Bias characterization of HCHO columns from OMI using aircraft and FTIR data

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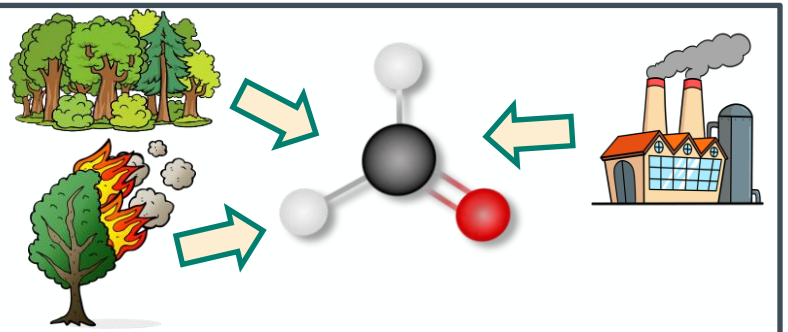
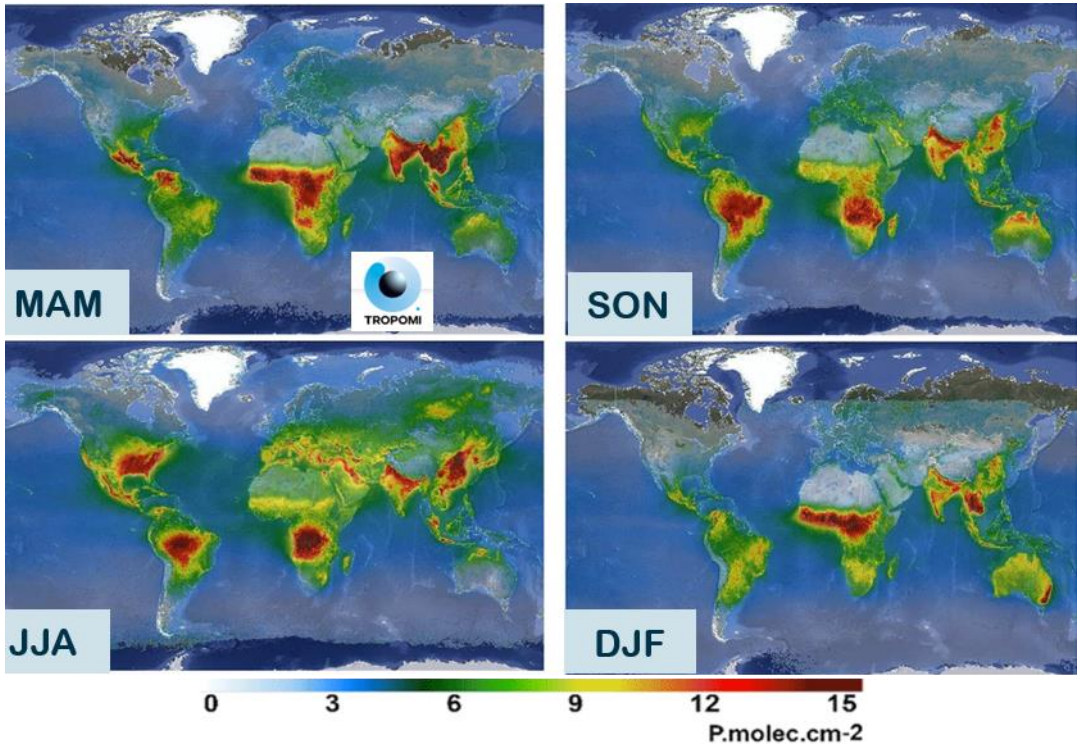
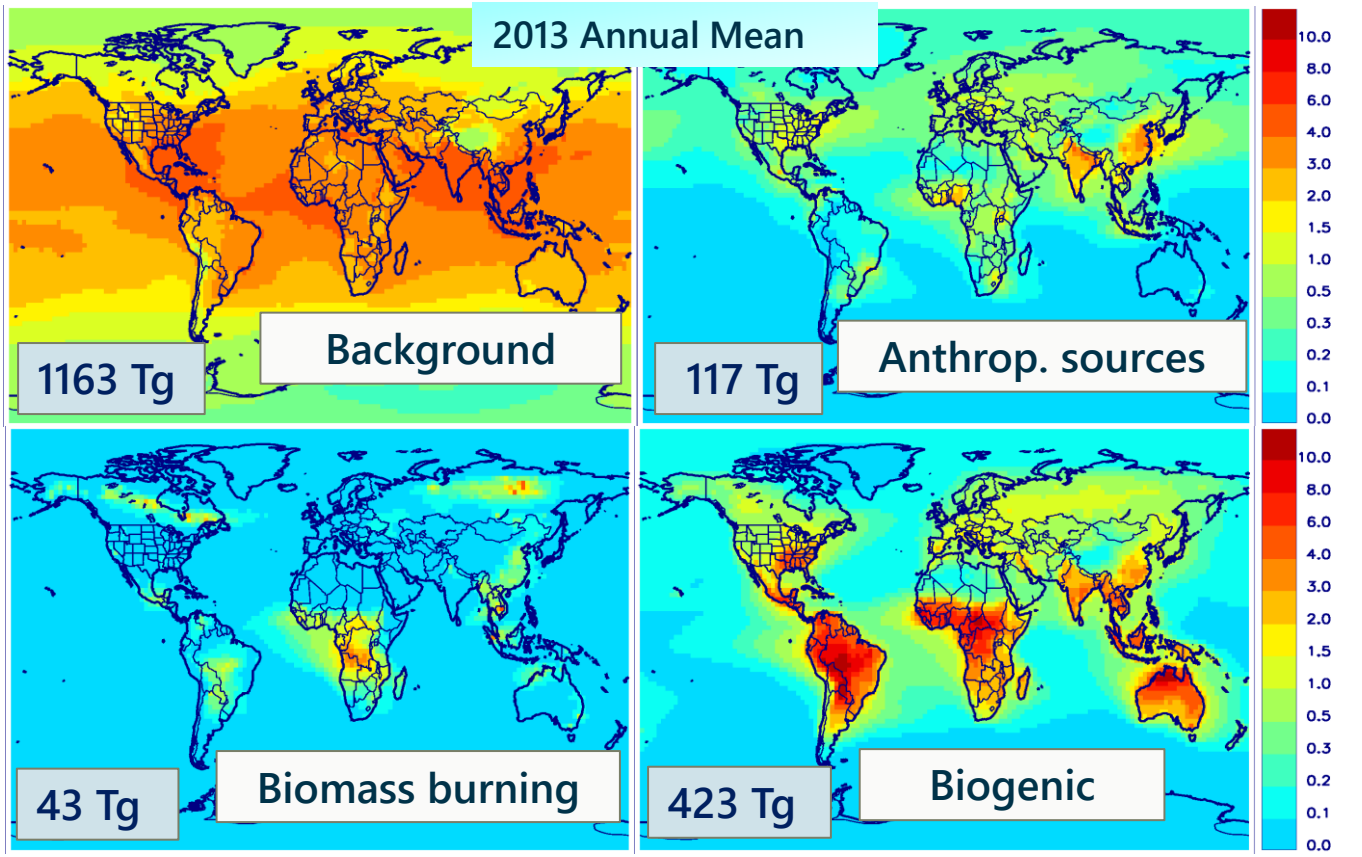
Spaceborne HCHO : a proxy for VOC emissions

