The need for atmospheric chemistry products from CrIS

Ask not what CrIS can do for the country, but what the country expects from CrIS

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Atmospheric composition data from space: facts and questions

- Data available since 1999. How much more data can we expect from current instruments?
- Is the data accurate and useful? How can we tell?
- Do we need more data and for what applications?
- Early products from CrIS

What (CO) data is available and how much more can we expect?

Launched in 1999

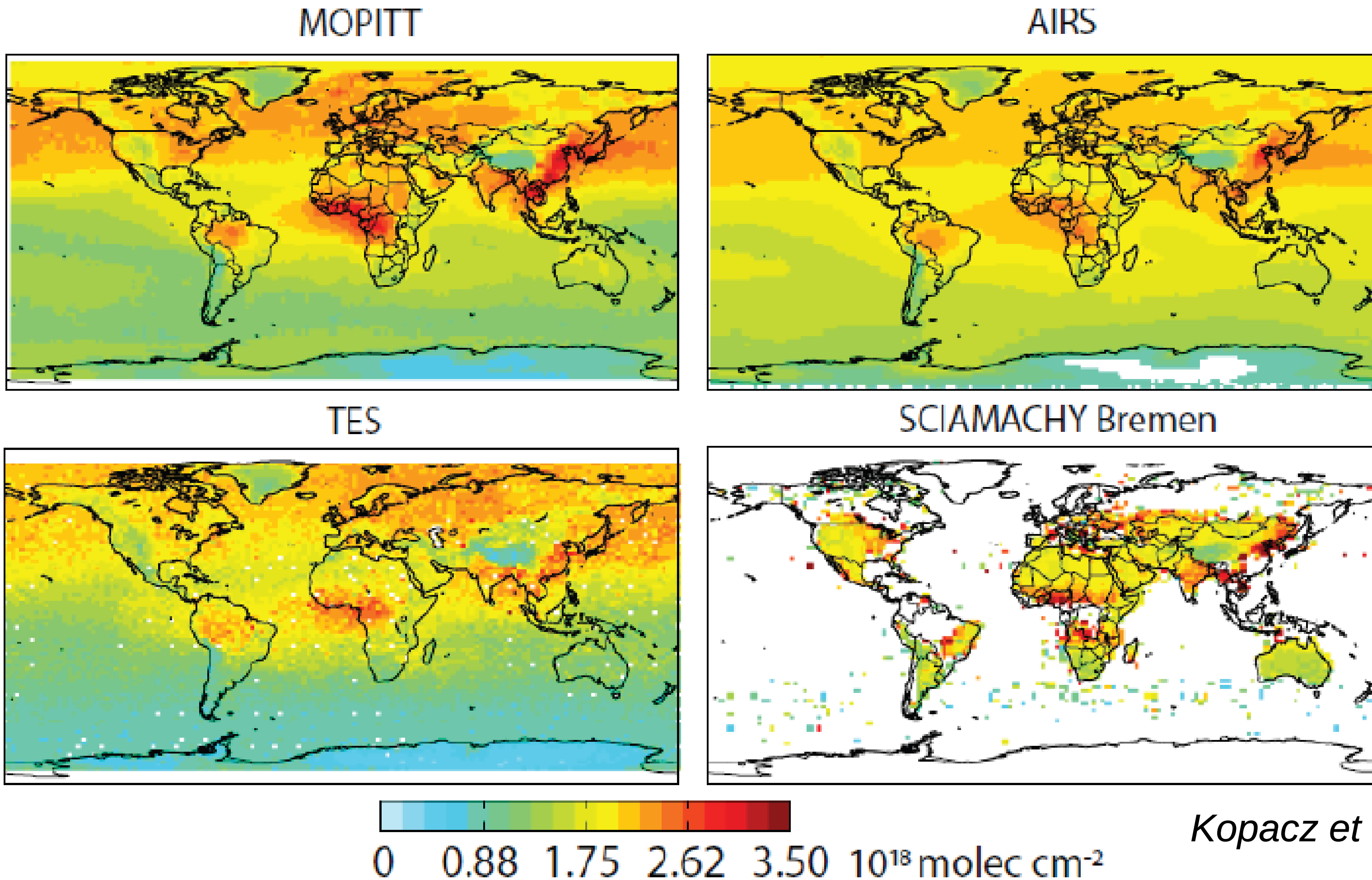
Launched in 2002, stopped working ~ 2006/2013

Launched in 2002

Launched in 2004

Launched in 2006 and 2012 (3rd one in 2016)

CO data from space: is it accurate?

