Sulfur dioxide retrievals from TROPOMI: Algorithmic developments, verification on synthetic spectra and application to OMI measurements

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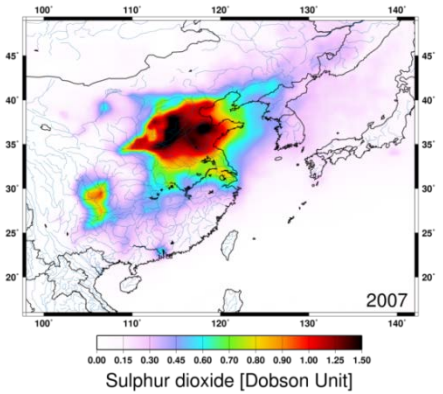
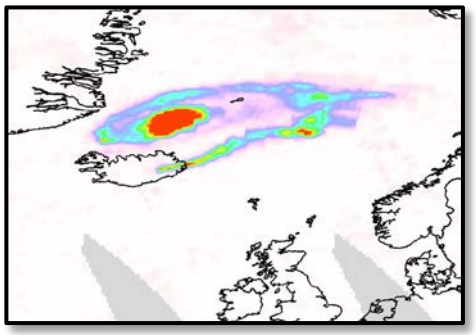




SO_2 plume from Holuhraun, 02-09-2014

Outline

- Prototype (BIRA) and verification (MPIC/DLR) algorithms
- Comparison of results for synthetic and measured OMI spectra (preliminary)
- Prototype algorithm - application to OMI: examples for volcanic and anthropogenic SO_2
- Summary

Prototype Algorithm (1)

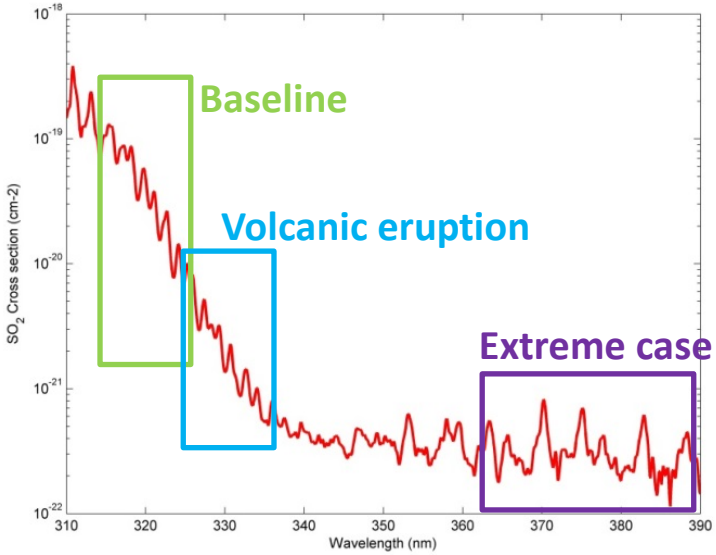
Three steps retrieval:

1. DOAS fit

- Adaptation to OMI:
  - Wavelength calibration based on Fraunhofer solar lines for each of the 60 detector rows
  - Daily earthshine reference spectra: one per detector row
  - Spikes removal

- Spectra for SO_2, O_3 (Pukite et al. approach) and Ring effect

- 3 fitting windows:
  - 312-326 nm (baseline)
  - 325-335nm (volcanic eruption, SCD>40 DU)
  - 360-390 nm (extreme cases, SCD>250 DU)



More details in:

- TROPOMI SO_2 ATBD (Theys et al., 2015).
- Theys, N., et al. (2015), J. Geophys. Res. Atmos., 120, doi:10.1002/ 2014JD022657

Prototype Algorithm (2)

Three steps retrieval algorithm

2. Background correction

- Automatic detection and removal of the detector rows affected by the row anomaly issue
- Background correction dependent on: time, cross-track position and measured O_3 slant column

3. Air mass factors

- Box-AMFs LUT (LIDORT v3.3) with dependences for viewing geometry, albedo (Kleipool et al, minimum surface reflectance dataset), surface/cloud height, wavelength, O_3 column
- 4 different a-priori profiles: 3 box profiles of 1km thickness: 0-1km a.g.l. and centered at 7 km and 15km altitudes (volcanic plumes), SO_2 profiles from the IMAGES model (BIRA-IASB product) or from the TM5 model (S5P operational algorithm) version MP1 beta tested for OMI 2005 (courtesy of H. Eskes, KNMI)

+error analysis and averaging kernels calculation

Verification Algorihtm

- **SCD retrieval by MPIC Mainz/**
  VCD calculation by DLR-IMF

- **Similar to Prototype:**

  3-steps DOAS algorithm, but different fit windows

  312-324 nm (312-326, degassing)
  318-335 nm (325-335, moderate eruptions)
  323-335 nm (360-390, major eruptions)

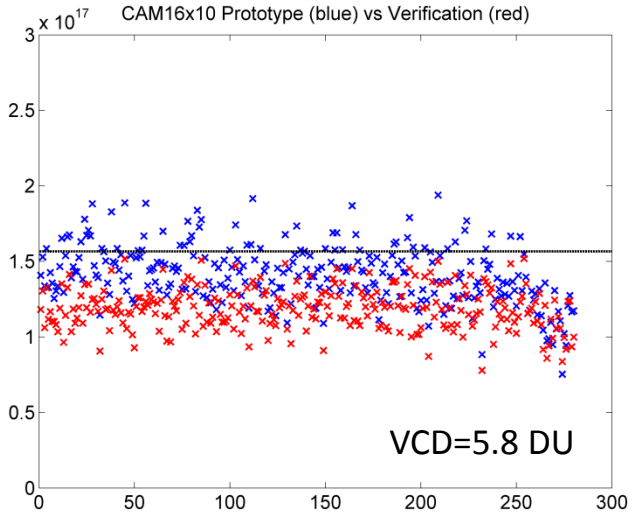
→ Verification Algorithm tries to guarentee *smooth* transition by mixing results from fit windows (based on synthetic spectra simulating volcanic eruptions)