HCHO: Short-lived product in the oxidation of most VOCs



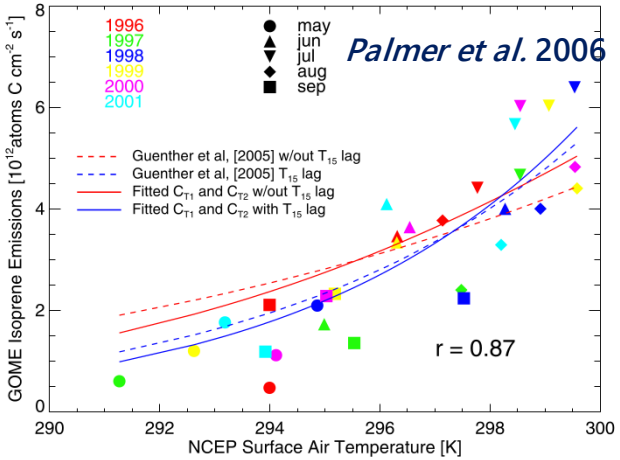


The total HCHO column is composed of

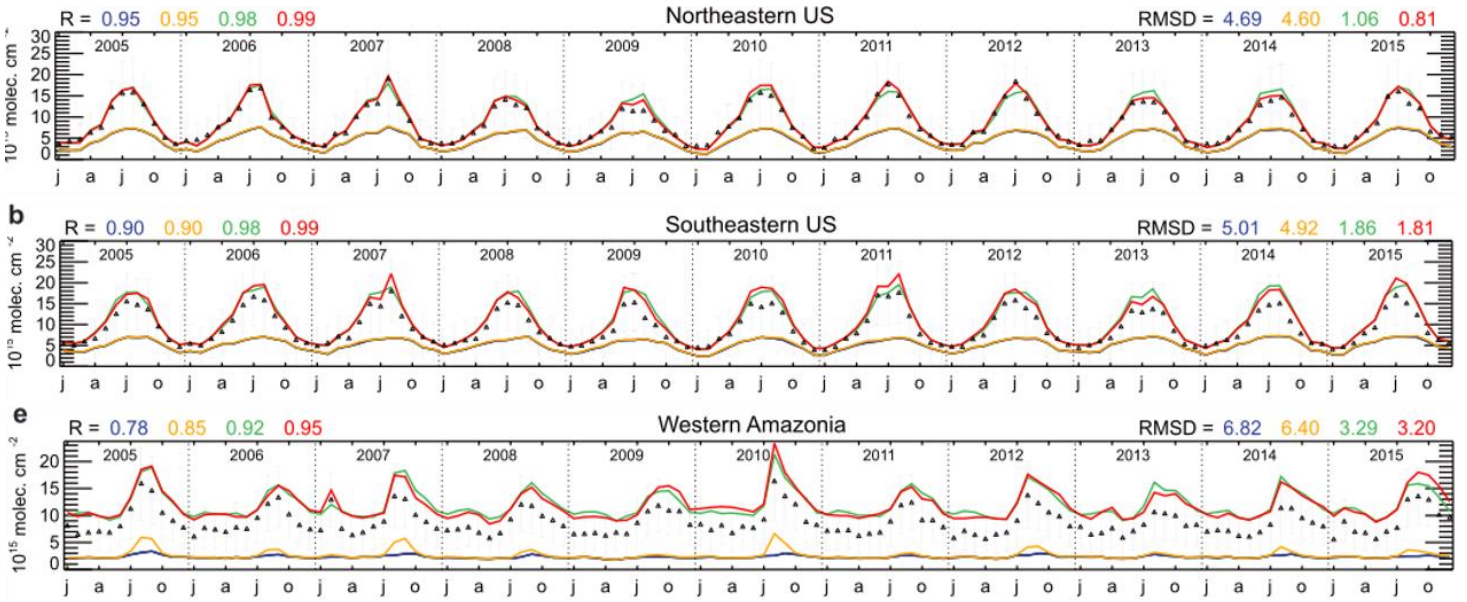


Spaceborne HCHO give insights on VOC temporal variability

HCHO variability reflects the meteorological dependence of biogenic isoprene emissions



