The TROPOMI/S5P formaldehyde prototype algorithm

Application to OMI and GOME-2 measurements

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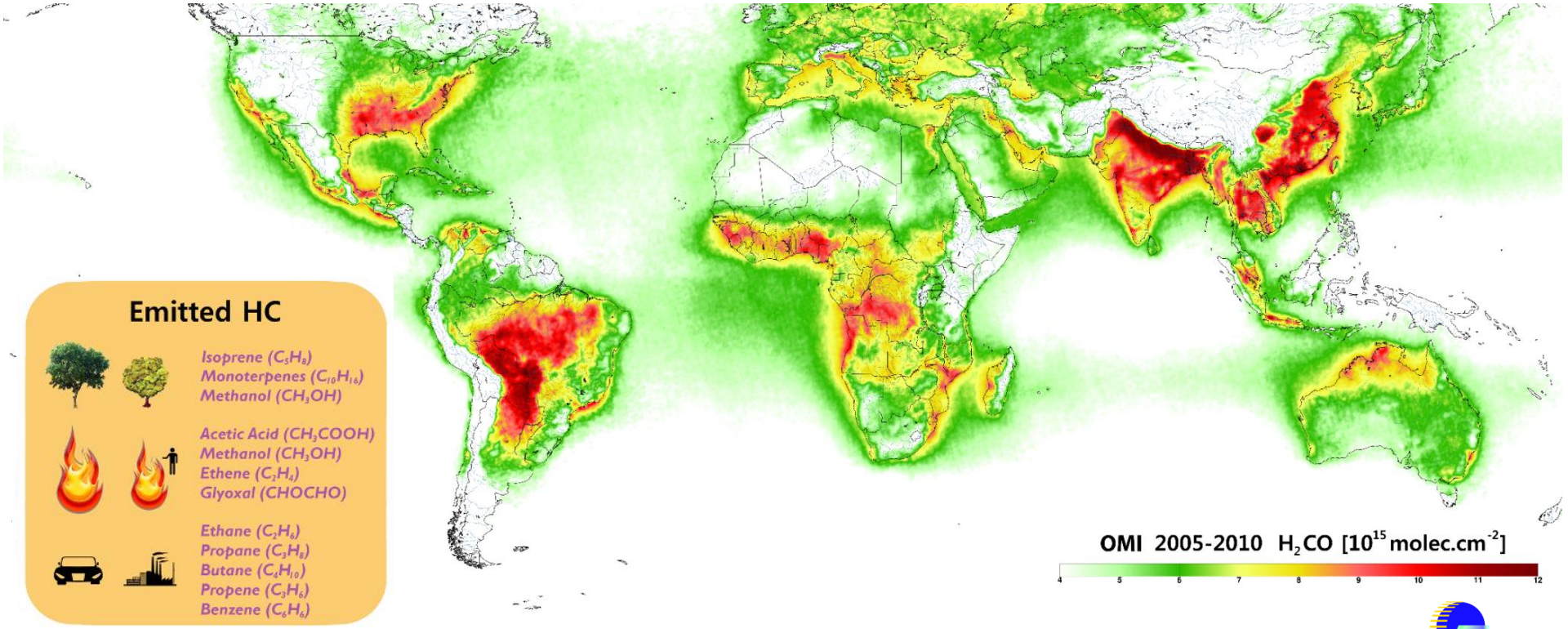
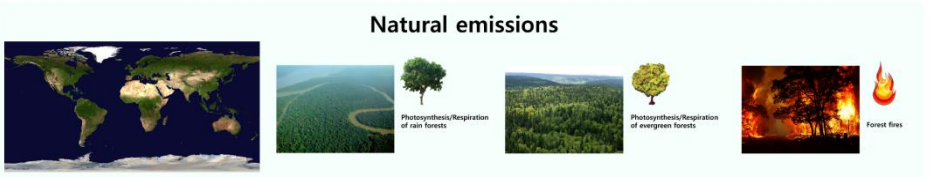
The TROPOMI/S5-P H_2CO prototype algorithm

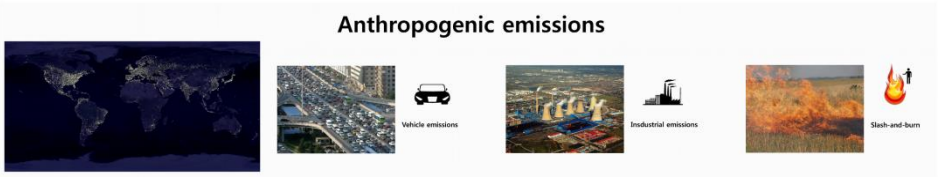
Global Map of Formaldehyde as a Tracer of Hydrocarbon Emissions



OMI

$$HC + OH \longrightarrow H_2CO + \ldots \longrightarrow\longrightarrow CO \longrightarrow\longrightarrow CO_2$$





» See the talk of T. Stavrakou this afternoon

Formaldehyde Prototype Algorithm

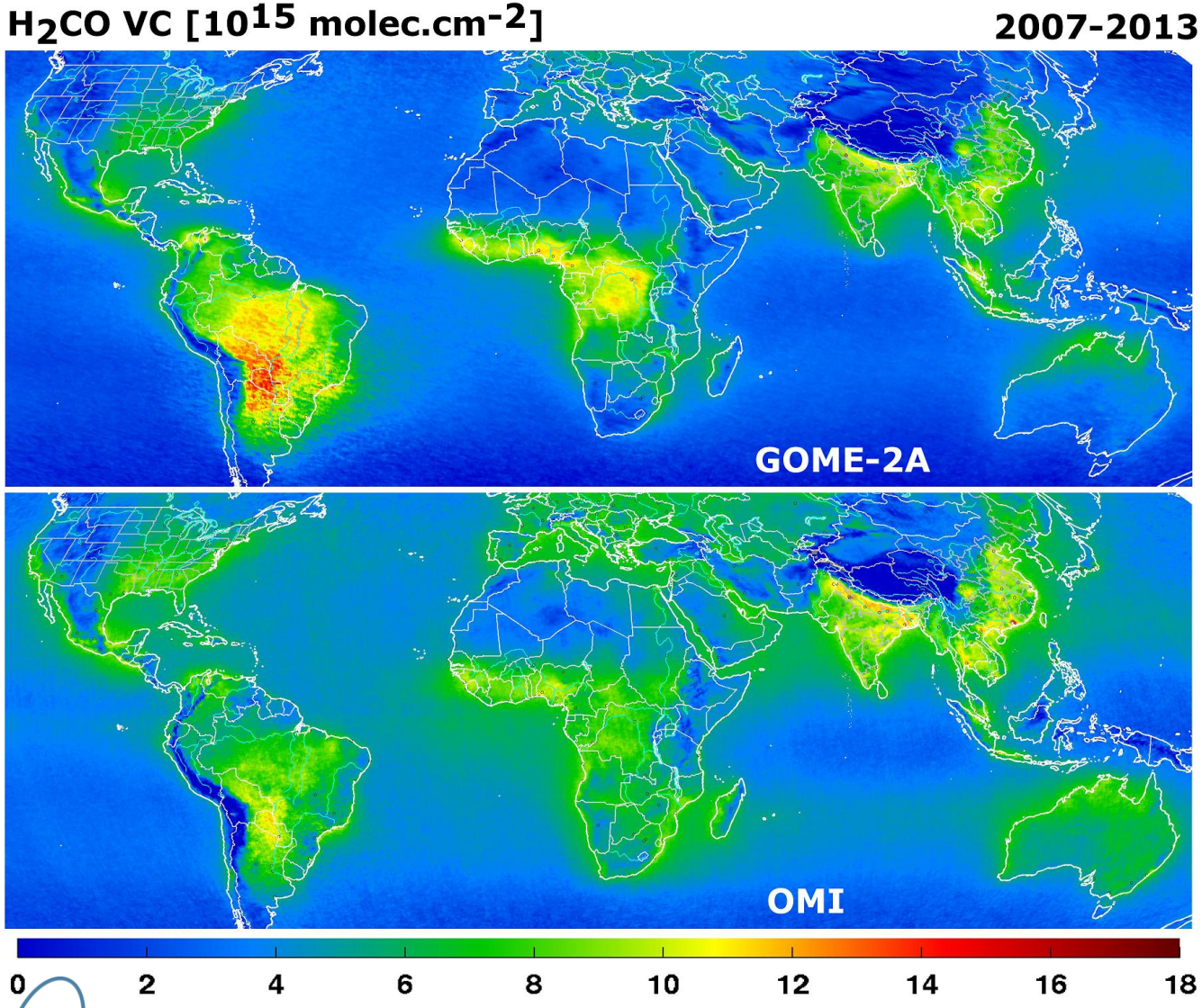
- 3-steps DOAS algorithm:

  1. Spectral fitting in 3 interlinked intervals
     - 339-364 nm (O_4)
     - 328.5-359nm (BrO + H_2CO)
     - 328.5-346 nm (H_2CO)
     - Earth radiances used as background spectra
  2. Background correction and destriping
  3. Air mass factor calculation using LIDORT RTM and:
     - BIRA data record: daily profiles from IMAGESv2 3D-CTM (Stavrakou, ACPD, 2015).
     - TROPOMI Level 2 product: TM5 daily forecast of H_2CO profiles, at 1° horizontal resolution (as for NO_2 and SO_2).