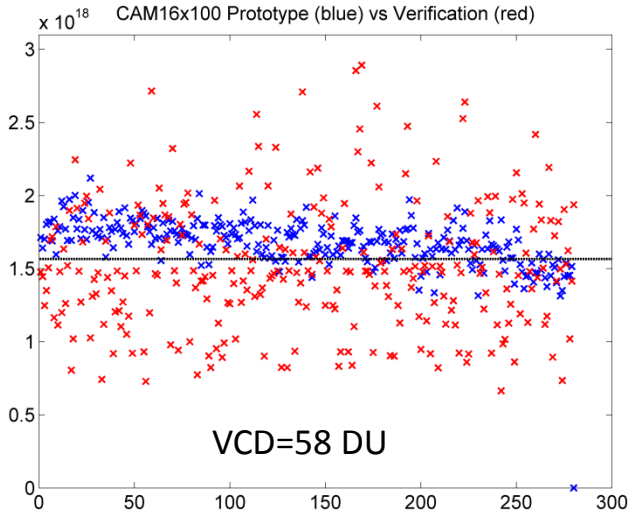
Intercomparison of SO_2 columns

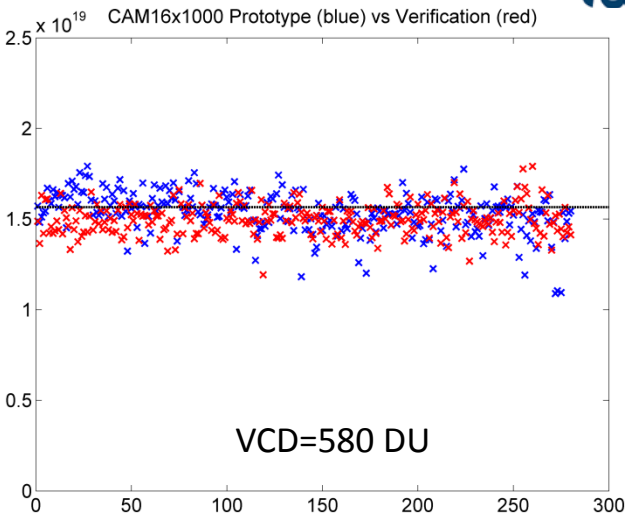
- Prototype and Verification Algorithm applied to a set of synthetic spectra (including noise) for a predefined atmosphere (Camelot profiles) and different viewing geomtries
- SO_2 profile x by 10, 50,100,300,500,1000 to cover a wide range of possible VCDs

→ general good agreement, but inconsistencies possible depending on fit window transition criteria

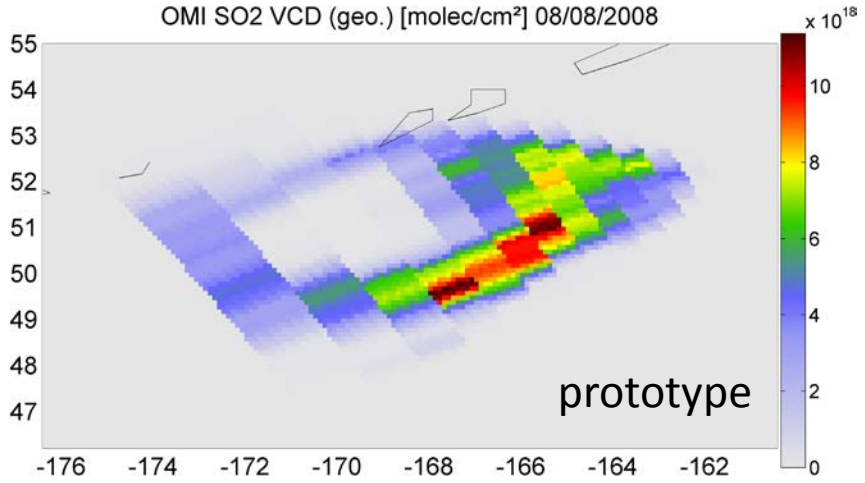
Blue: verification
Red: prototype

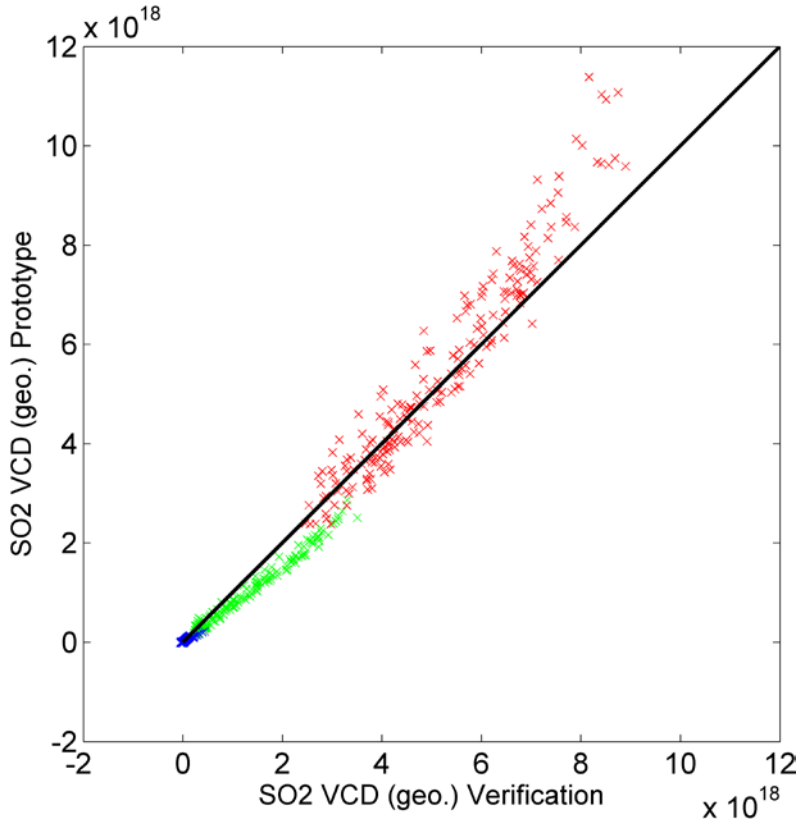






Intercomparison of SO_2 columns





Prototype fit windows colorcoded (312-326nm: blue, 325-335nm: green, 360-390nm: red)