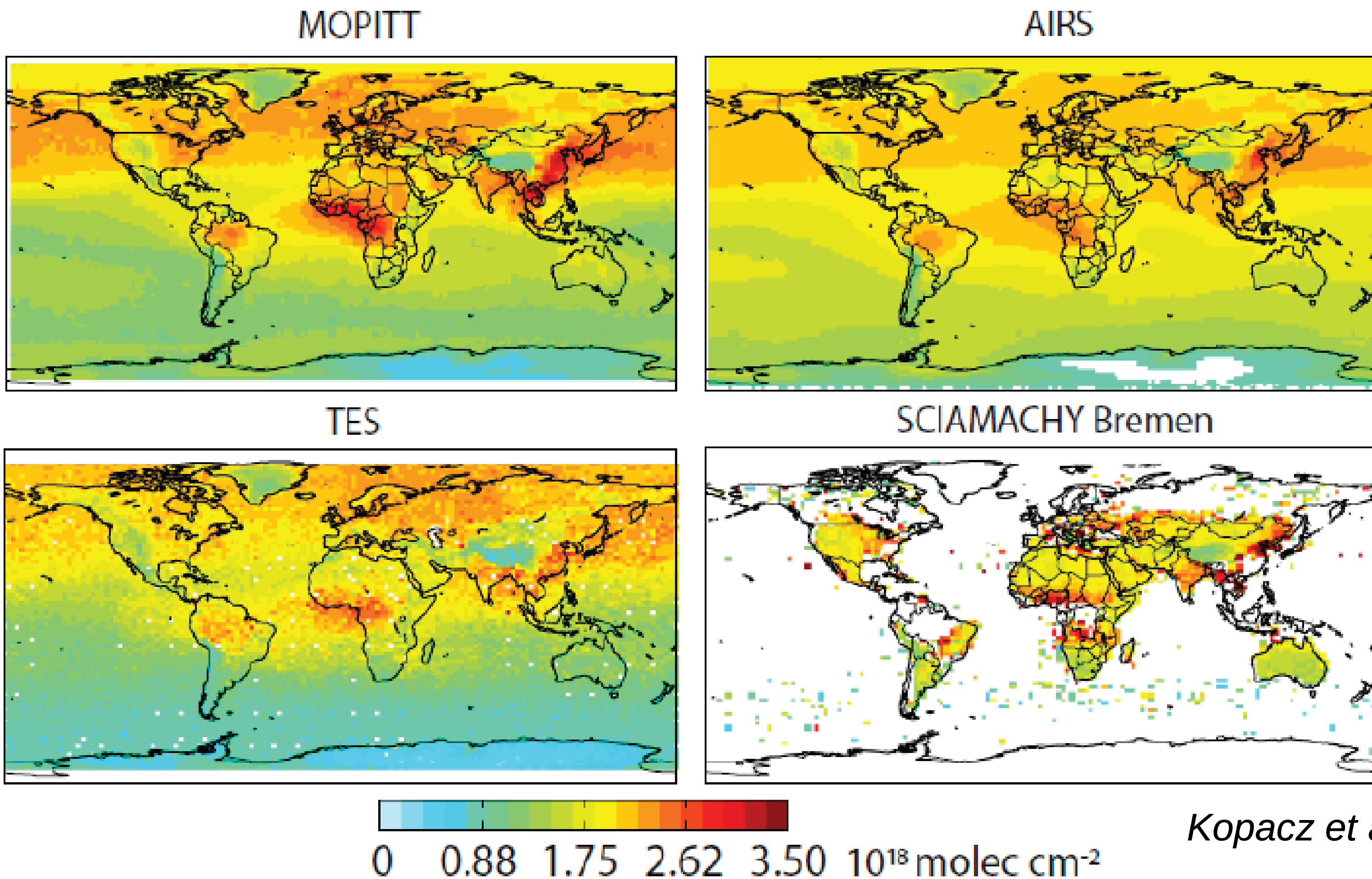


Kopacz et al. 2010

Which one of these is "the best"?

Long term record? MOPITT
High accuracy? TES
Dense global coverage? AIRS
Sensitivity near the surface? SCIAMACHY

CO data from space: is it accurate?