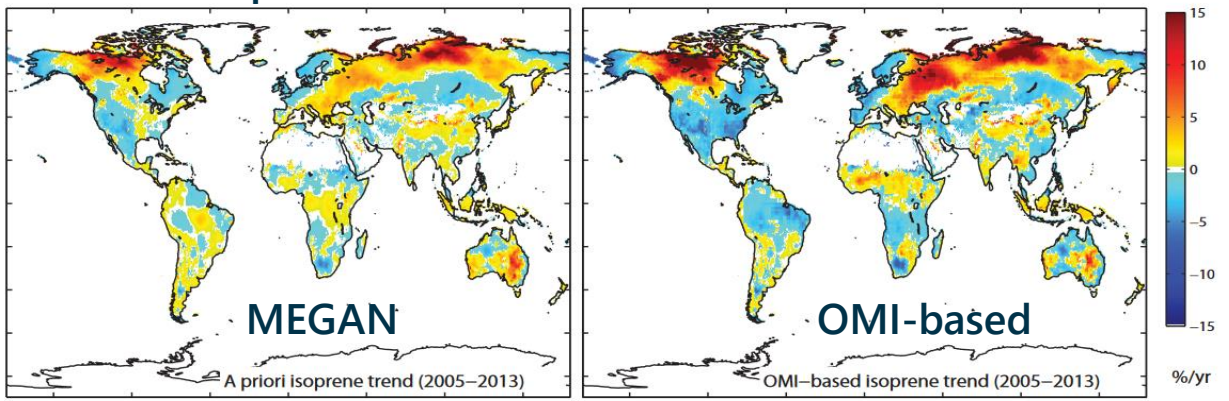
Palmer et al. 2006



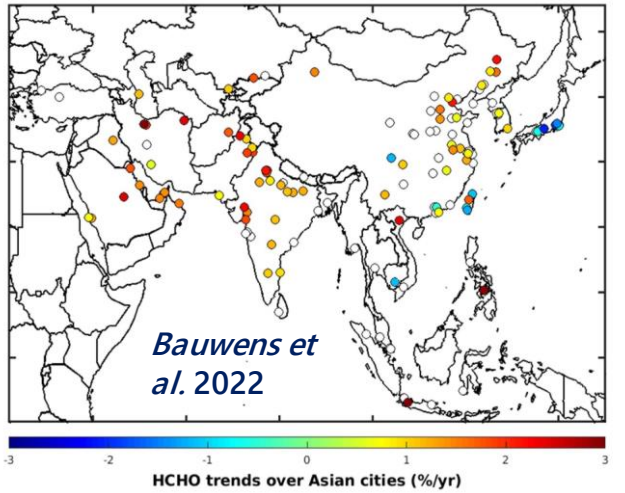
Stavrakou et al. 2018

Isoprene emission trend, 2005-2013

Bauwens et al. 2016

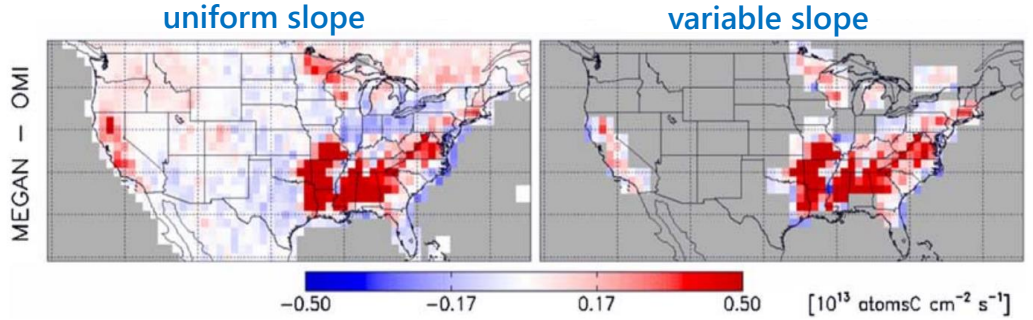


HCHO trend over cities, 2005-2019



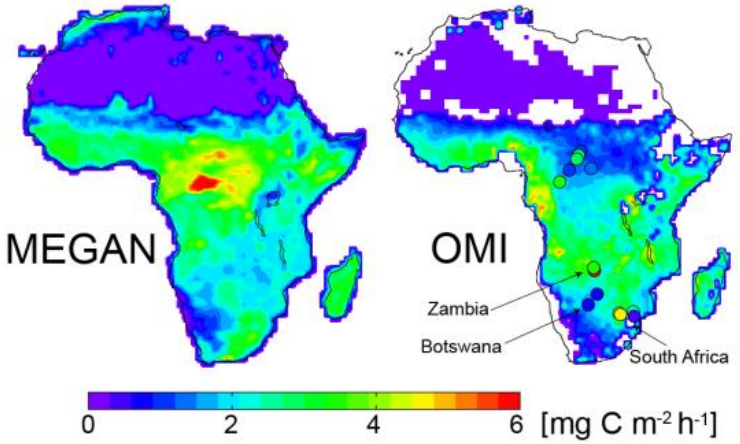
Past studies suggest an overestimation of bottom-up VOC emissions

Models overestimate spaceborne HCHO columns, especially over strong biogenic hotspots



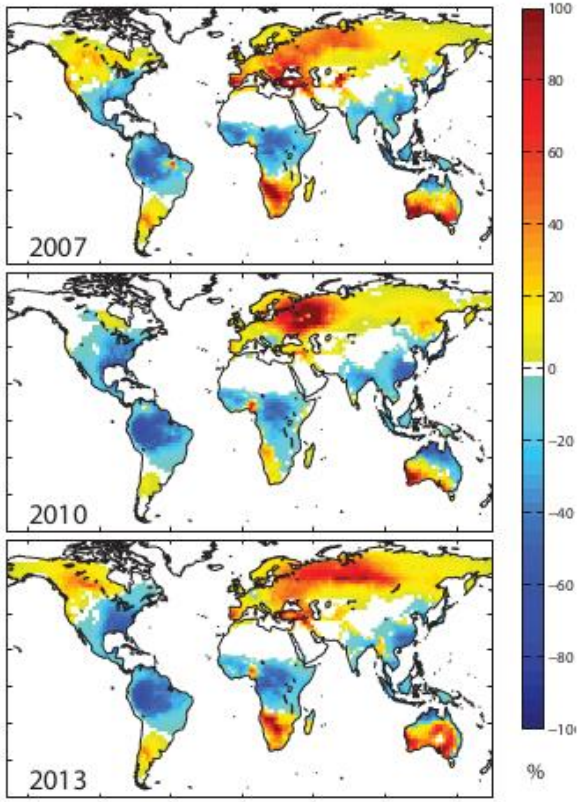
Millet et al. 2008

$E_{MEGAN} - E_{OMI}$

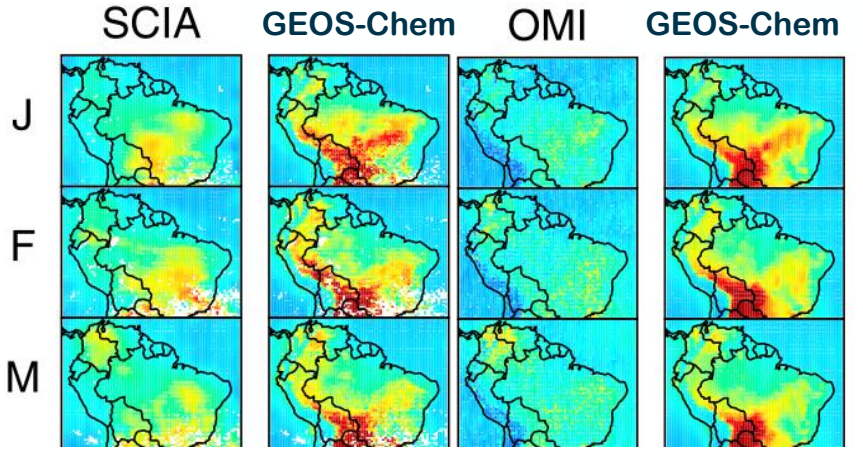


Marais et al. 2014

Isoprene flux update (%)