Kasatochi eruption

Verification on OMI spectra for volcanic and anthropogenic SO_2 cases is ongoing

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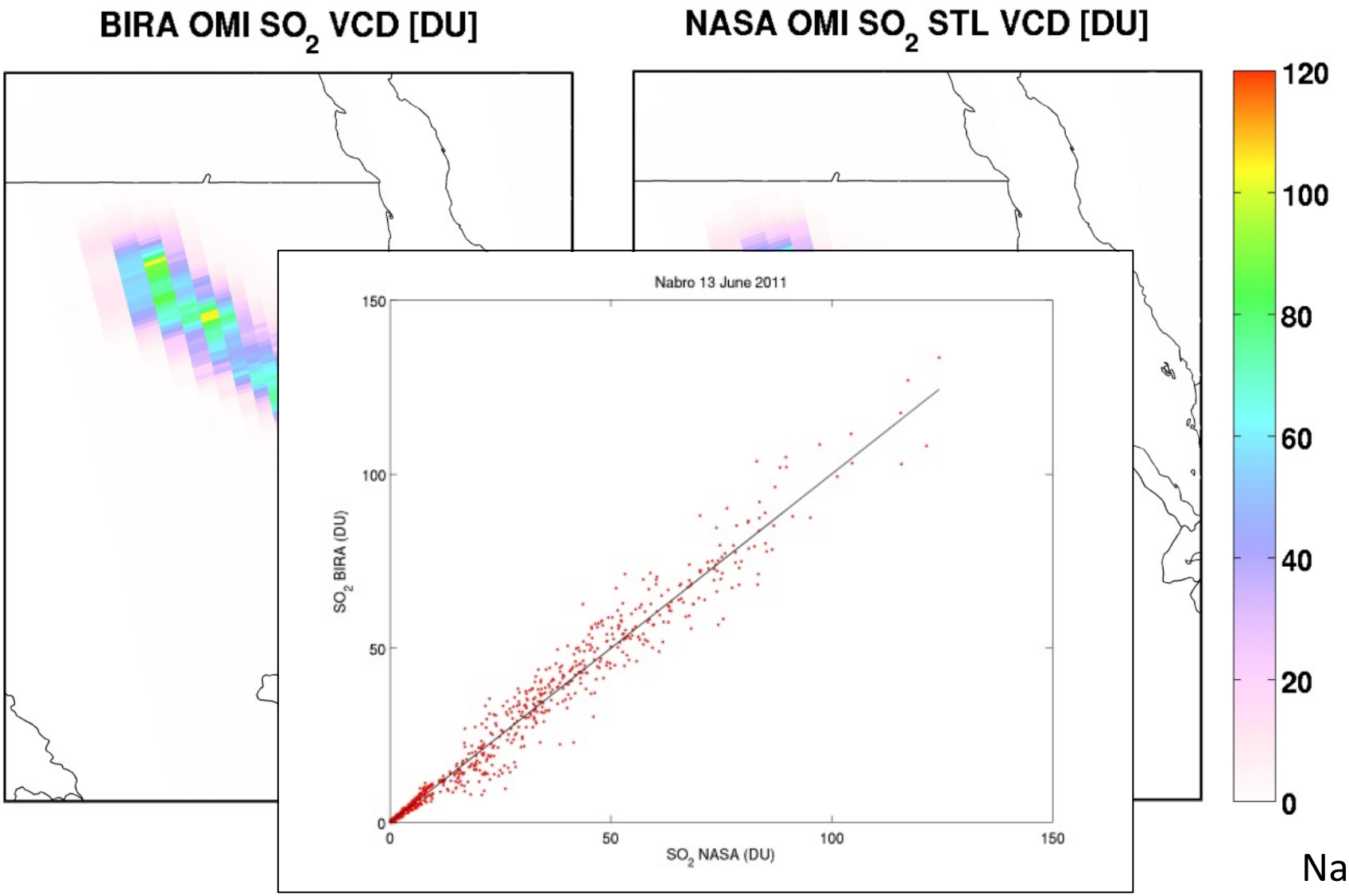
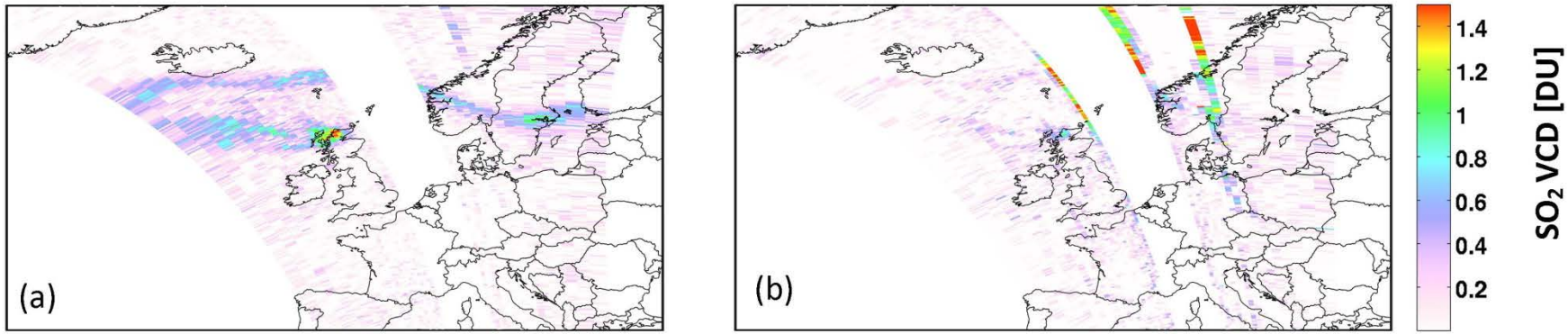
Prototype algorithm: application to OMI