  \+ Error analysis and averaging kernels

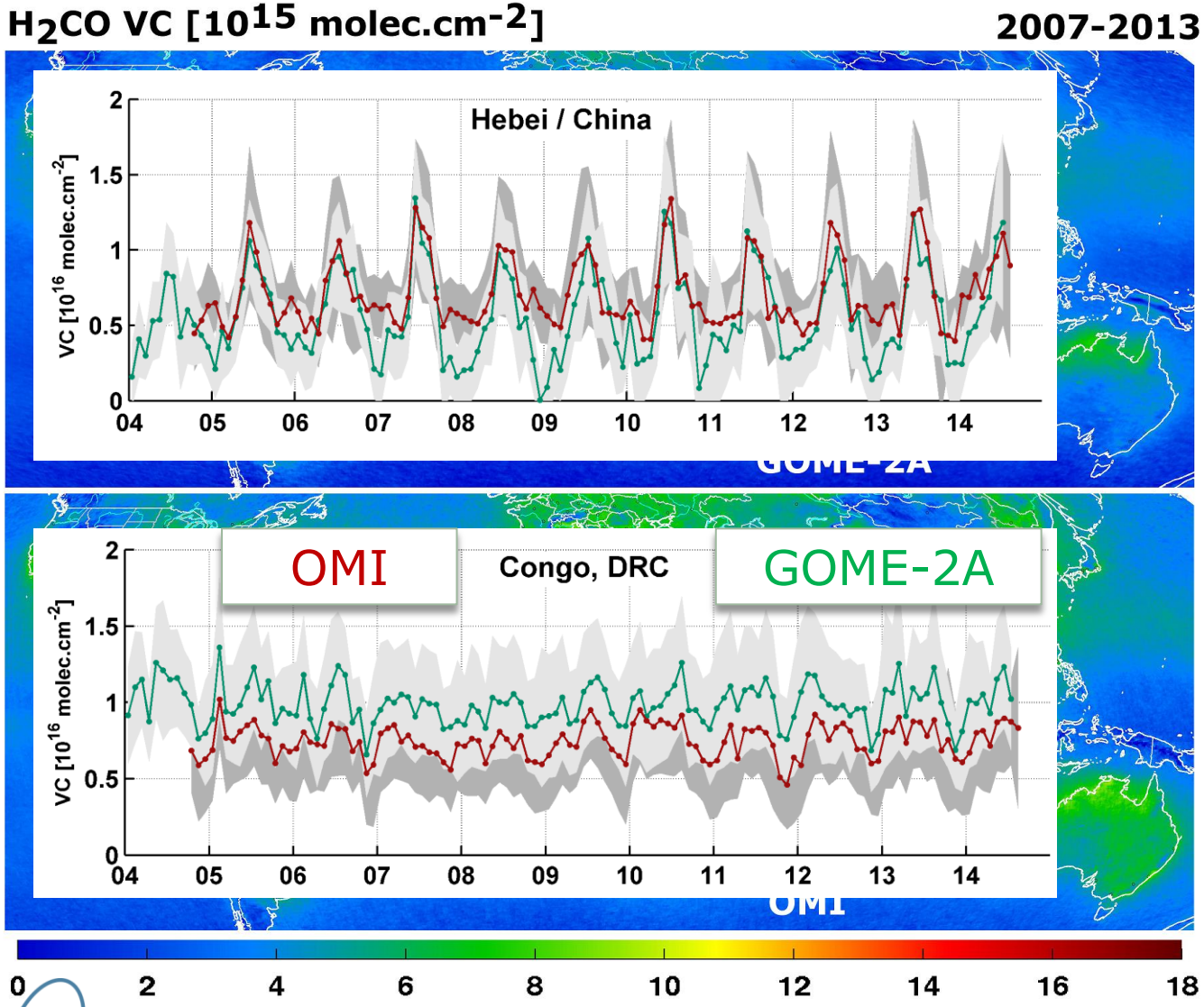
- Prototype algorithm tested on OMI and GOME-2 data and compared with ground-based datasets (De Smedt et al., 2015)
- Comparison with the verification algorithm using synthetic and OMI spectra.

Application to OMI and GOME-2 measurements



- BIRA product v14 (De Smedt et al., ACPD, 2015)
- 339-364 nm (O_4)
- 328.5-359nm (BrO + H_2CO)
- **328.5-346 nm (H_2CO)**
- Earth radiances used as background spectra
- Daily IMAGES profiles at satellite overpass time (09h30 and 13h30) (Stavrakou, ACPD, 2015).
- Cloud filtering + cloud correction

Application to OMI and GOME-2 measurements



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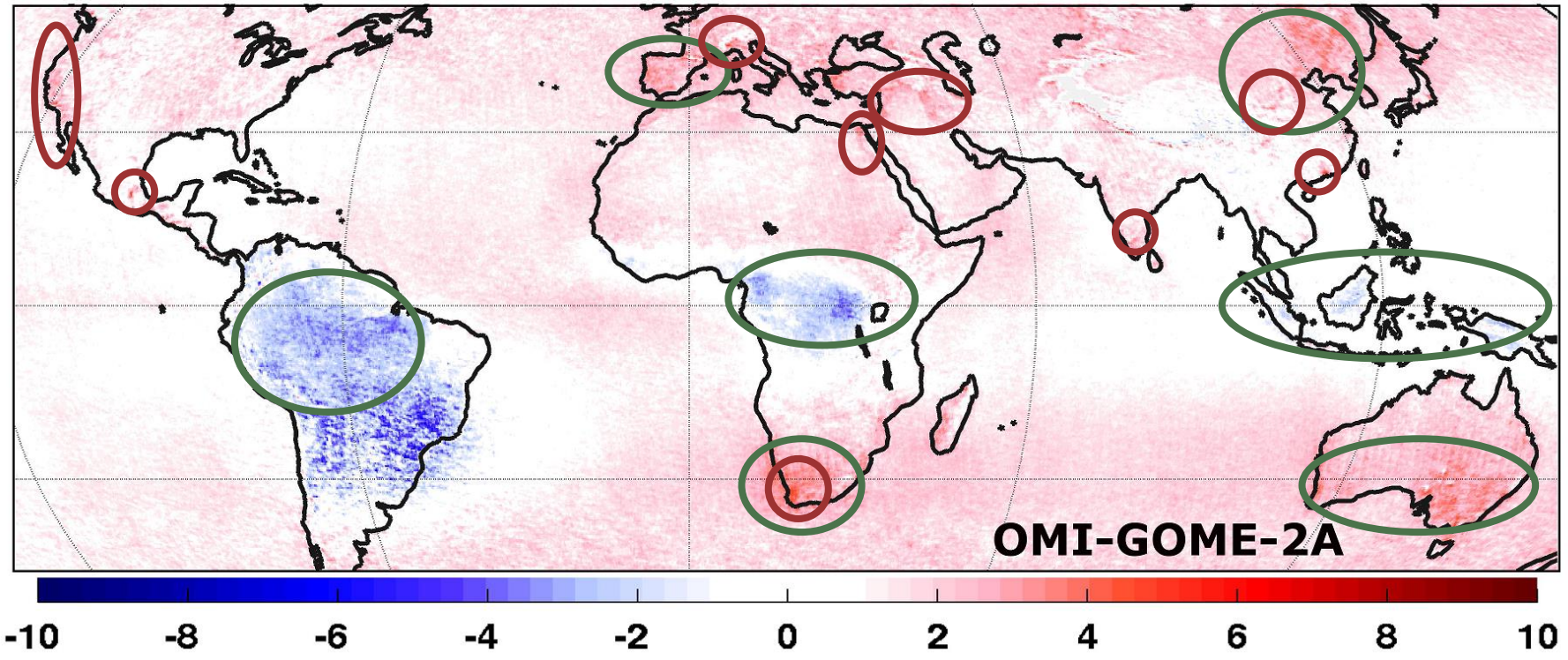
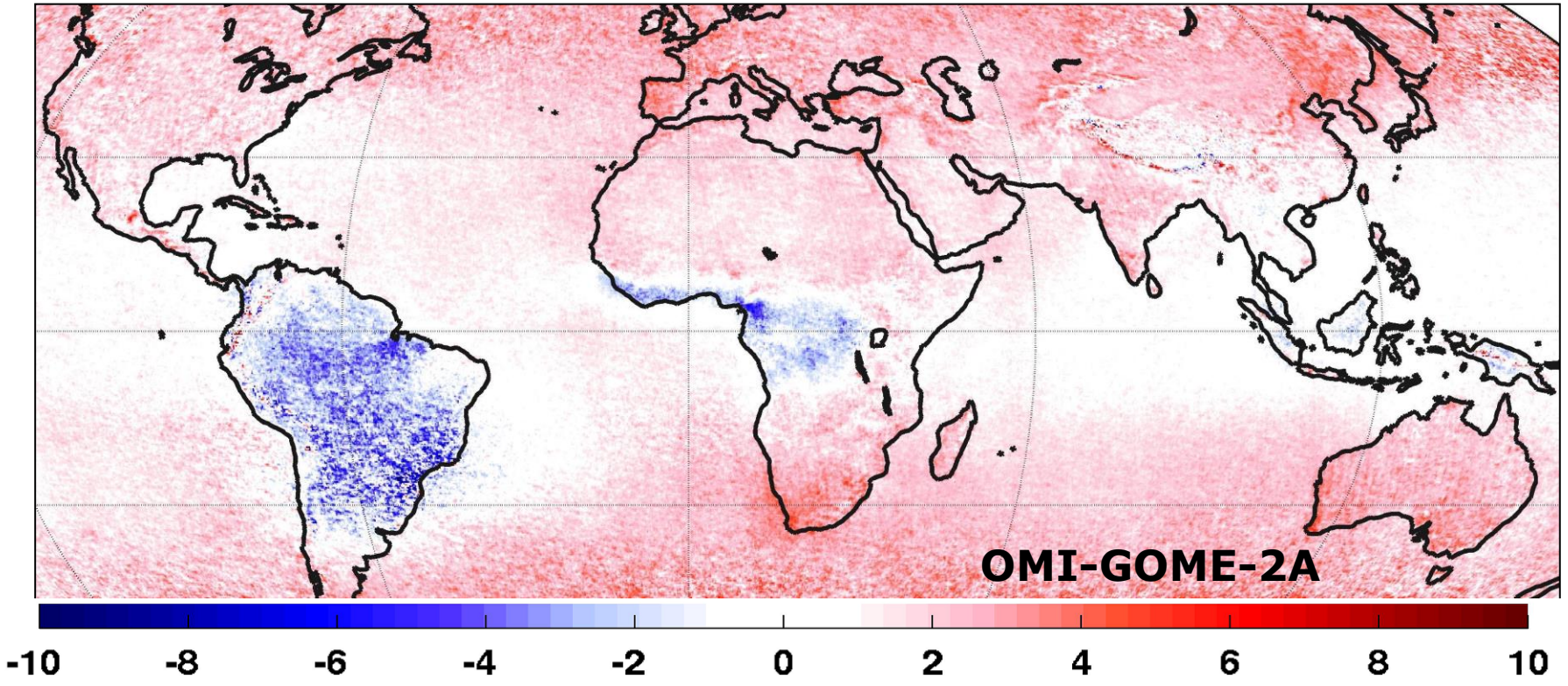
Observed diurnal variation between 09h30 and 13h30



