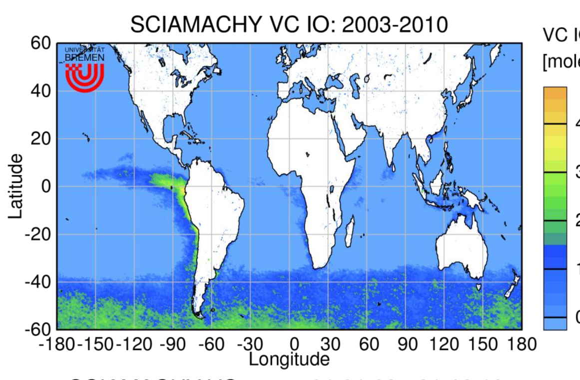


Comparison of IO columns (top) with sea ice concentration (bottom). AMSR-E data: L. Kaleschke, University of Hamburg.



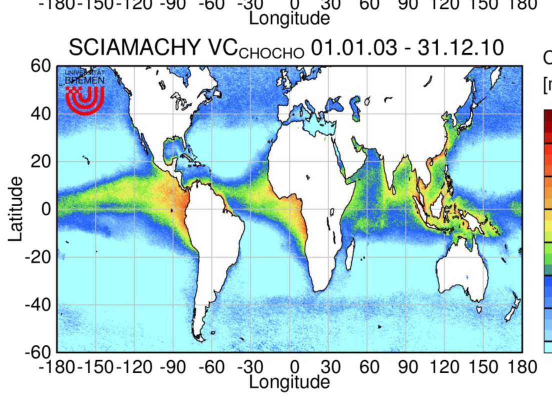
Enhanced chlorophyll-a concentrations in the water demonstrate the biological activity in the Antarctic Ocean (left figure). Regions rich in Chl-a partly coincide with areas showing enhanced IO amounts (right). Here, IO data use an air mass factor for 0.05 reflectance for water surfaces and are masked by chl-a data. Chl-a data from GlobColour Project, funded by ESA, http://www.globcolour.info.

Comparison of IO with CHOCHO, Chl-a and diatom observations for oceanic regions



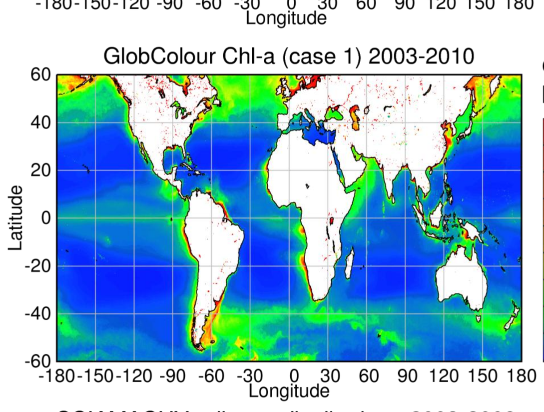
IO

- IO retrieval from SCIAMACHY nadir observations
- Less sensitivity above oceans than over ice/snow, absolute amounts need to be treated with caution
- IO is present above some oceanic regions and coast lines



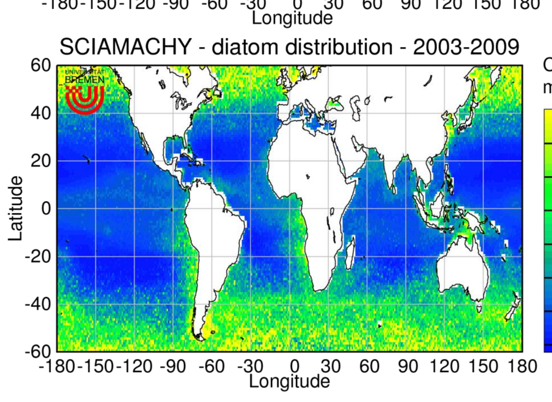
CHOCHO

- Glyoxal (CHOCHO) is retrieved from SCIAMACHY by the DOAS technique (Wittrock et al. 2006)
- Wavelength window: 436 – 457 nm
- Originates from hydrocarbon oxidation in the atmosphere
- Influences from biomass burning are present