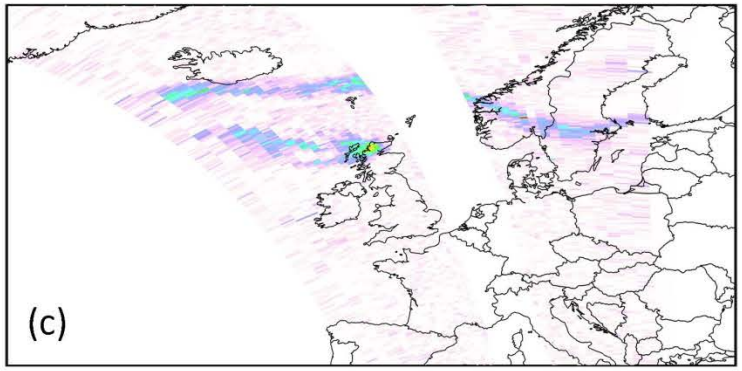
Nabro

Prototype algorithm: application to OMI

13 June 2011



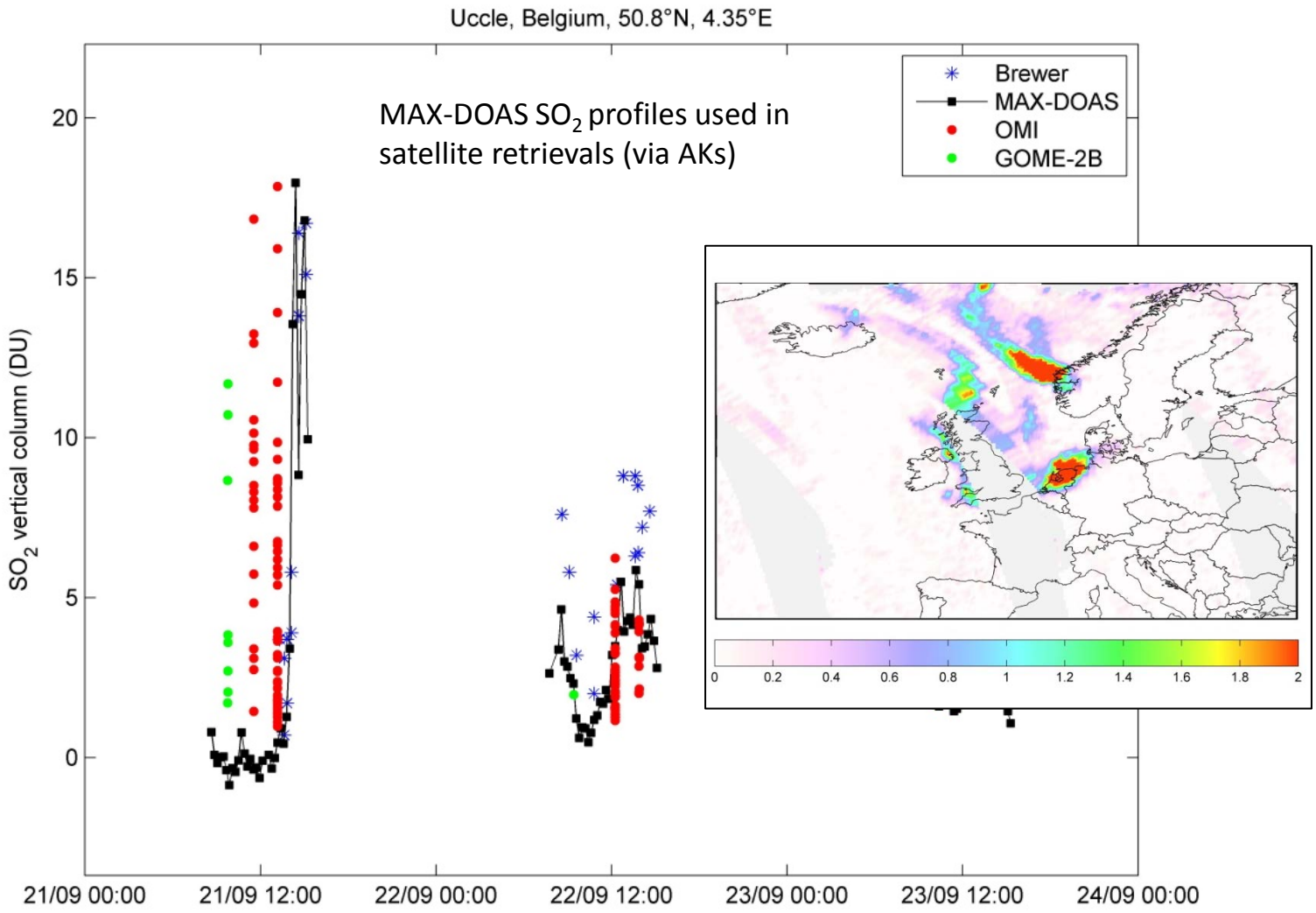
(a) DOAS
(b) LF
(c) PCA



Grimsvötn

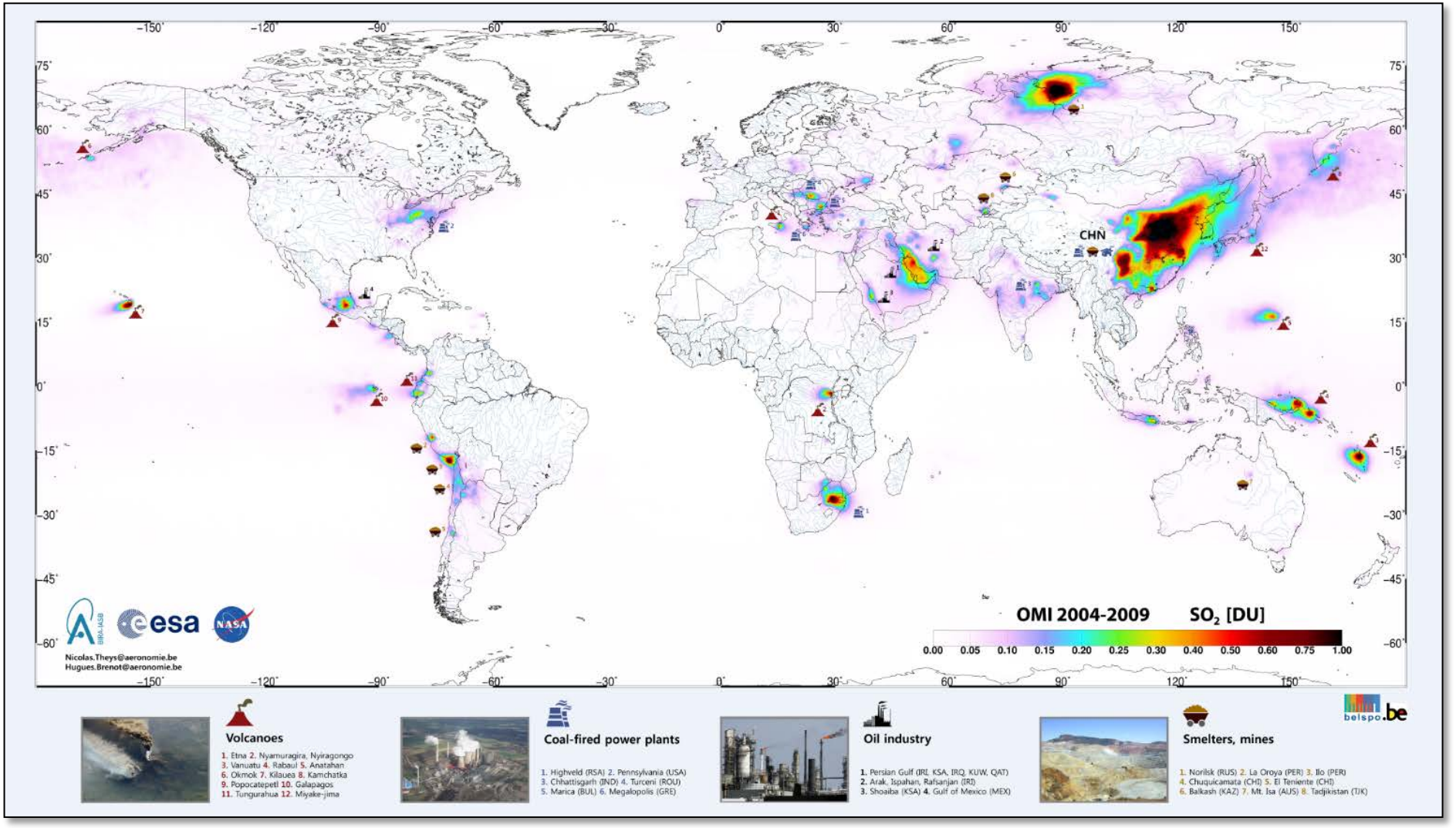
Courtesy of N. Krotkov & C. Li (NASA)