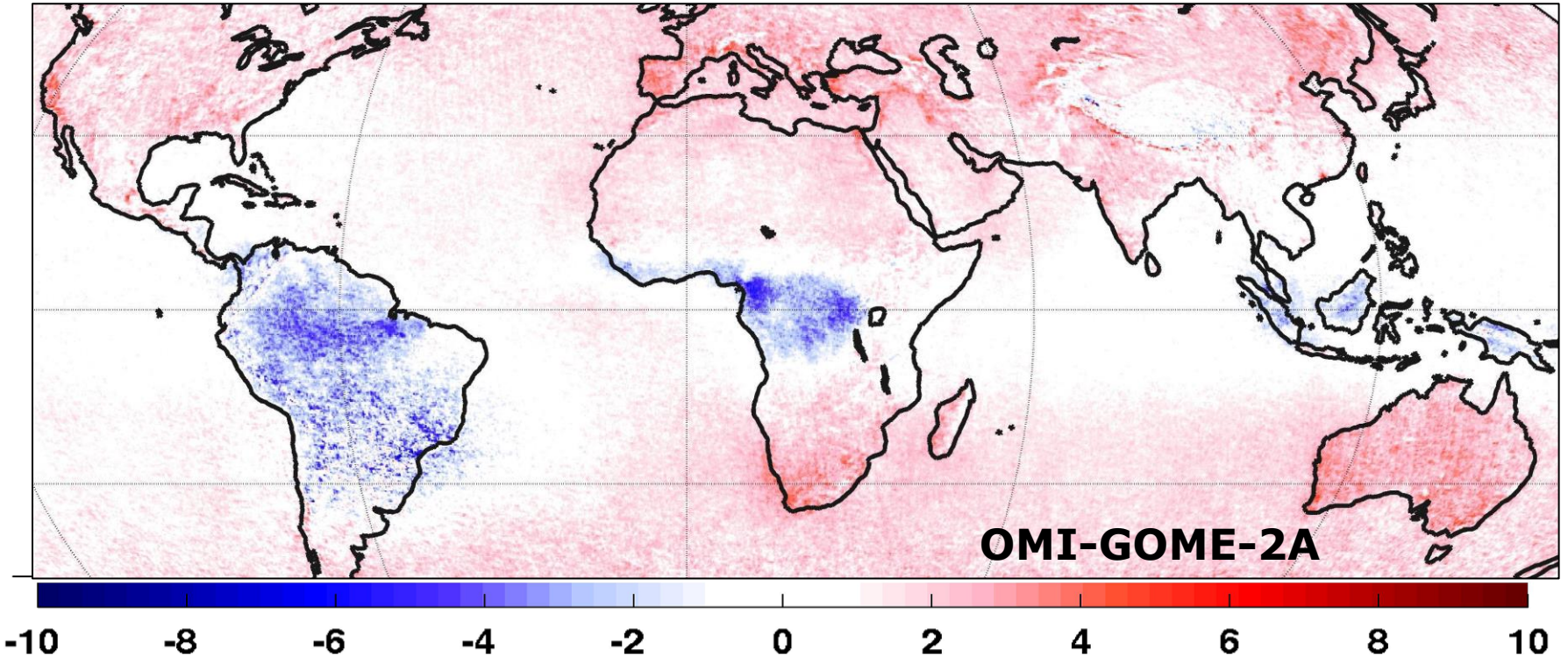
- Diurnal variation of the H_2CO columns
- OMI horizontal resolution
- Different retrieval sensitivities between morning and afternoon observations.

Cloud impact on the observed diurnal variation

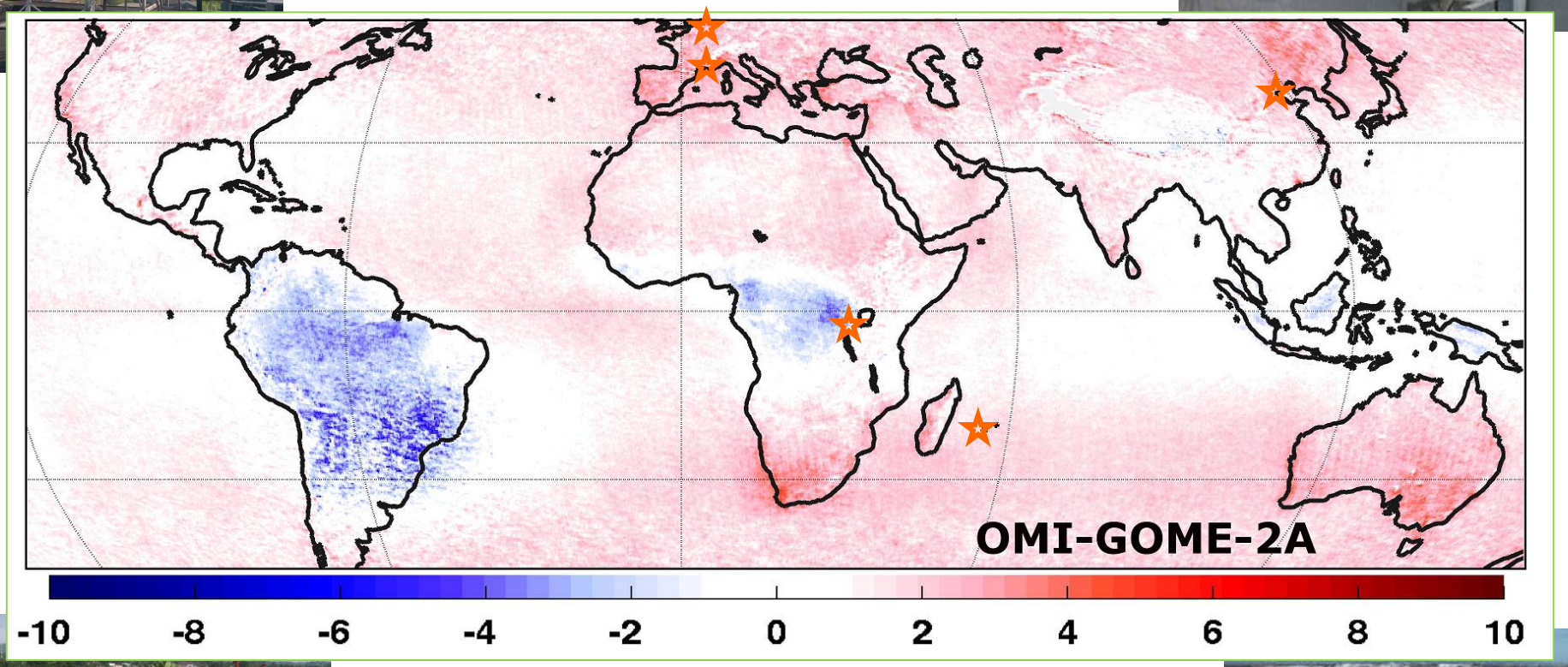


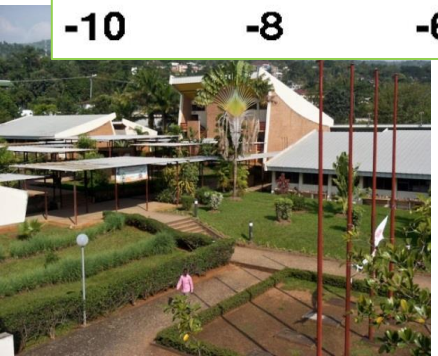
- Cloud free observations, no cloud correction

A priori profile impact on the observed diurnal variation



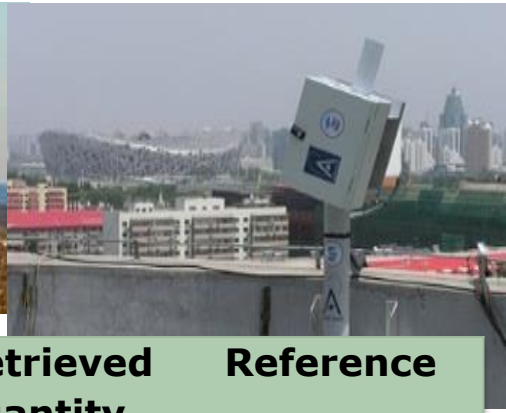
- Afternoon profiles used in GOME-2 retrieval