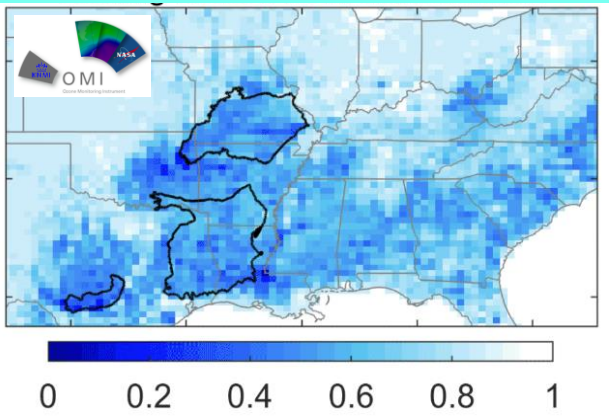


Bauwens et al. 2016



Barkley et al. 2011

OMI-based : Optimized/A priori

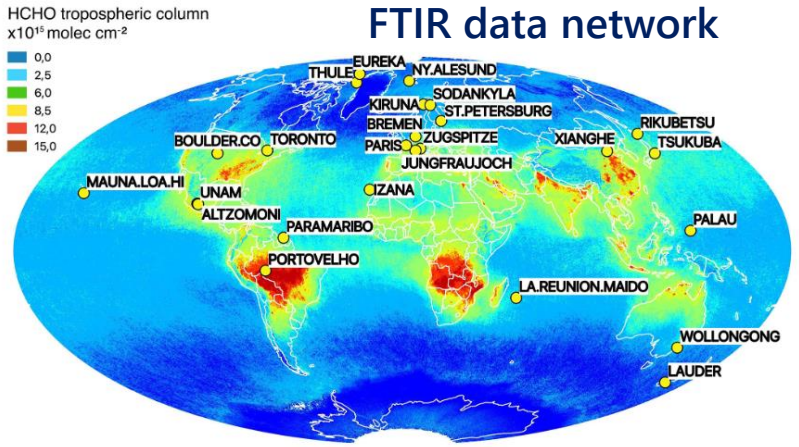


Kaiser et al. 2018

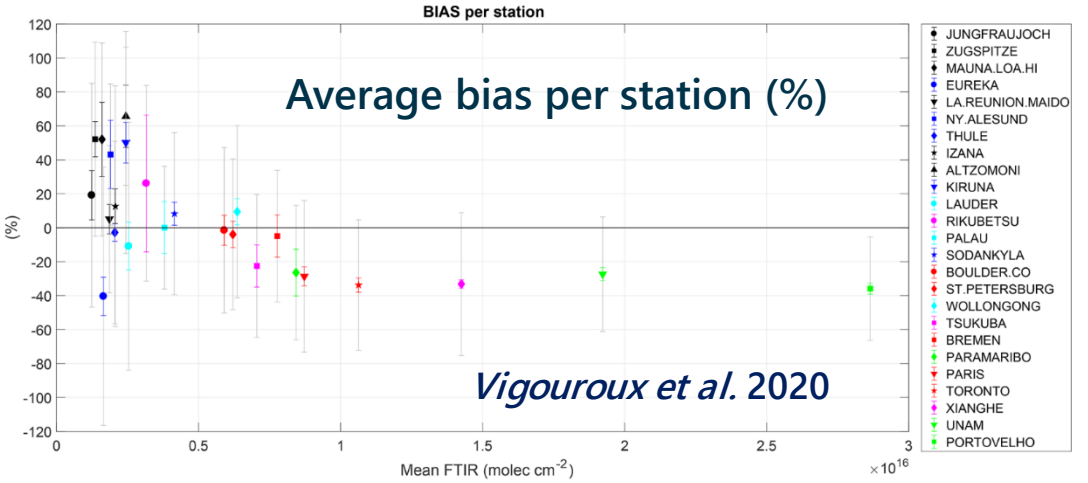
Kaiser et al. 2018

But… can satellite data be trusted? The case of TROPOMI

FTIR data network

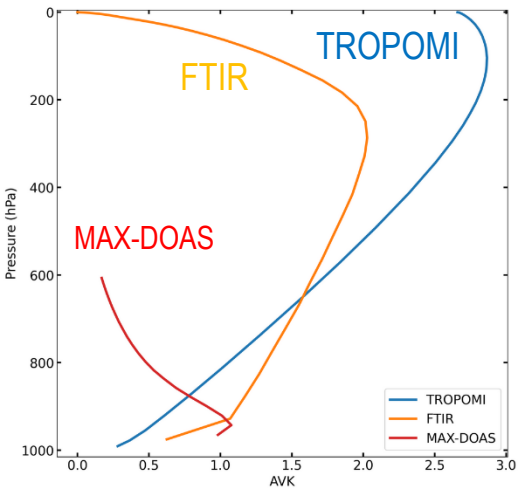


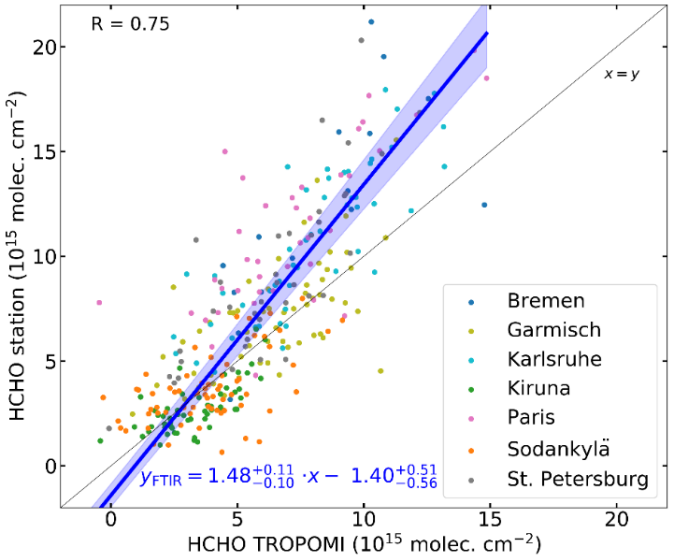
Average bias per station (%)