Holuhraun

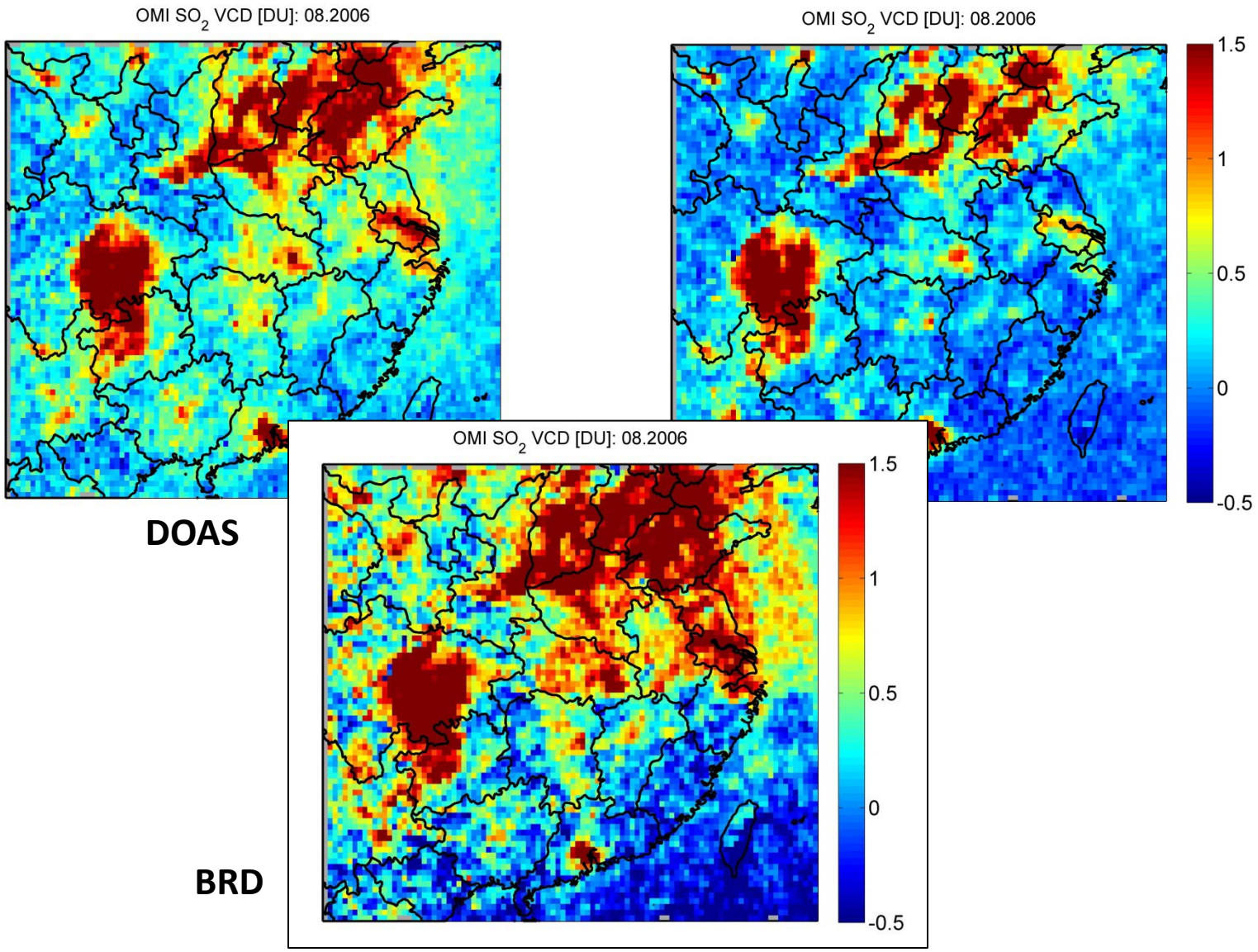


Brewer data: Courtesy of H. Debacker (RMI)

Anthropogenic SO_2 as seen by OMI



China



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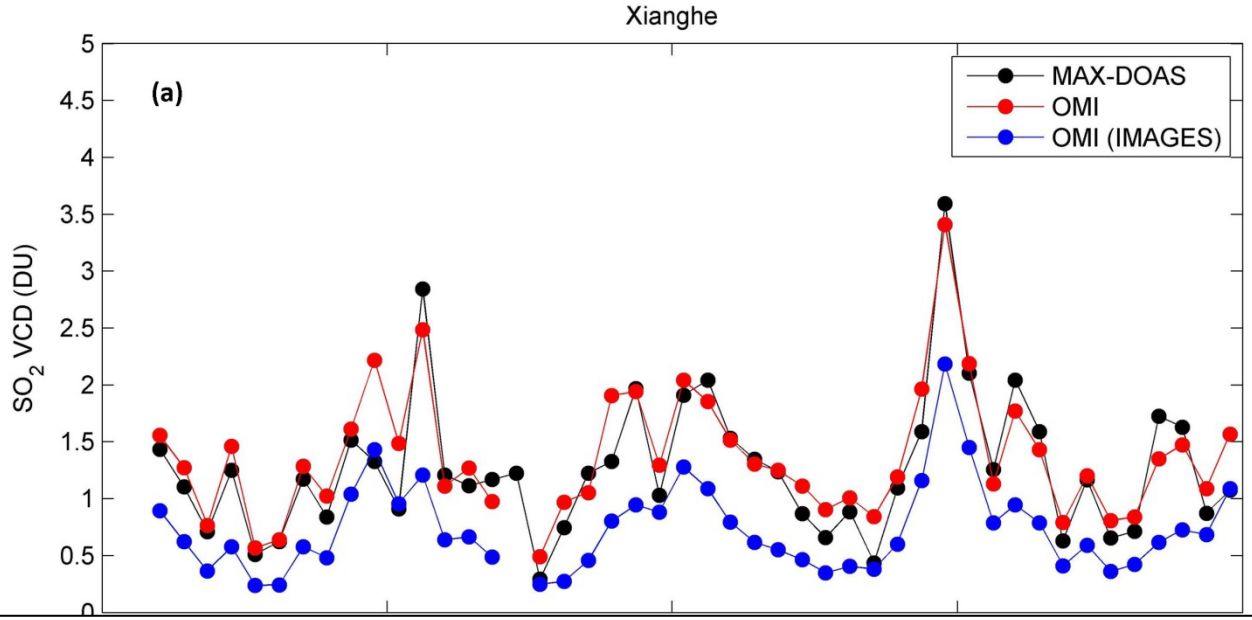
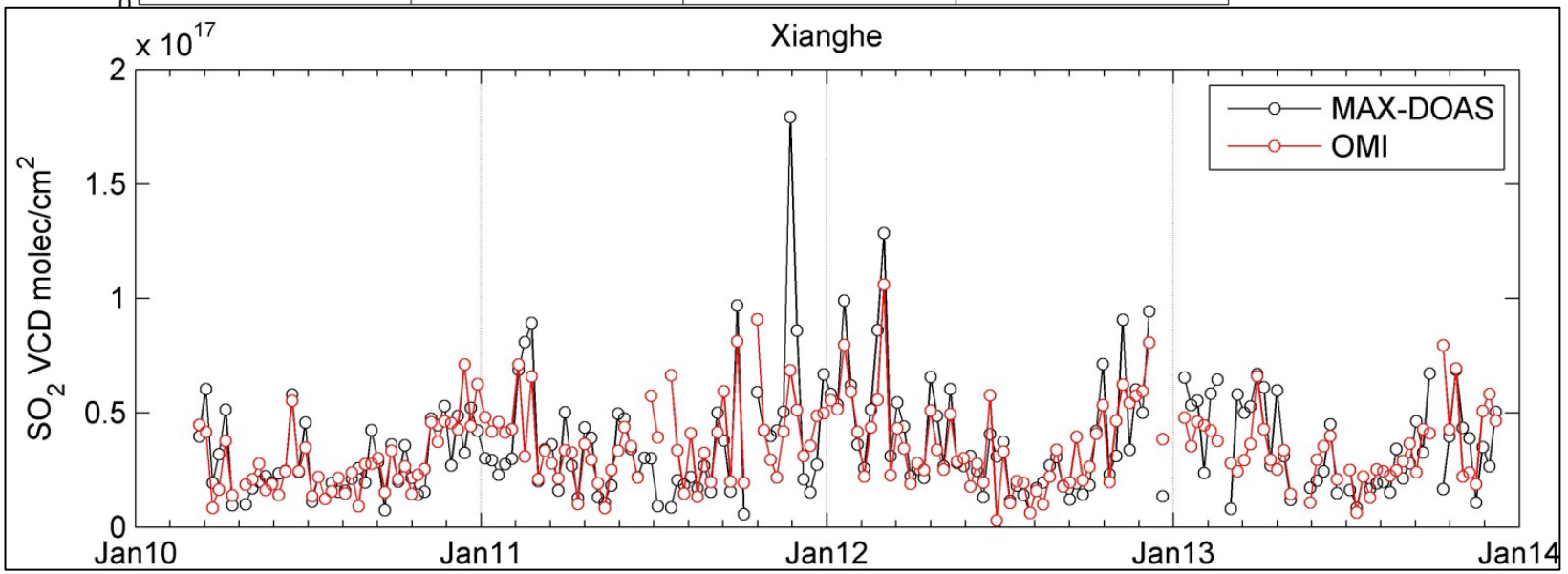
Validation: China