Validation of the observed diurnal variation

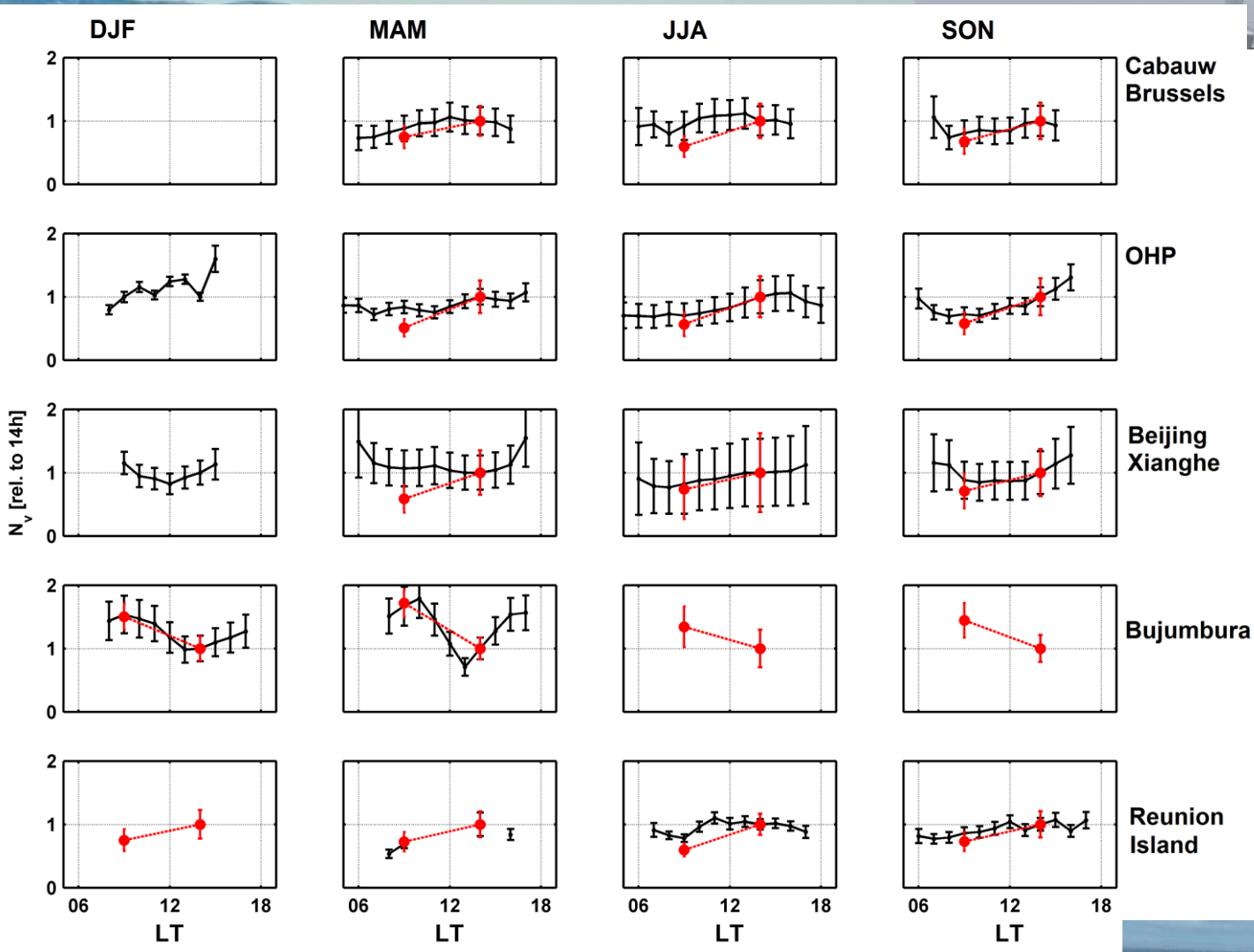




Station/Country (lat, long)	Instrument	Period	Retrieved quantity	Reference
Cabauw/The Netherlands (52° N, 5° E)	MAX-DOAS	18/06/2009-21/07/2009	VCD	Pinardi et al., 2013
Brussels/Belgium (50.78° N, 4.35° E)	Mini-MAX-DOAS	01/05/2011-23/04/2012	VCD	Gielen et al., 2014
OHP/France (43.94°N, 5.71°E)	MAX-DOAS	26/06/2007-20/03/2013	VCD	Valks et al., 2011
Beijing/China (39.98°N, 116.38°E)	MAX-DOAS	03/07/2008-17/04/2009	VCD + Profile	Vlemmix et al., 2014
Xianghe/China (39.75° N, 116.96° E)	MAX-DOAS	07/03/2010-26/12/2013	VCD + Profile	Vlemmix et al., 2014
Bujumbura/Burundi (3°S, 29°E)	MAX-DOAS	25/11/2013-22/04/2014	VCD + Profile	Pinardi et al., 2013
Reunion Island/France (20.9° S, 55.5° E)	FTIR	01/08/2004-25/10/2004 21/05/2007-15/10/2007 02/06/2009-28/12/2009 11/01/2010-16/12/2010	VCD	Vigouroux et al., 2009

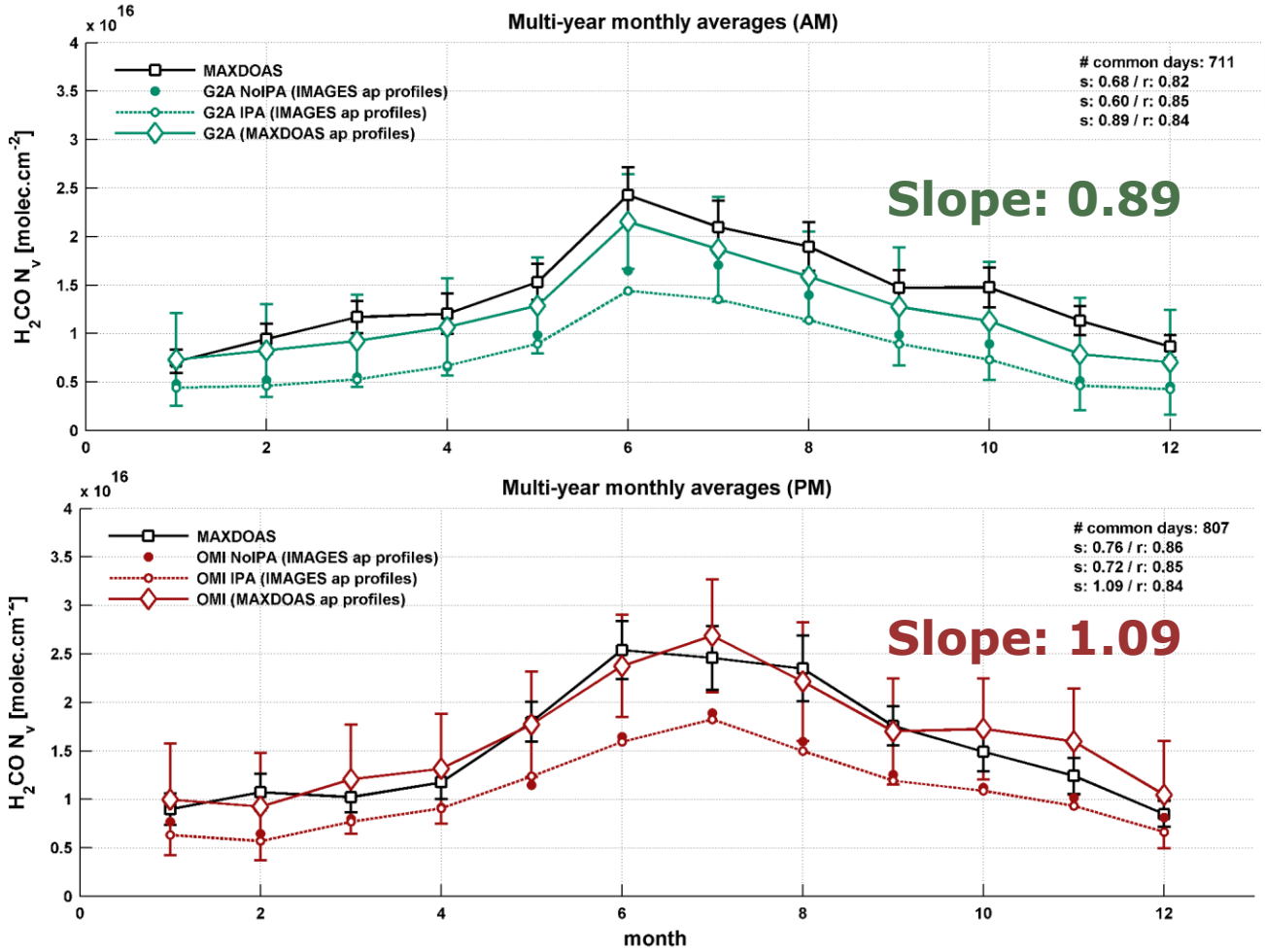
Validation of the observed diurnal variation