Vigouroux et al. 2020

Averaging kernels





Oomen et al. 2024

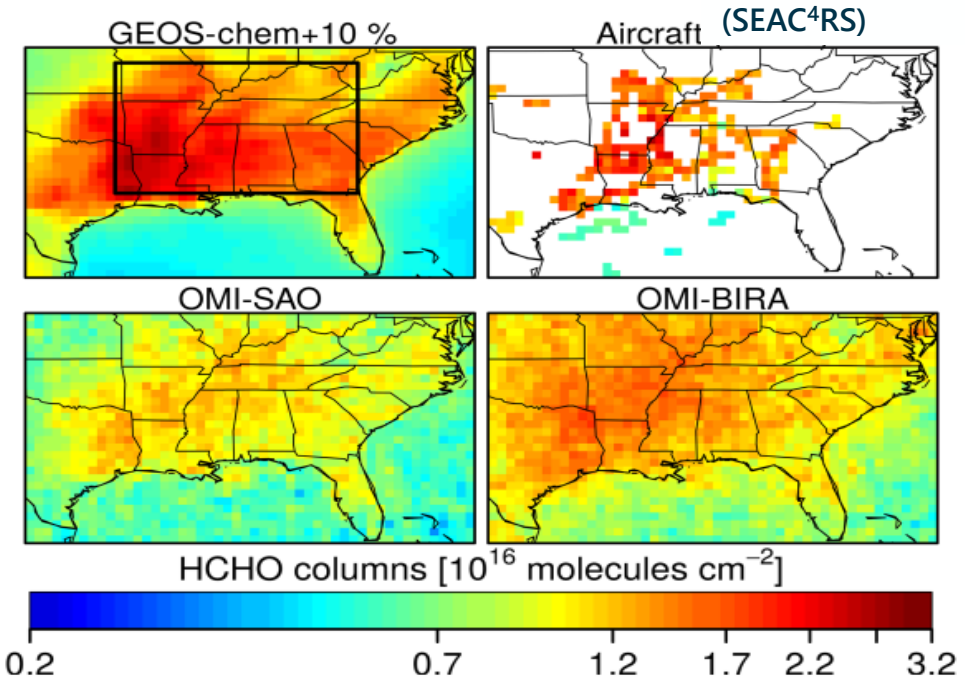
Pros of FTIR

- Harmonized settings
- Wide range of columns
- Vertical profile of sensitivity (AVK) similar to TROPOMI

Cons

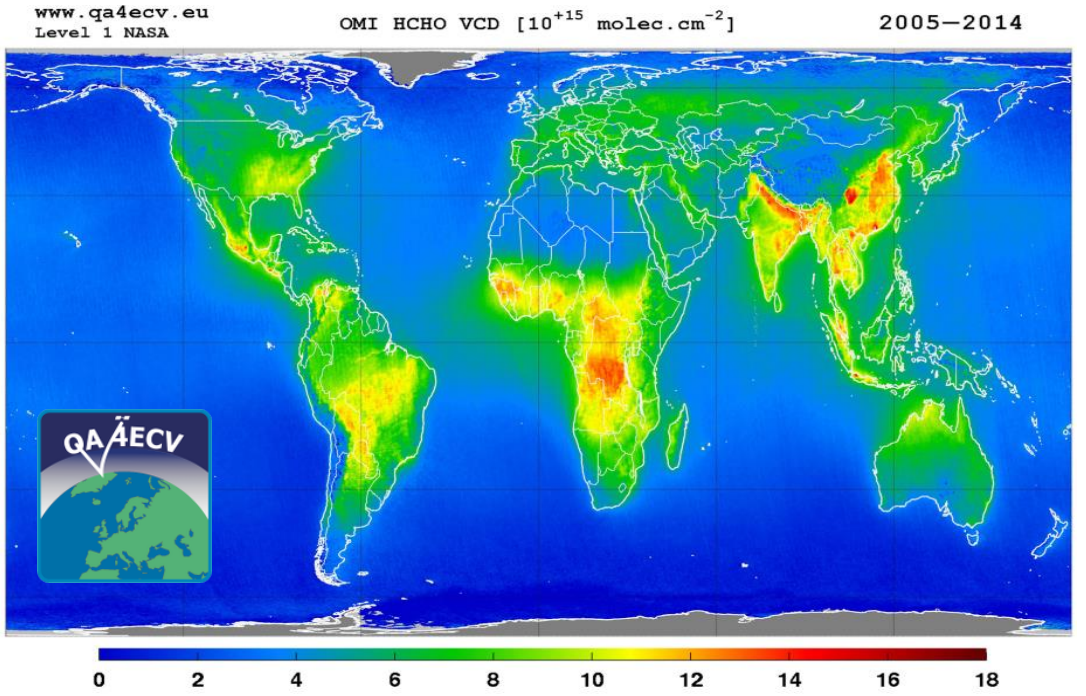
- Many sites are in cities, mountains
- Few sites are well-suited to validate biogenic hotspots

What about OMI?



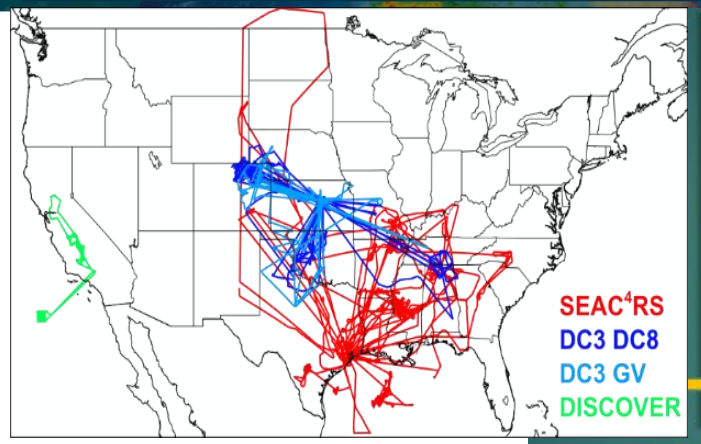
Zhu et al. 2016

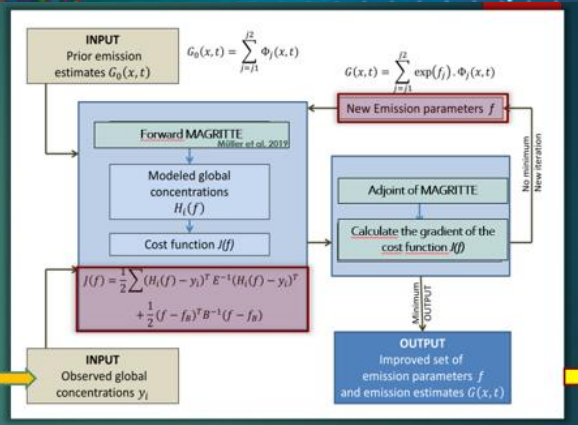
- OMI underestimates HCHO columns derived from in situ measurements from aircraft campaigns
- The biases depend much on vertical profile assumptions and data filtering (clouds, outliers)



- We focus on the QA4ECV retrieval (*De Smedt et al.* 2018)
  (QA4ECV = Quality Assurance for Essential Climate Variables)
- OMI QA4ECV and TROPOMI share the same retrieval