- Xianghe: sub-urban site
- 50 km radius
- Clear-sky pixels
- No volcanic SO_2
- SZA<65°

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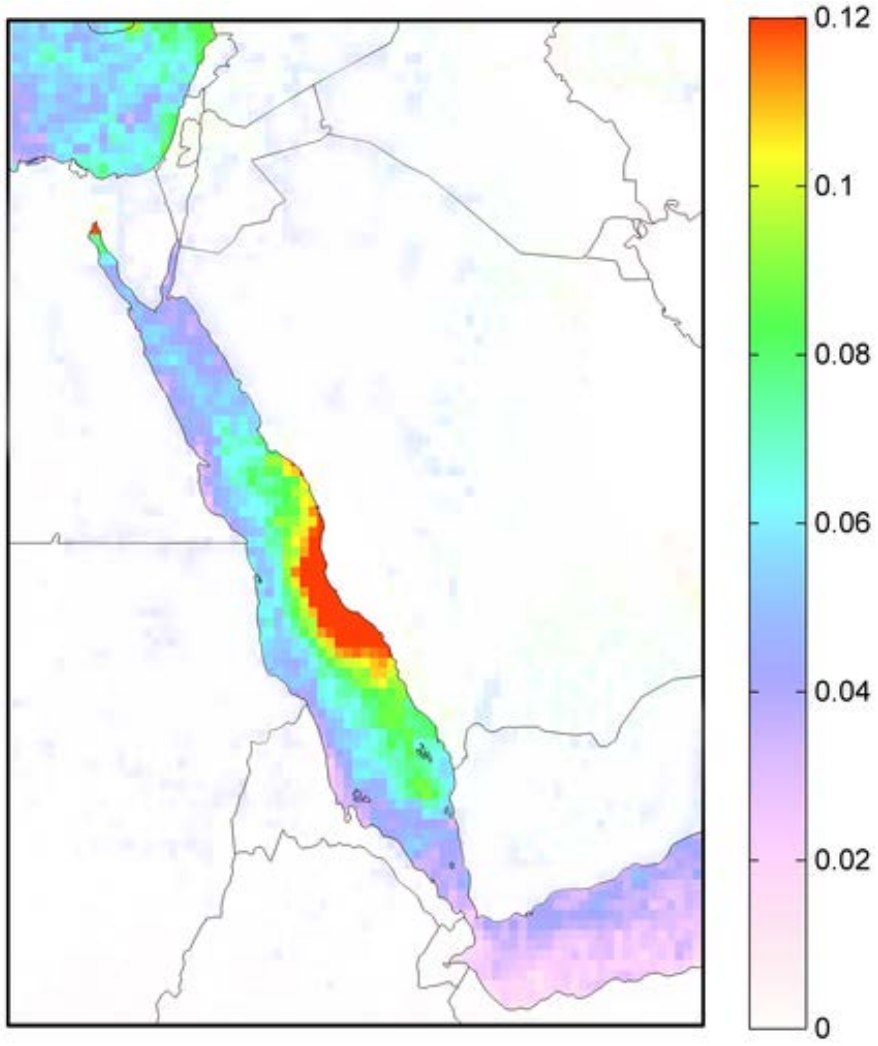
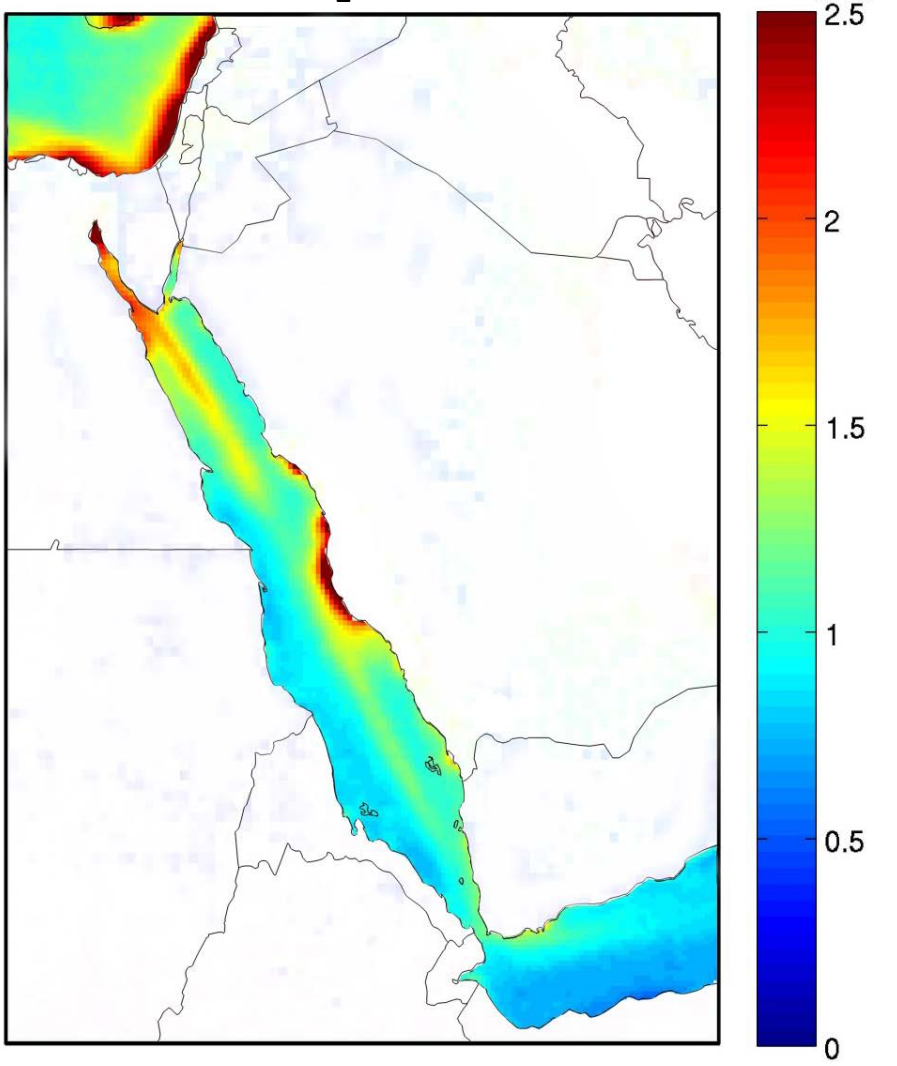
SO_2 from ships