- Seasonal Averages
- MAX-DOAS FTIR diurnal records

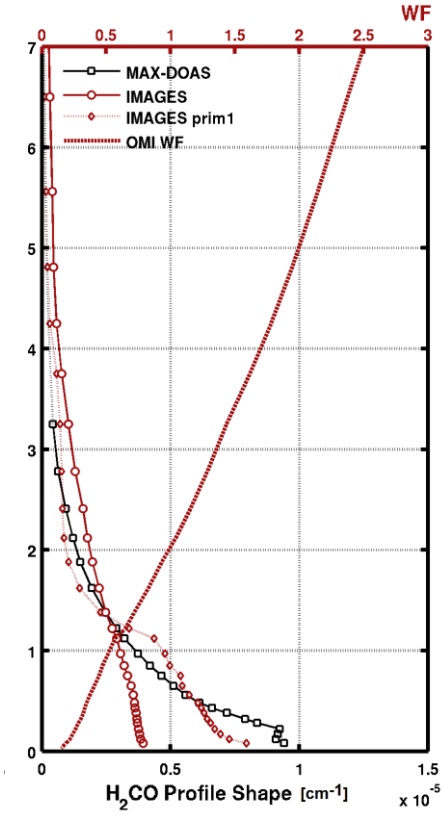


Validation of the observed diurnal variation

Validation of the tropospheric column

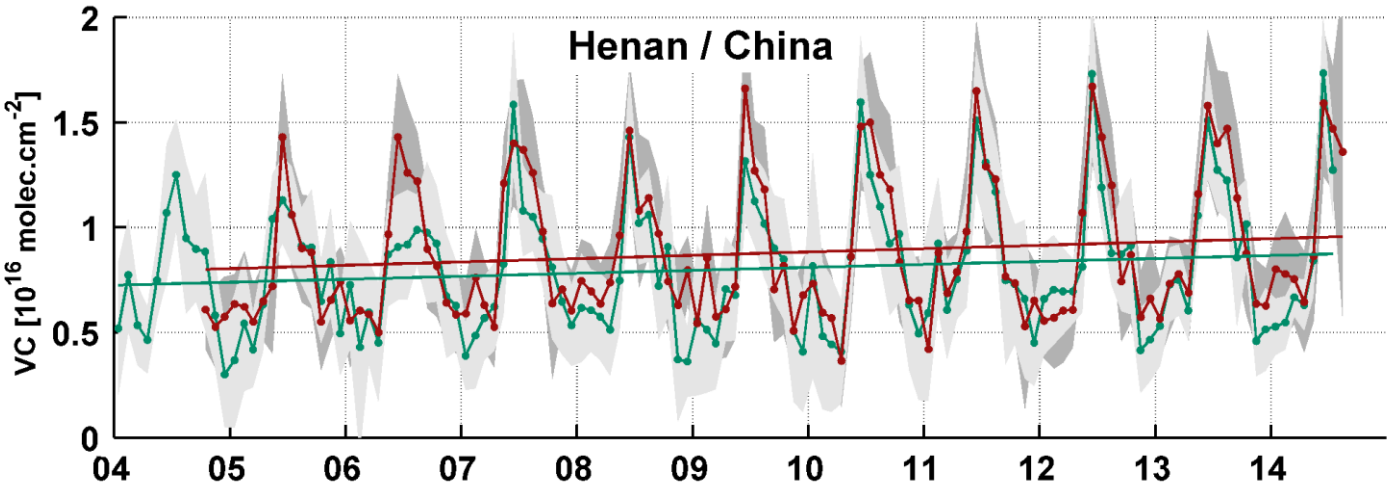


Beijing/Xianghe

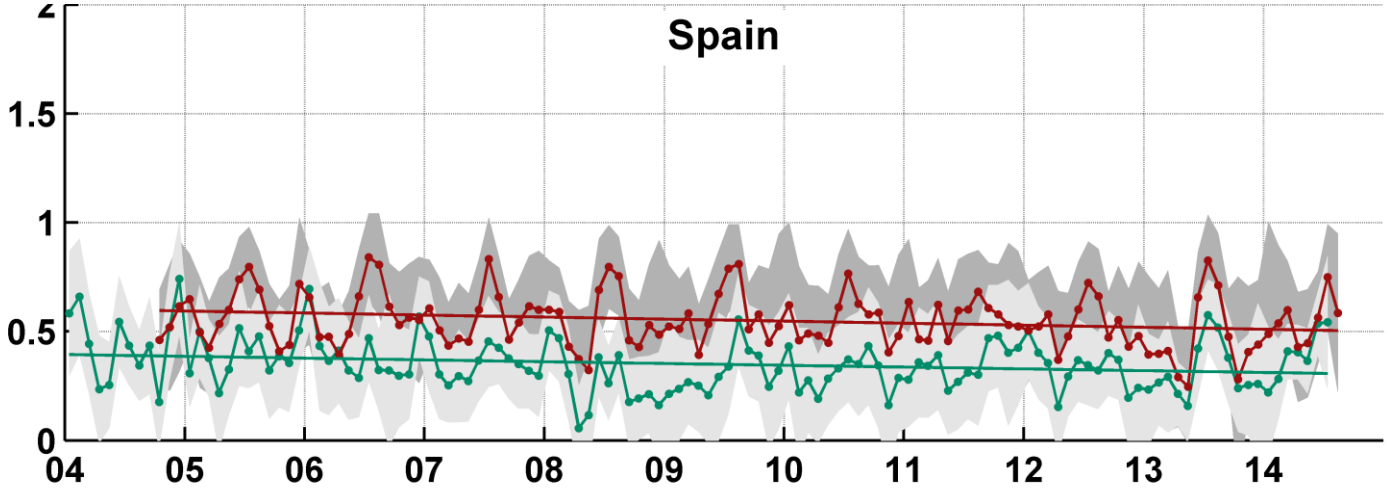


- little systematic impact of the cloud correction on the monthly averaged columns.
- systematic effect of the *a priori* vertical profile on the vertical columns.

Trends in OMI H_2CO columns

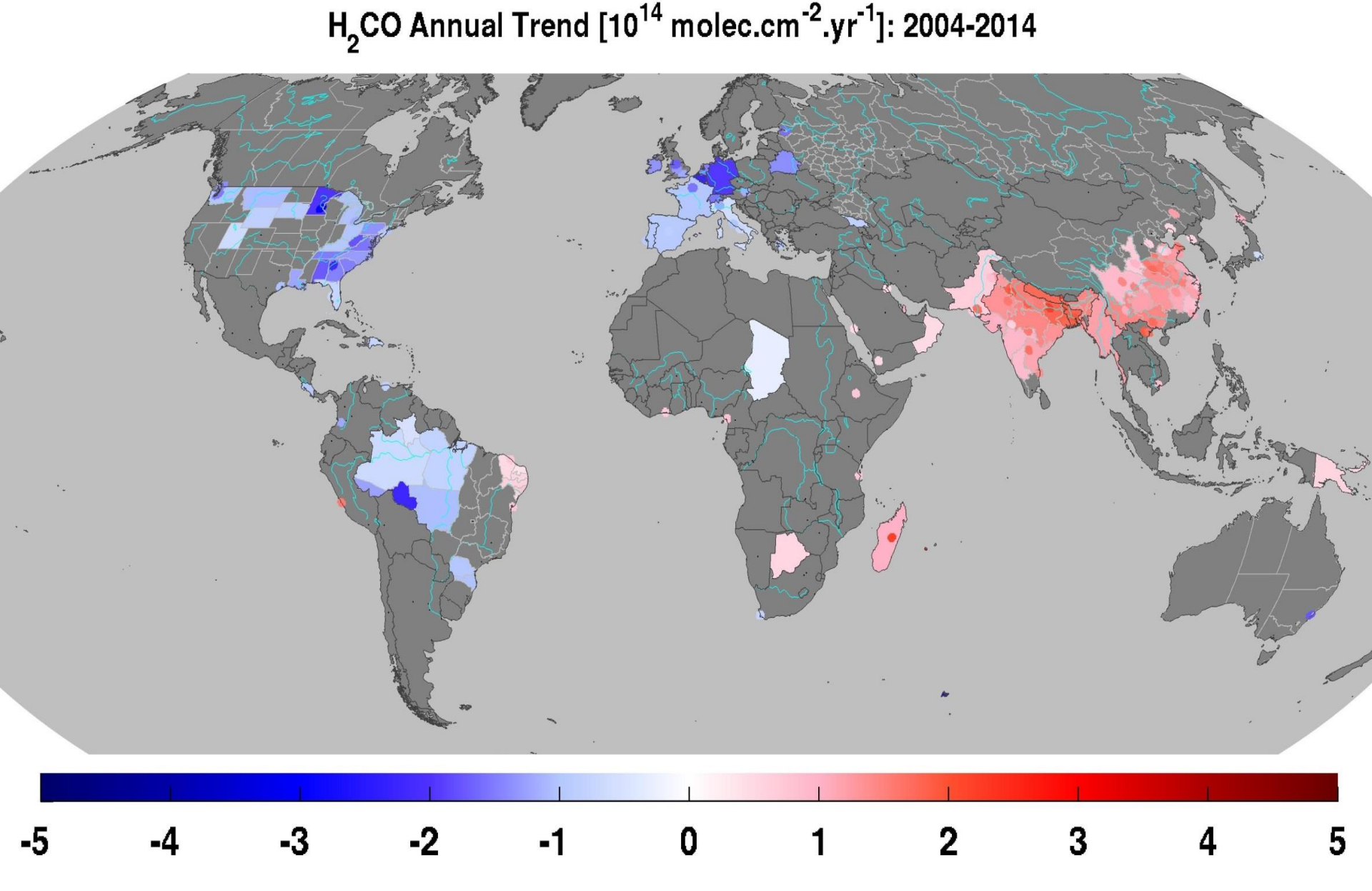


Annual trends: 1.4 +- 0.4 1.6 +- 0.4 10^{14} molec.cm^{-2} yr^{-1}
1.9 +- 0.6 2.0 +- 0.5 % yr^{-1}

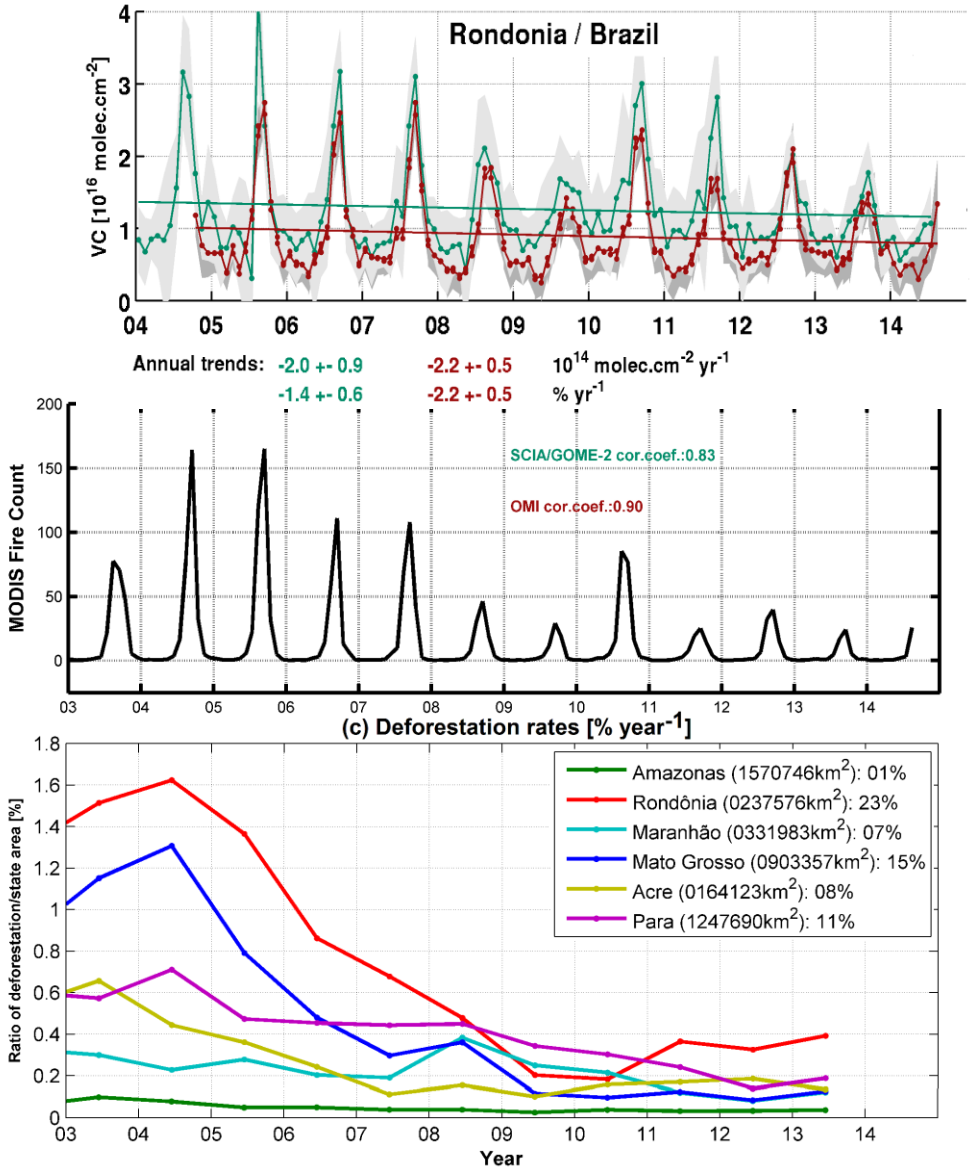


Annual trends: -0.8 +- 0.3 -0.9 +- 0.2 10^{14} molec.cm^{-2} yr^{-1}
-2.1 +- 0.7 -1.6 +- 0.3 % yr^{-1}