Aircraft and FTIR data show that OMI HCHO is also biased

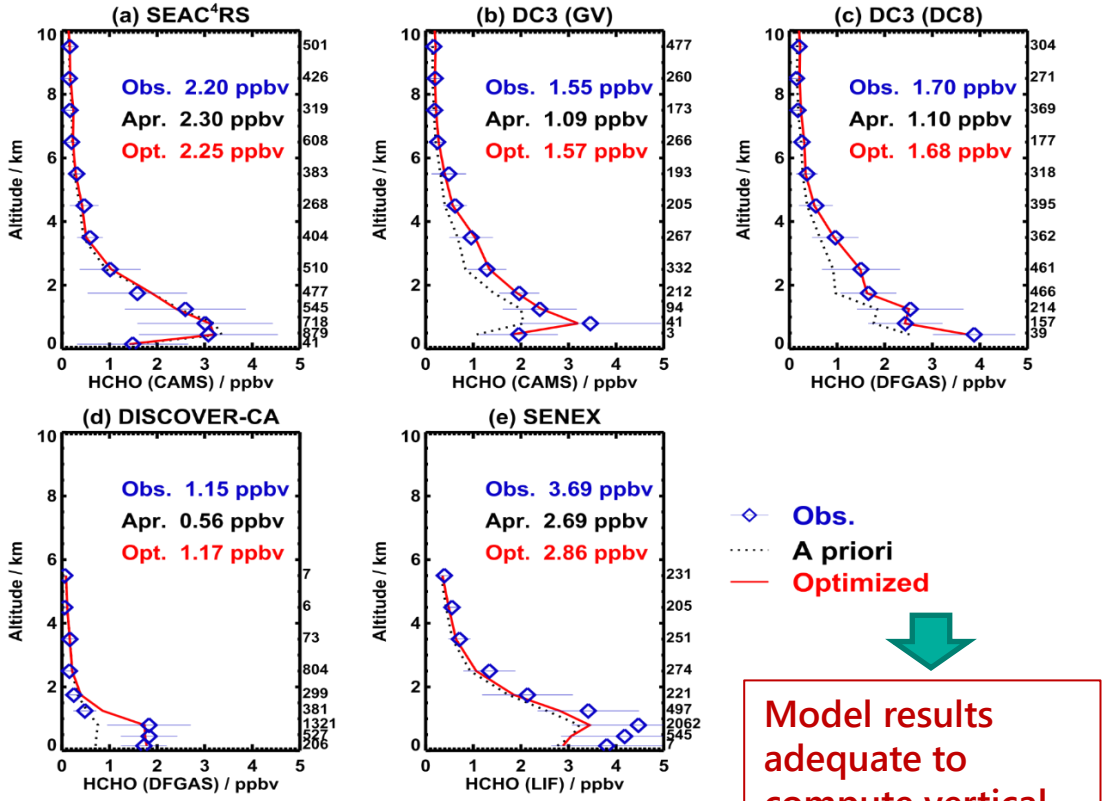


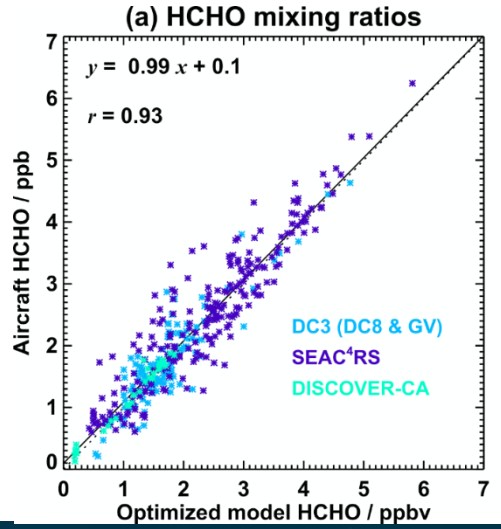


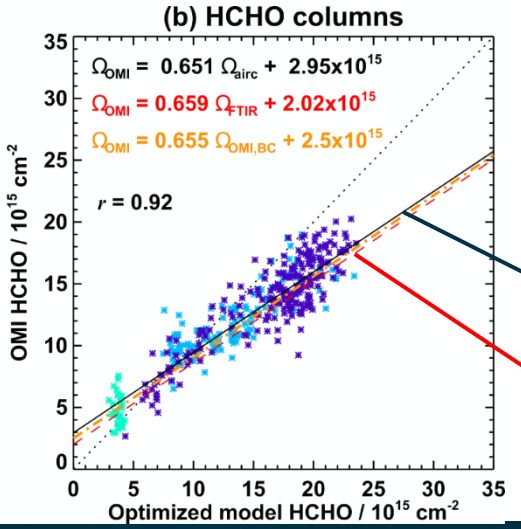
Comparison with OMI QA4ECV HCHO data for same years, months, locations

Updated mixing ratios matching the aircraft data → aircraft-based columns = « truth »

Excellent match of optimized model with observed horizontal and vertical distribution of in situ HCHO







Regression of OMI against aircraft

Regression of OMI against FTIR

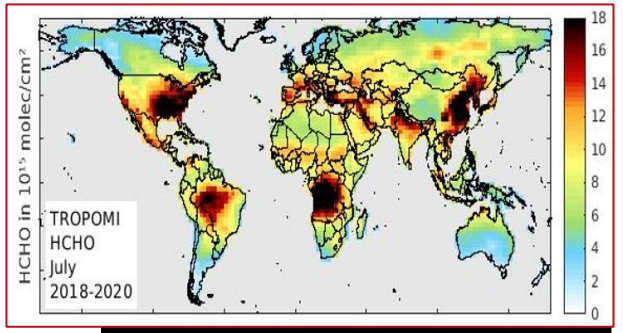
Model results adequate to compute vertical columns that represent well the aircraft measurements

Müller et al. 2024

Adjoint inversion tool to derive top-down fluxes

A priori emissions

Bias-corrected spaceborne HCHO



INPUT
Prior emission estimates $G_0(x,t)$

$$G_0(x,t) = \sum_{j=j1}^{j2} \Phi_j(x,t)$$

Forward MAGRITTEv1.1

New Emission parameters f

Modeled global concentrations $H_i(f)$

Calculate $\nabla J(f)$ using the discrete adjoint of IMAGESv2

Cost function $J(f)$

No minimum= New iteration

Minimum=OUTPUT

$$J(f) = \frac{1}{2}\sum (H_i(f) - y_i)^T E^{-1} (H_i(f) - y_i)^T + \frac{1}{2}(f - f_B)^T B^{-1} (f - f_B)$$