OMI SO_2 VCD [DU]

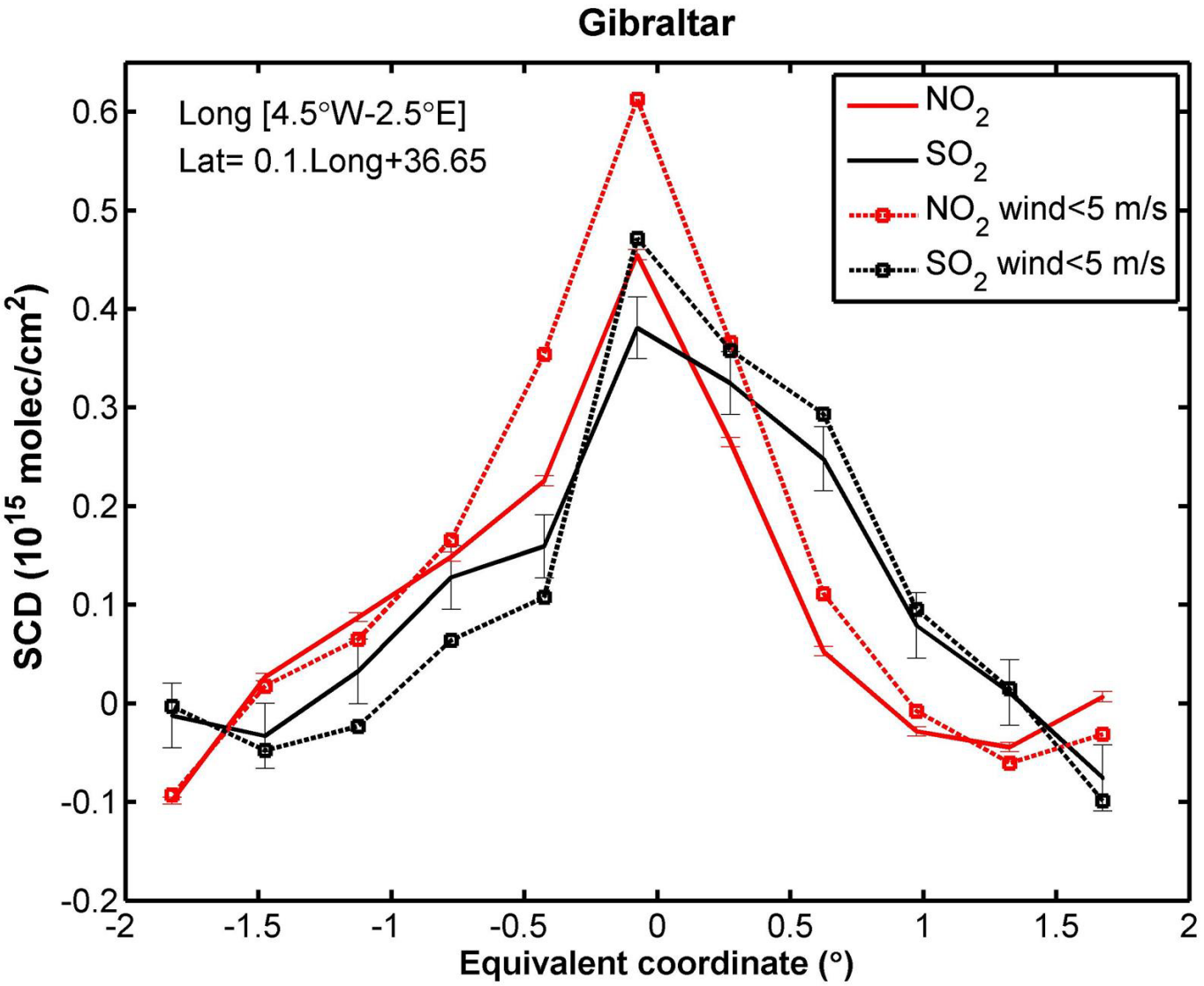


OMI tropo. NO_2 VCD [molec.cm^{-2}]



2005-2009

SO_2 from ships



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Summary

- Development of S5P prototype and verification algorithms. The algorithms have been succesfully applied to OMI.