Trends in OMI H_2CO columns



Negative trend over the Amazon forest

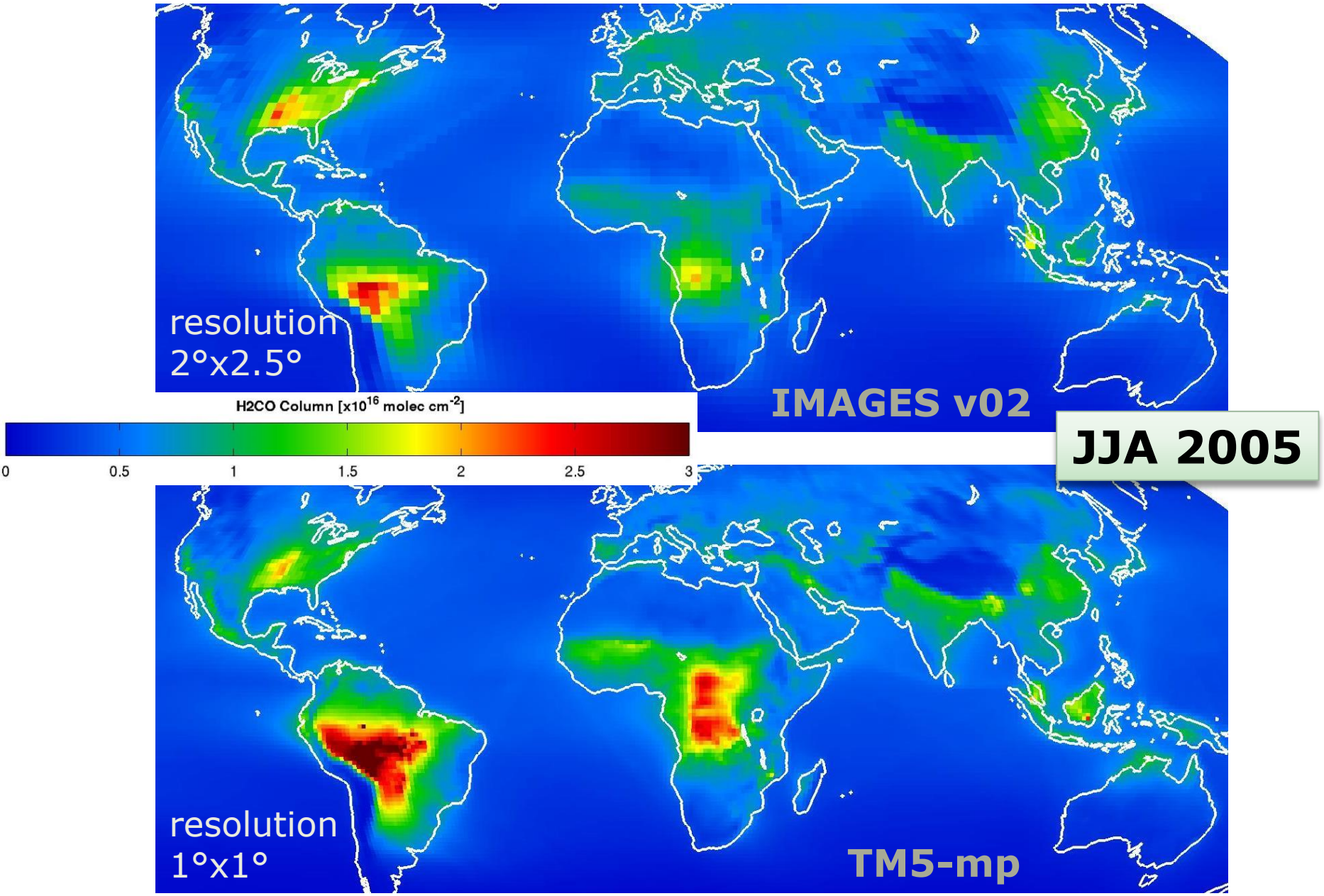


- High correlation between fires and H_2CO columns
- Fires and reported deforestation rates have decreased in Rondônia since 2004
- Direct effect on H_2CO columns

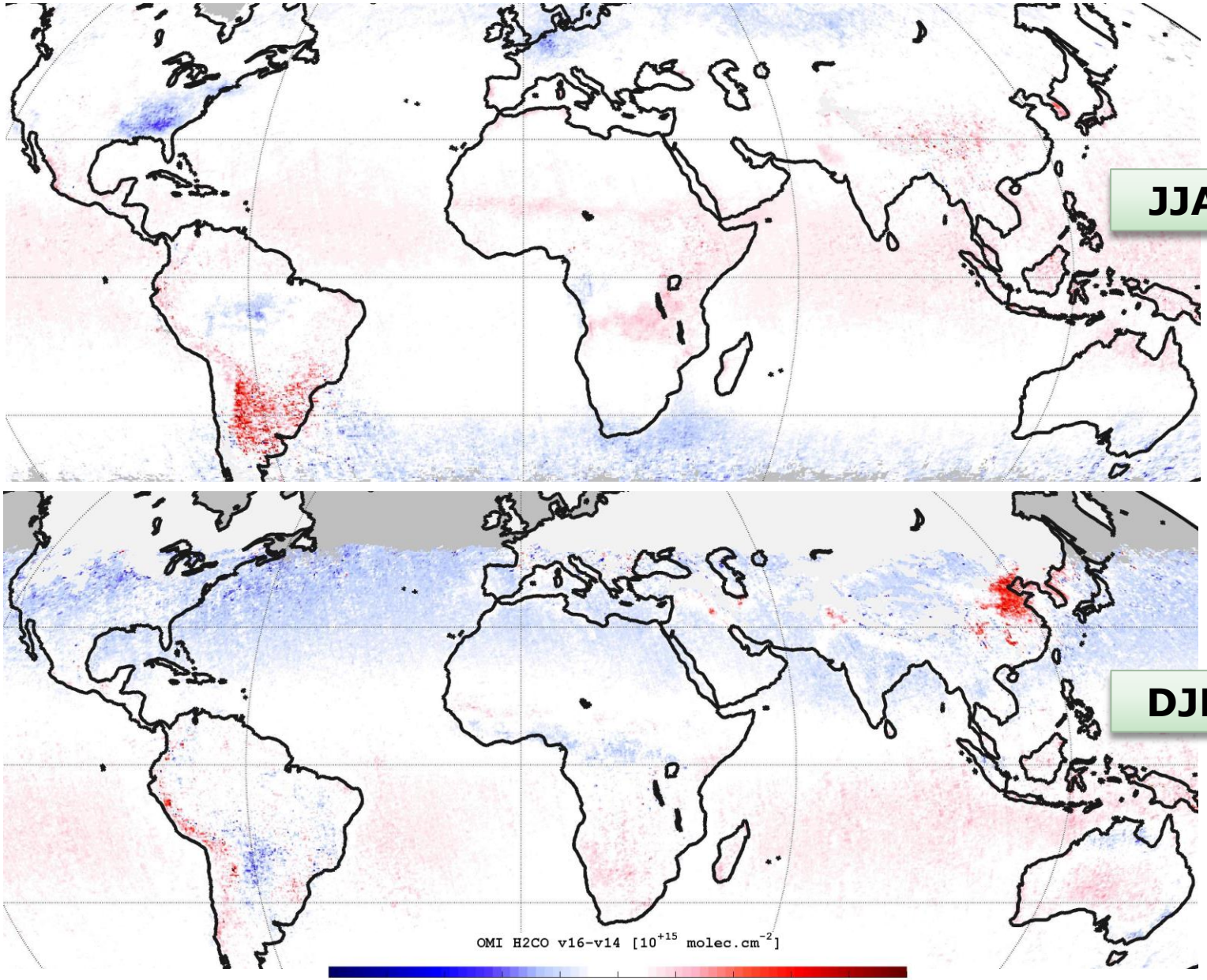
Formaldehyde Prototype Algorithm: TM5 Profiles

- Differences can be large between model H_2CO columns but
- the impact on the satellite H_2CO VCD is limited (only profile shape matters)
- TM5-mp leads to
  - finer spatial resolution over cities
  - increase of the H_2CO columns over NE China in winter time (difference in profile shape)