INPUT
Observed global concentrations y_i

OUTPUT
Improved set of emission parameters f and emission estimates $G(x,t)$

$$G(x,t) = \sum_{j=j1}^{j2} \exp(f_j).\Phi_j(x,t)$$

Top-down fluxes

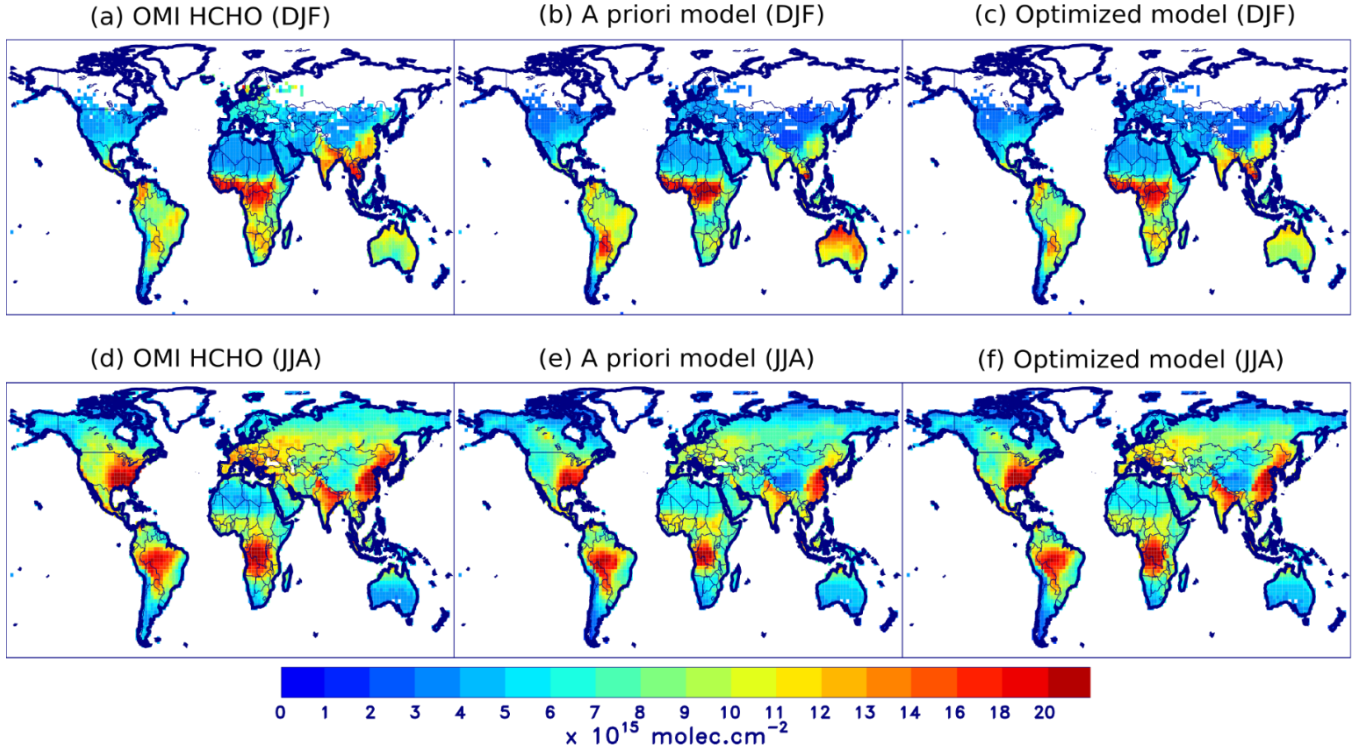
- Global inversion at 2°x2.5°

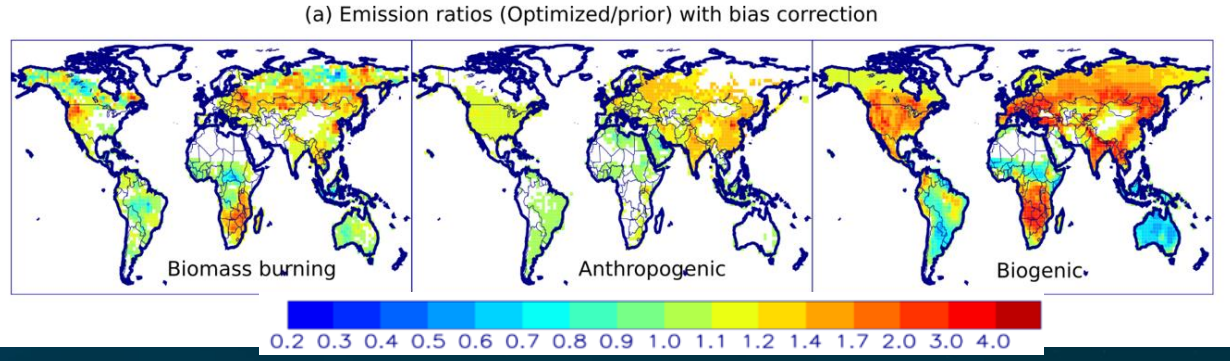
MAGRITTE = ***Model of Atmospheric composition at Global and Regional scales using Inversion Techniques for Trace gas Emissions***

Müller et al. 2005, Stavrakou et al. 2009, 2015, Bauwens et al. 2016, Müller et al. 2019

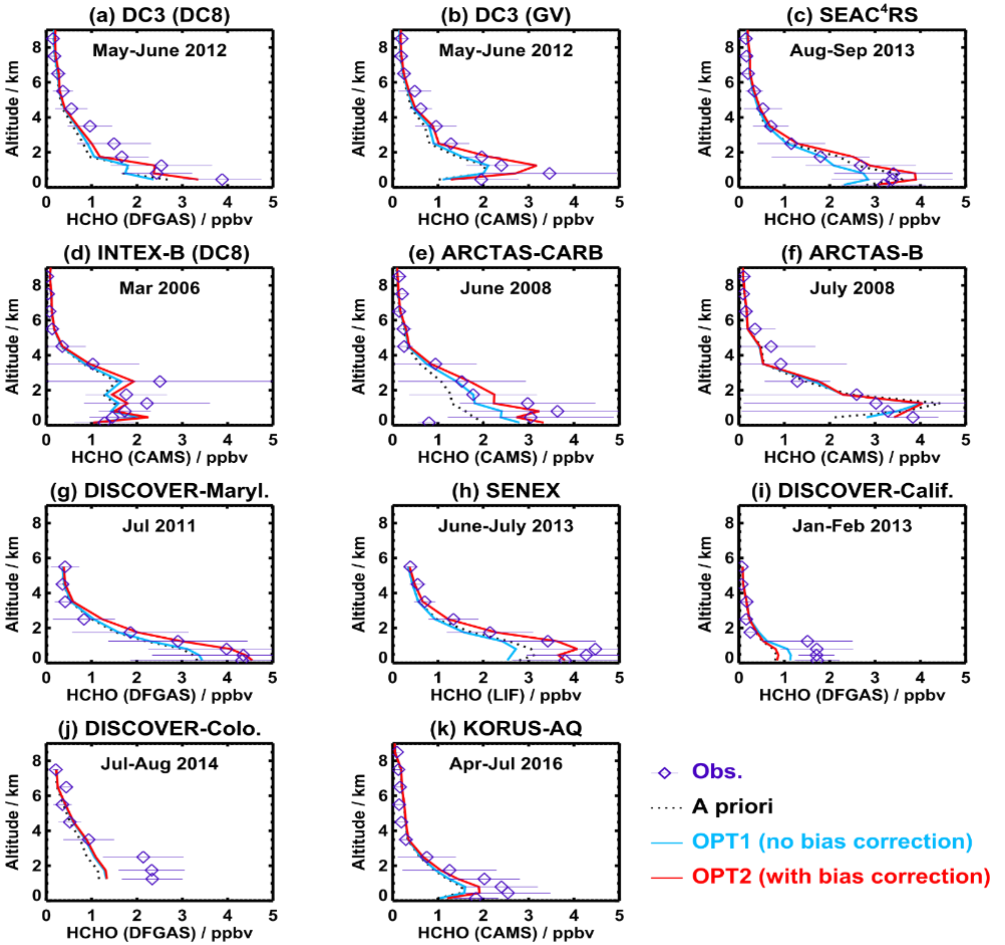
https://tropo.aeronomie.be/index.php/models/magritte