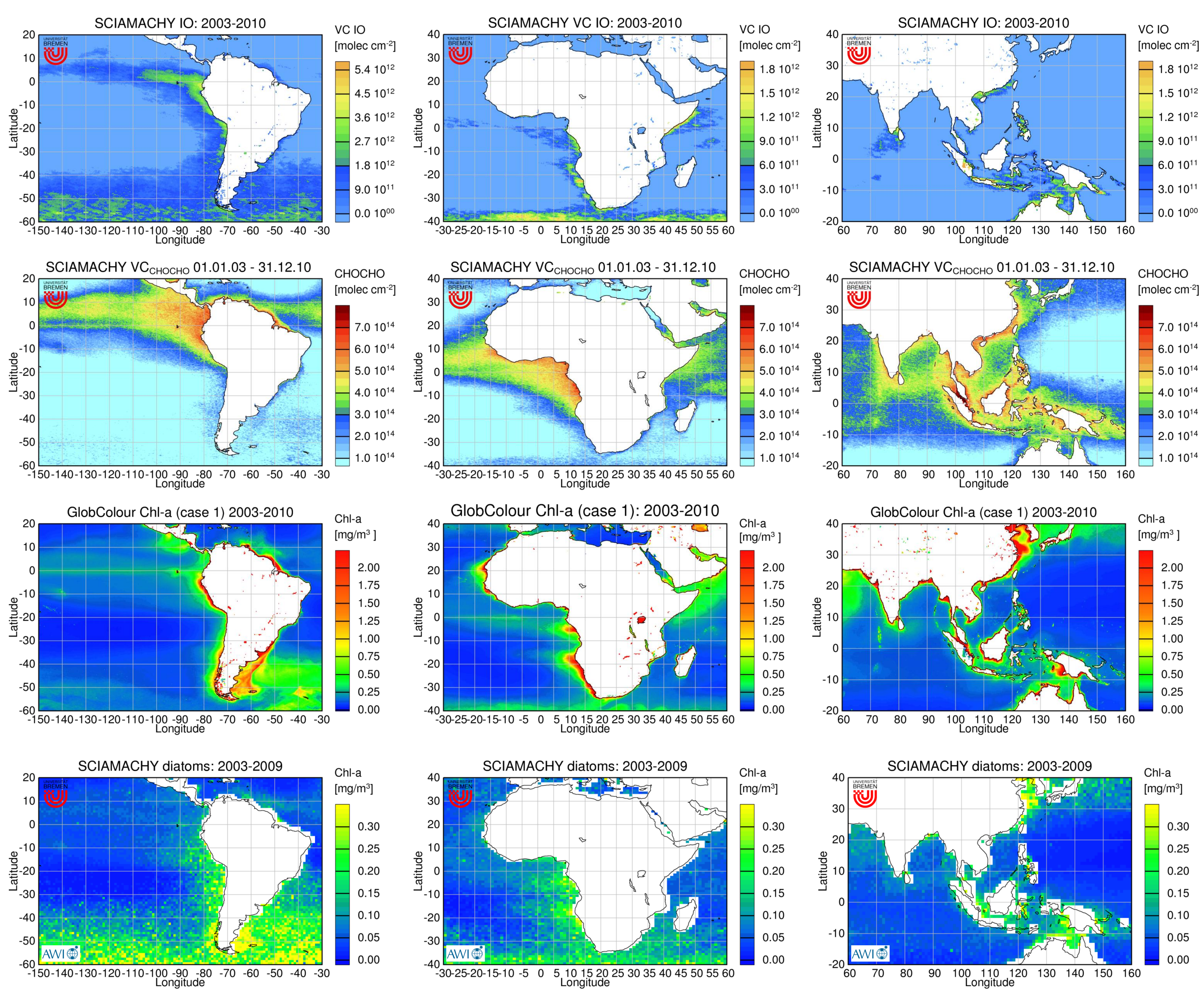
Chlorophyll-a

- Chlorophyll-a data provided through GlobColour
- GlobColour Chl-a (representing total phytoplankton biomass) for case 1 water from monthly merged MERIS/MODIS/SeaWiFS product (GSM method)
- Enhanced Chl-a generally hints at biological activity



Diatoms

- Chl-a concentrations from diatom species in the ocean are derived by PhytoDOAS (Bracher et al., 2009)
- SCIAMACHY observations used at 429 – 495 nm
- Different phytoplankton types may emit different species and different amounts of iodine precursors
- Derived Chl-a amount depends on diatom depth profile



South East Pacific: *The Humboldt current (from the Southern Ocean, forming a link to the biosphere around Antarctica) reaches the surface close to the coast, waters are rich in biology. IO and CHOCHO are enhanced, but the spatial patterns are different.*

Oceans around Africa *IO and Chl-a patterns show some similarity, e.g., enhancements above the Benguela current (SW coast); but no IO above the Mauretanian upwelling (NW coast), similar to the diatom distribution. No IO above inland Lake Victoria (i.e. no spectral interference between Chl-a and IO).*

South East Asia *Important region for troposphere-stratosphere exchange. Enhanced IO and CHOCHO observed at several locations (coasts/islands), similar pattern to total Chl-a and Chl-a from diatoms. IO is not enhanced at some Chl-a rich regions such as the Yellow Sea.*

Conclusions

- Comparison between IO, total Chl-a concentrations and Chl-a from diatoms yields an ambiguous picture: Several areas identified with positive relation between IO and total Chl-a while other regions do not reveal such a relation (Chl-a present but no IO).
- In some regions, IO shows better relation with diatoms than with total Chl-a, e.g., Atlantic west of Africa, while some areas reveal IO abundances but no diatoms, e.g. Horn of Africa.
- Limitations of total and diatom Chl-a: derived Chl-a is biased towards the surface, but still data contain information on the whole phytoplankton column
- In the Eastern Pacific, Chl-a is partly present where IO and CHOCHO are enhanced, but the spatial pattern is not the same.
- IO and CHOCHO are both enhanced at some locations (coasts, islands) in the SE Asian ocean with implications for troposphere-stratosphere exchange.
- Additional factors presumably play a role for iodine emissions, e.g. phytoplankton type and the chemical and physical status of the ocean/atmosphere. There also might be inorganic sources of I_2.

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Universität Bremen

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