Model Total Columns: Seasonal Mean



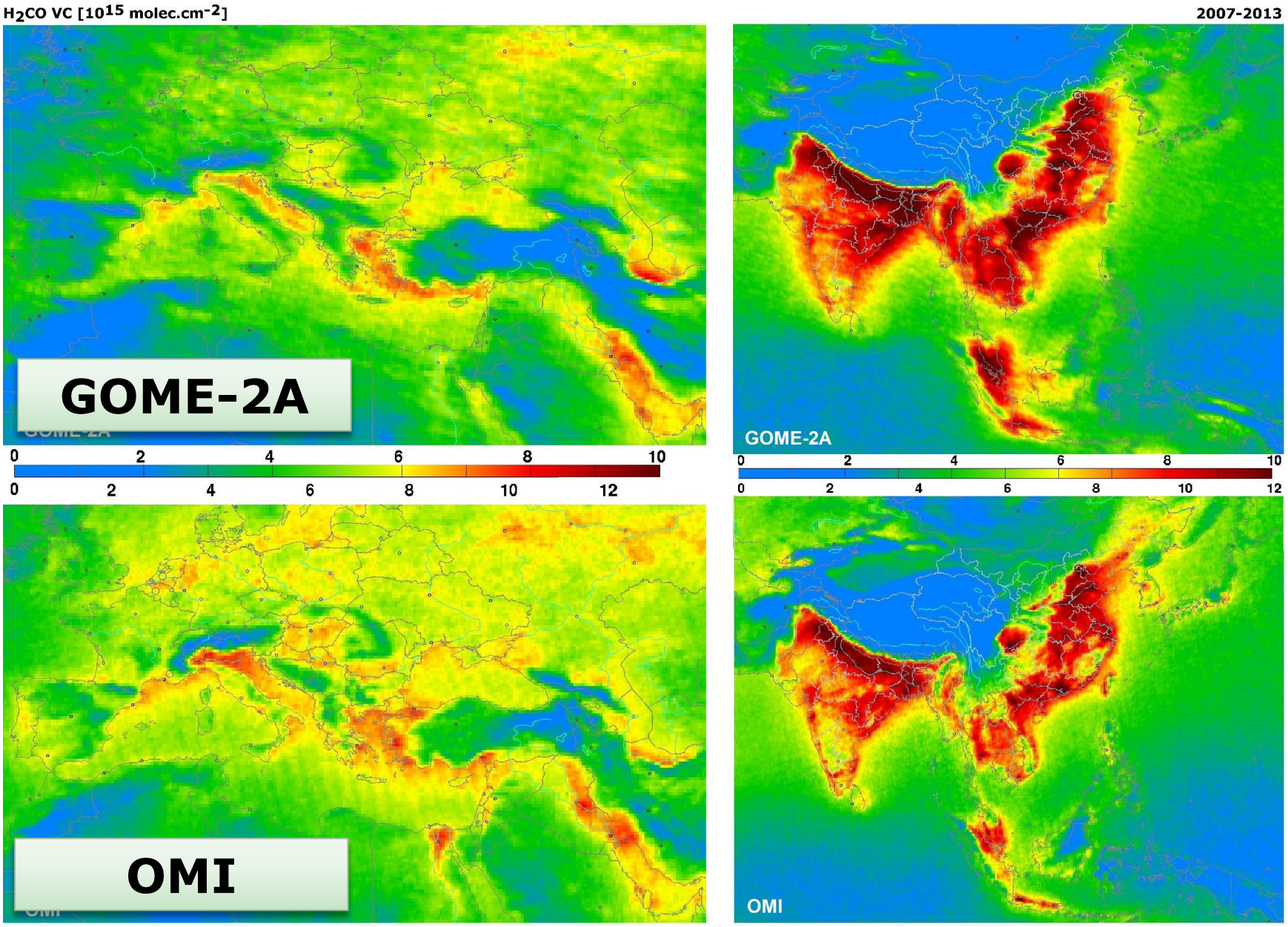
IMAGES and TM5 a priori Profiles: VCD



Conclusions

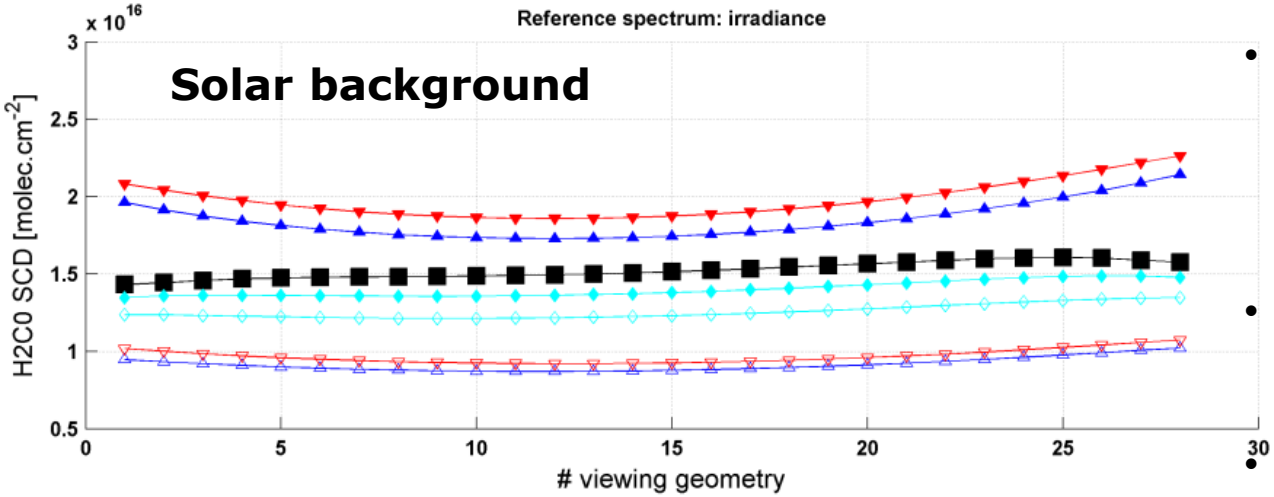
- ✓ Prototype algorithm successfully applied to GOME-2 and OMI data records
- ✓ TM5 a priori profiles will be used in air quality TROPOMI level2 products (H_2CO, NO_2, SO_2)
- ✓ The 7x7km² spatial resolution of TROPOMI, combined with a SNR equivalent (or even better) than OMI, is expected to significantly improve the H_2CO observations.

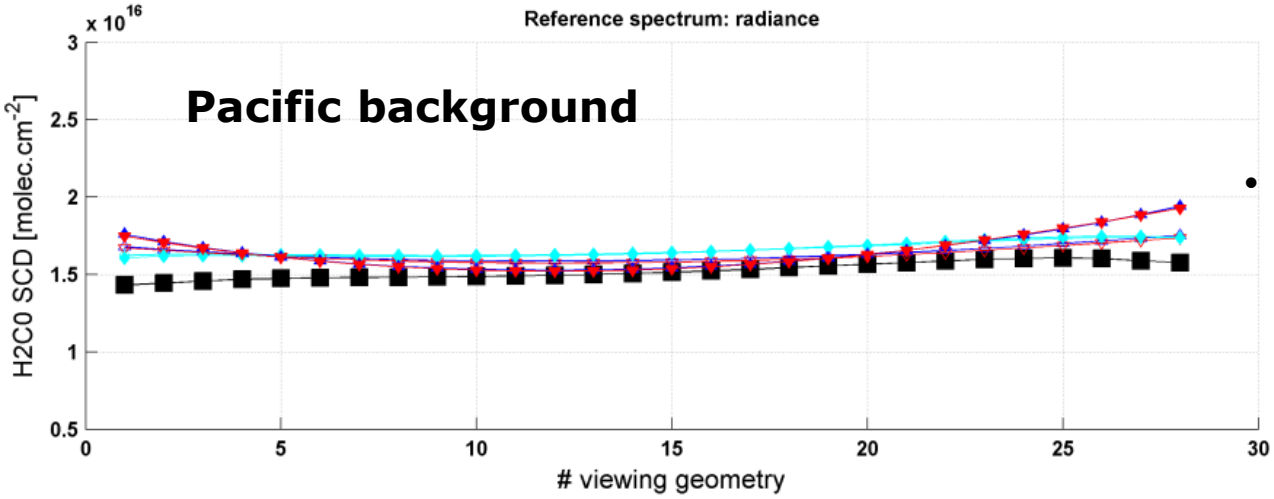
Conclusions



Ongoing work: verification

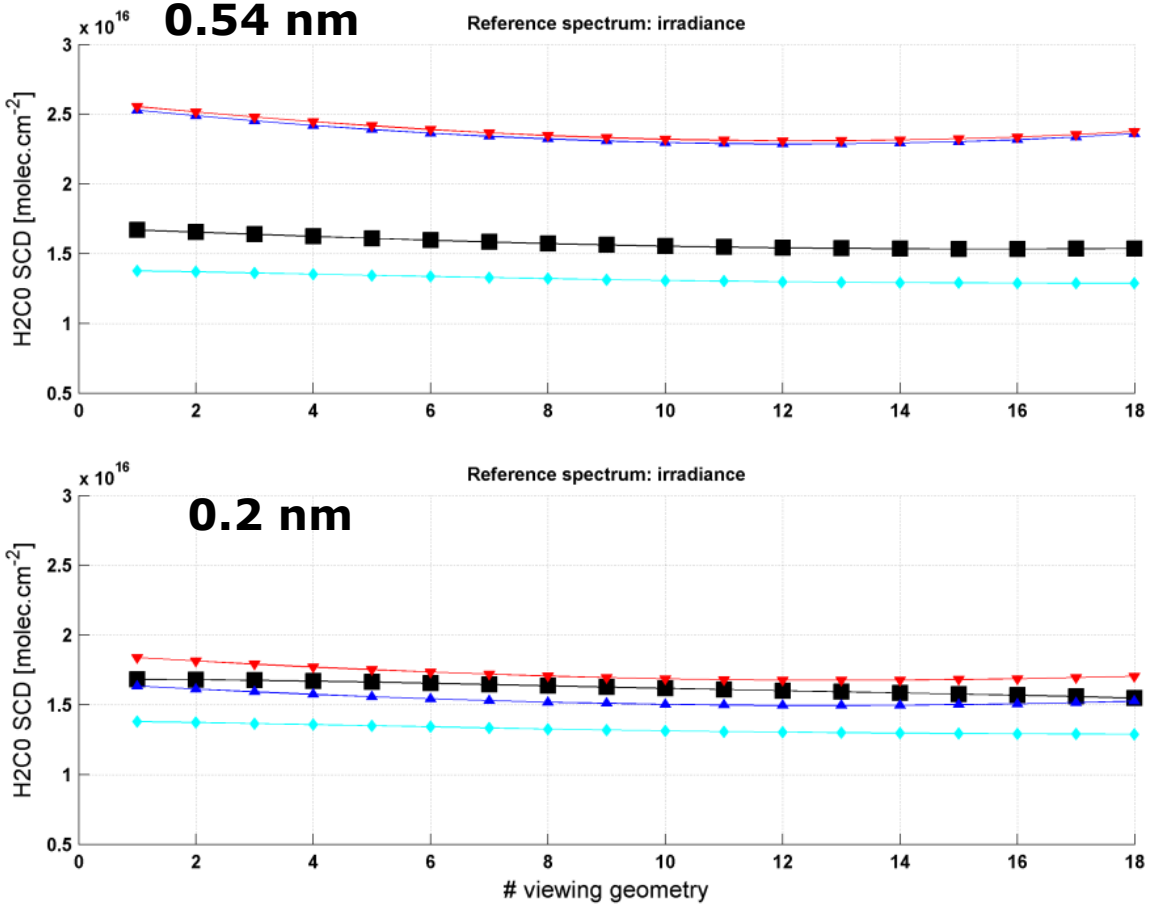
Verification results using synthetic spectra
Earth radiance as background spectrum





- H_2CO columns applying different settings for synthetic spectra using CAMELOT scenarios
- True SCDs are indicated with black squares
- H2CO SCD can display significant and variable offsets in comparison to true columns
- The use of a radiance spectrum selected in the background Pacific allows to mitigate a large part of the observed interferences.