Top-down emissions based on OMI HCHO data and evaluation



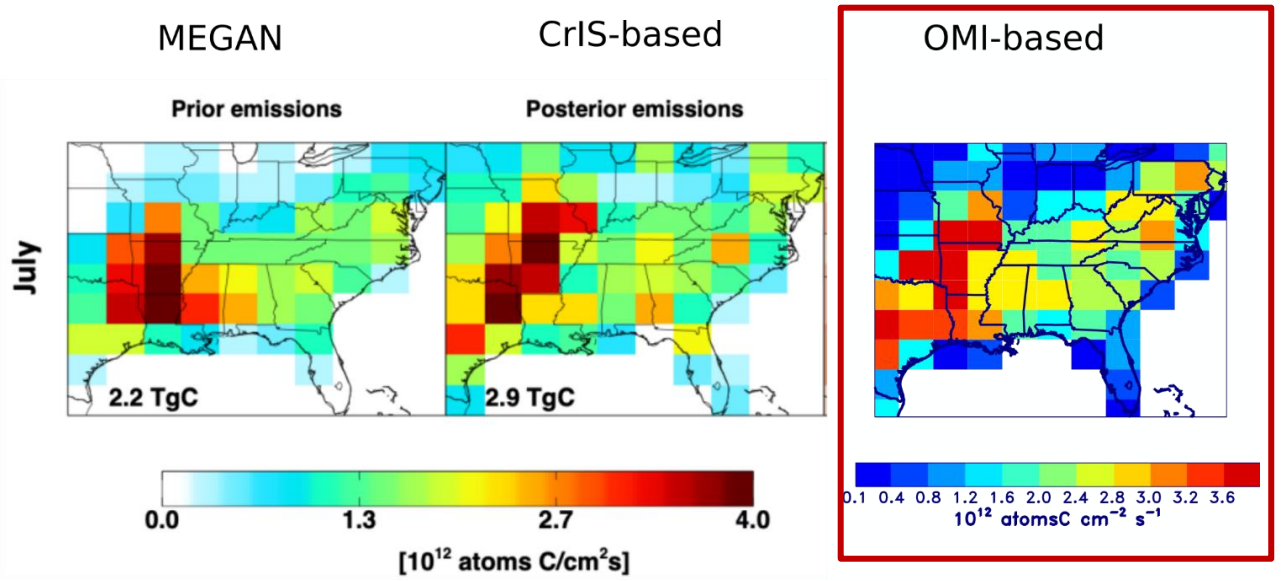


Inversion performs generally very well; exception: low-emission regions where the model remains too low



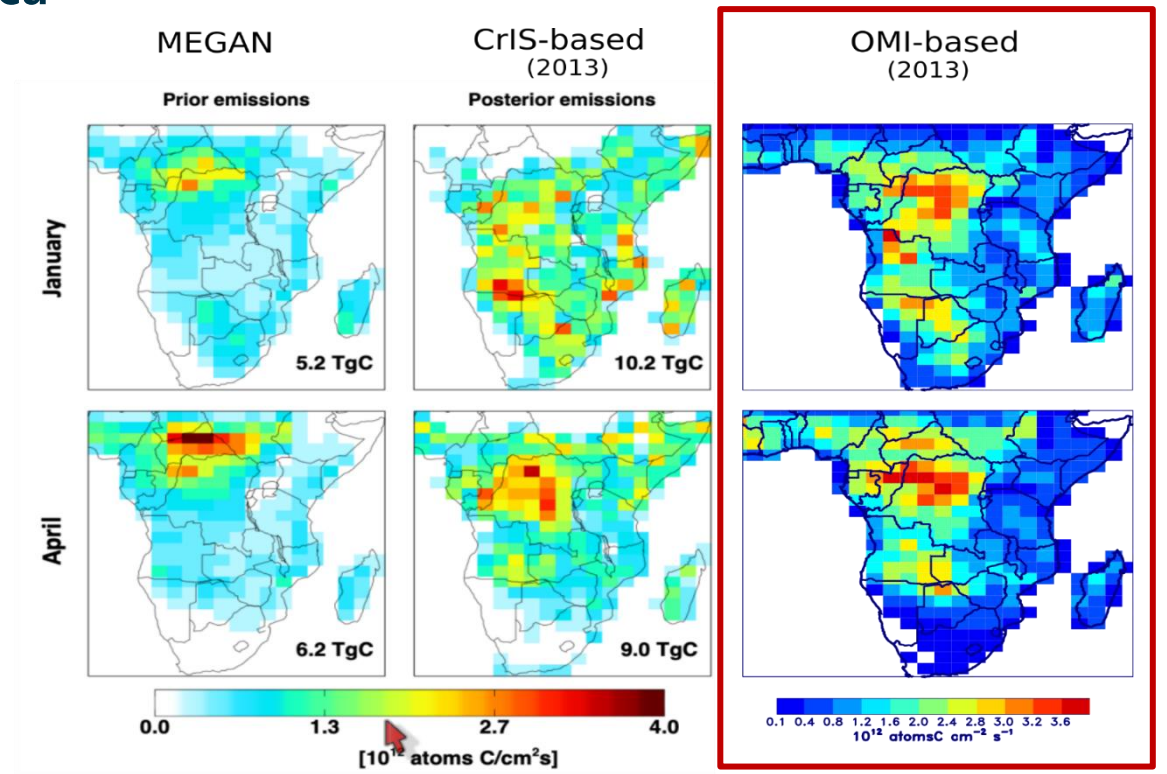
CrIS-based vs OMI-based isoprene emissions

Remarkable similarities over Eastern U.S. and SH Africa



Wells et al. 2020

This work



Wells et al. 2020

This work

Take-aways

- Satellite HCHO extremely useful to probe VOC spatiotemporal variability, but caution is required due to biases wrt independent data. The reasons for those biases are not understood (yet).
- Bias correction improves the performance of emission optimizations based on spaceborne HCHO. Similar biases of OMI HCHO are derived from FTIR and aircraft data
- Very similar top-down VOC emissions based on OMI and TROPOMI
- Bias correction leads to higher top-down emissions over source areas