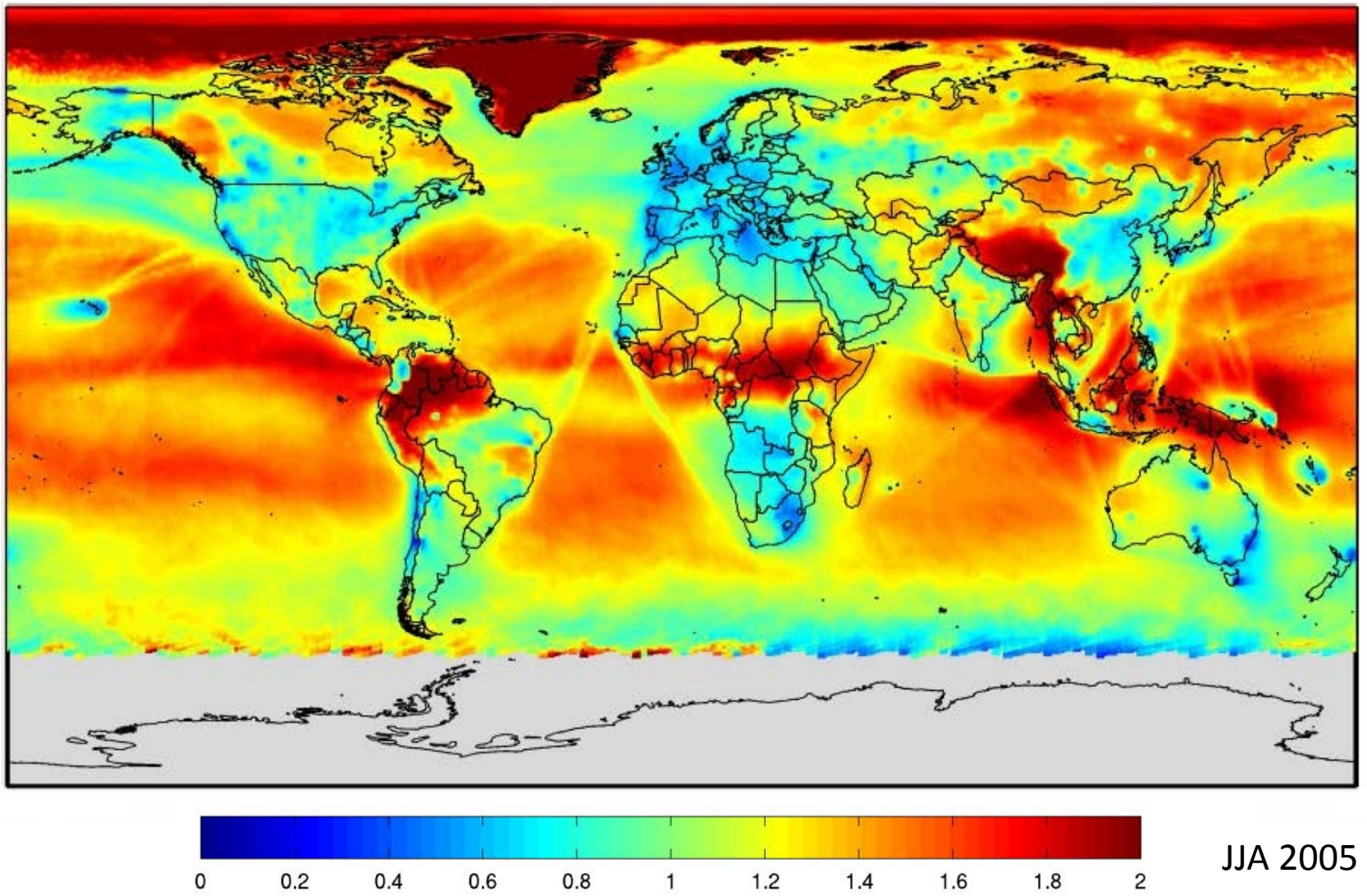
- Comparison results on synthetic and OMI spectra (mostly for volcanic scenarios) are reasonable. Improvement on the use of multiple fitting windows is expected. Comparison for anthropogenic SO_2 cases is ongoing.

- BIRA-IASB OMI SO_2 product is generally consistent with other satellite products.

- Anthropogenic SO_2:
  - -PCA and prototype are fairly consistent (except for background correction)
  - -Excellent agreement with MAX-DOAS measurements in Xianghe
  - -Very weak sources are detected in long-term averages (e.g. shipping SO_2)

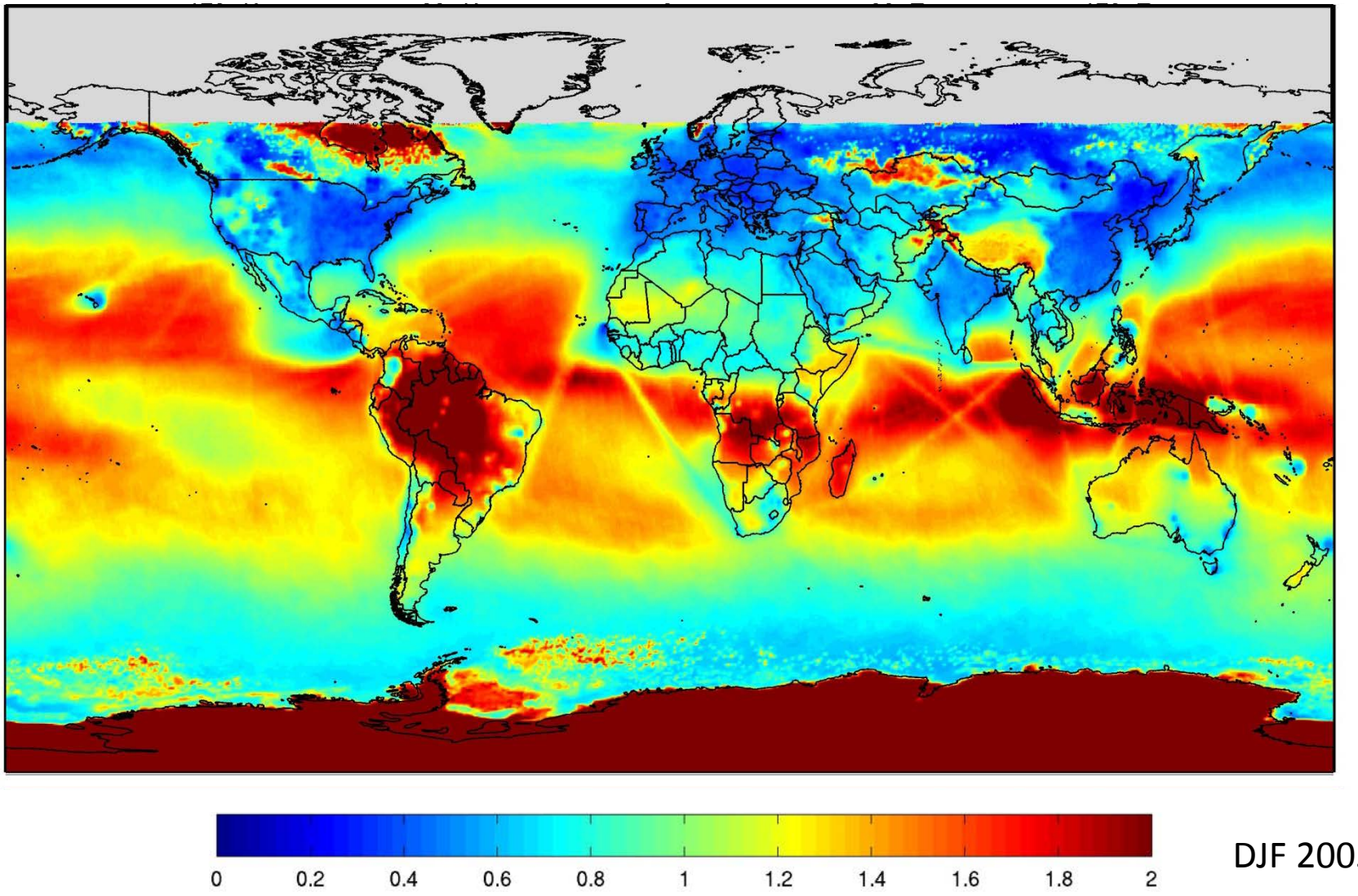
- **The 7°x7° spatial resolution of TROPOMI, combined with a SNR equivalent (or even better) than OMI, is expected to significantly improve the SO_2 observations.**

AMF (clear-sky)



JJA 2005

AMF (clear-sky)



DJF 2005