Verification results using synthetic spectra spectral resolution effects



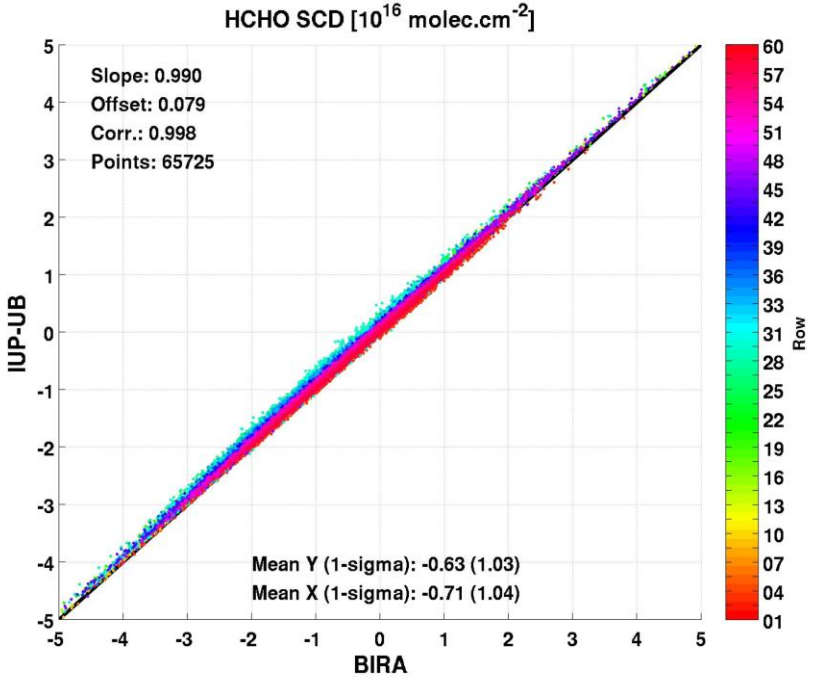
- Such spectral interferences have a smaller impact on simulations at 0.2 nm (representative of previous sensors) than at 0.54 nm.
- The use of a radiance spectrum selected in the background Pacific allows to mitigate a large part of the observed interferences

Verification results using OMI test data

- Intercomparison of verification (IUP-UB) and prototype (BIRA) processing chains, using identical settings and input.
- Goal: to verify that the processing chains behave as expected
- Unique way to identify and fix problems in the algorithms.

- Spectral fitting in multiple intervals
  - w1: 339-364 nm (O_4)
  - w2: 328.5-359nm (BrO + HCHO)
  - w3: 328.5-346 nm (HCHO)

- Solar irradiance as background spectrum



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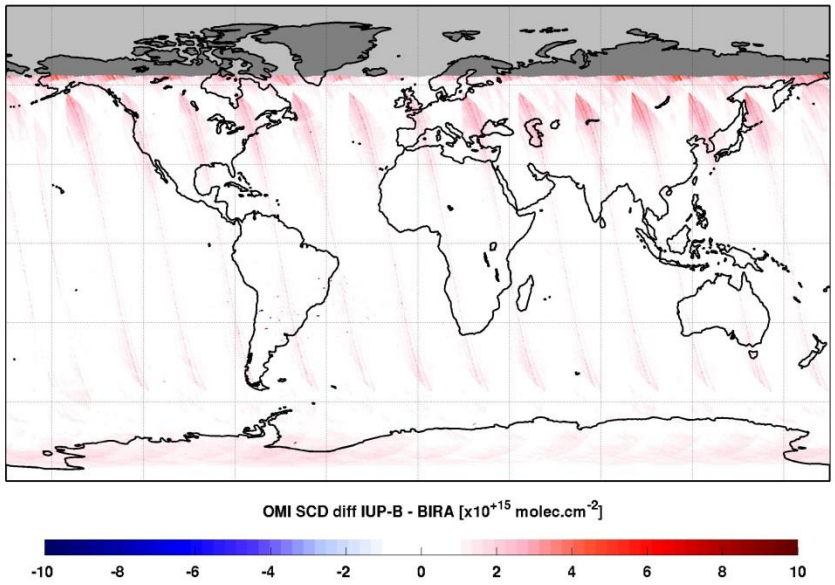
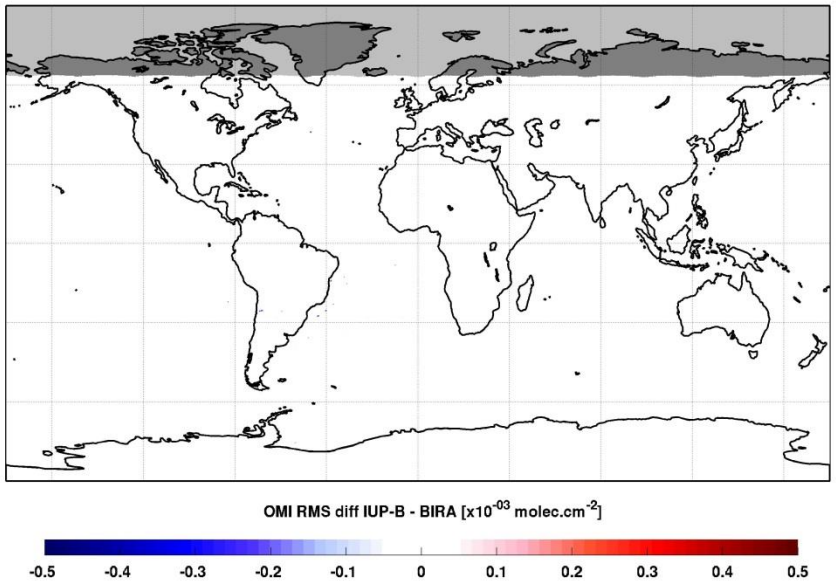
IUP-BIRA HCHO SC



IUP-BIRA RMS

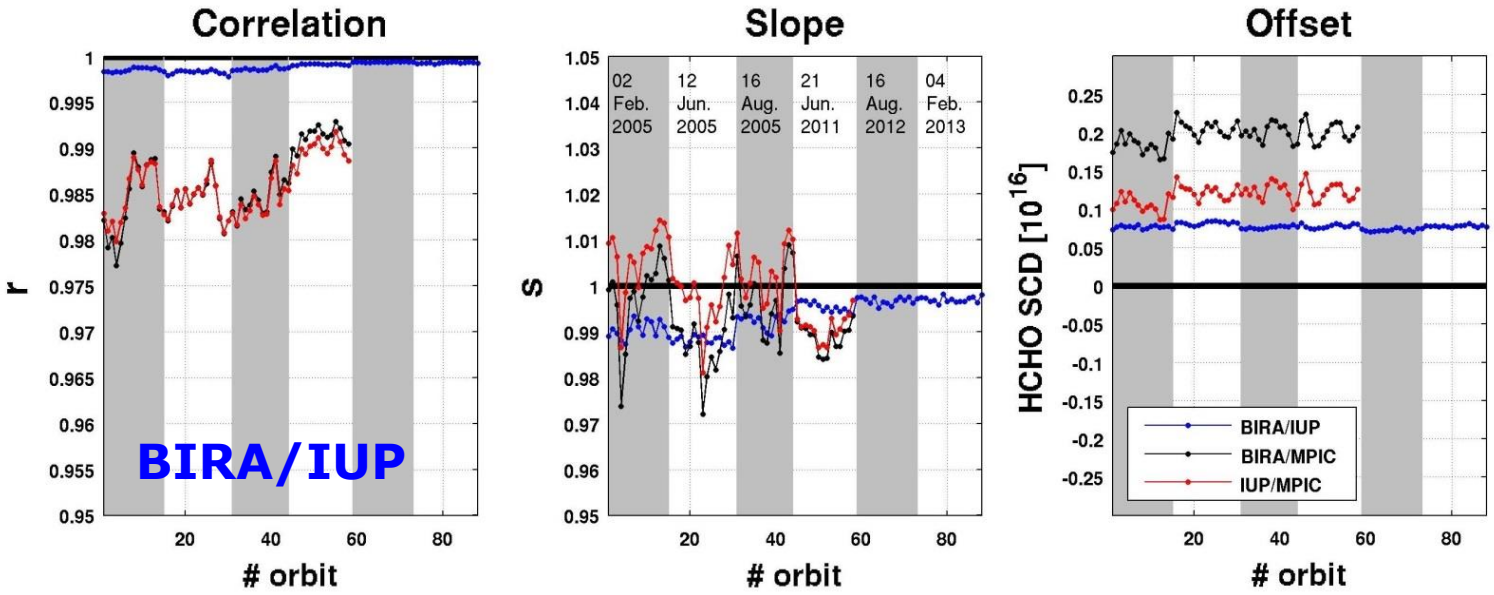


Verification results using OMI test data

Range of uncertainty when using exactly the same settings:

BIRA/IUP:
corr: 0.998,
slope: -1%,
offset: 9e14

IUP/MPIC:
corr: 0.985,
slope: +- 1%,
offset: 12 e14



- When using identical settings, the agreement in slant columns between prototype and verification algorithms is excellent (problems identified and fixed).
- Large sensitivity to small changes in treatment of OMI convolution, intensity offset correction or wavelength alignment.
- Background correction is needed and will reduce remaining offsets.
- Verification work ongoing (AMFs, background correction)

Thank you