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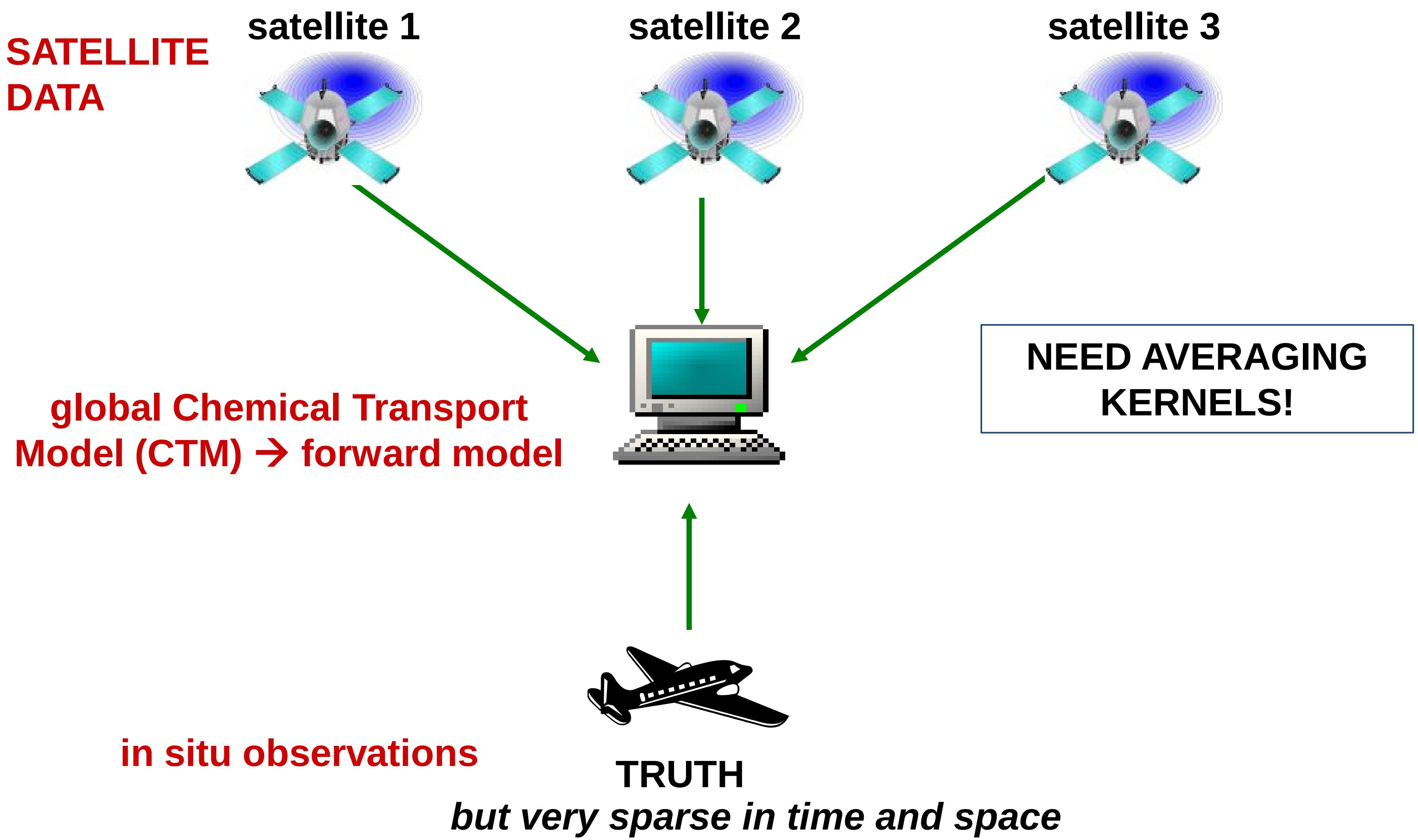
CrIS

Is the data accurate? How can we tell?

Chemical Transport Model (CTM) as a comparison platform



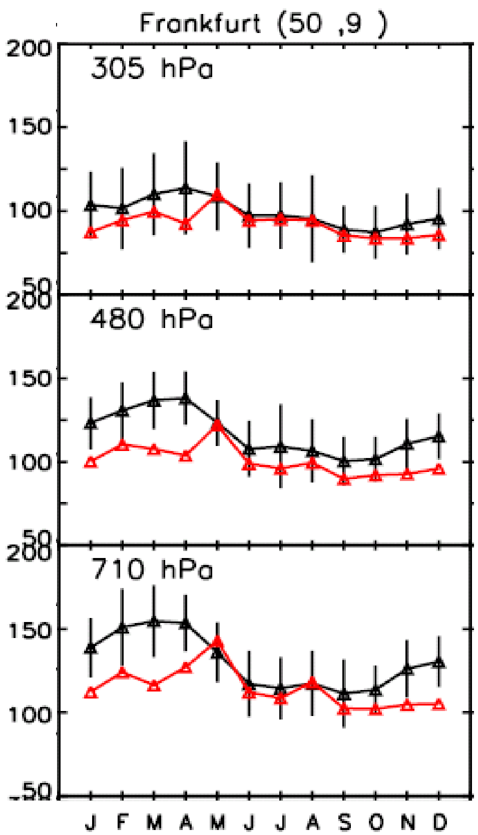
GEOS-Chem Chemical Transport Model (CTM): the comparison platform

EMISSIONS $\xrightarrow{\textbf{CTM}}$ **CONCENTRATIONS**

Compare with in situ data

aircraft

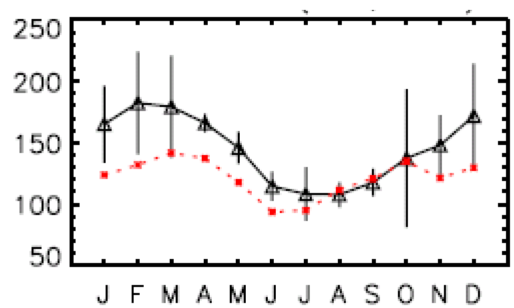
MOZAIC



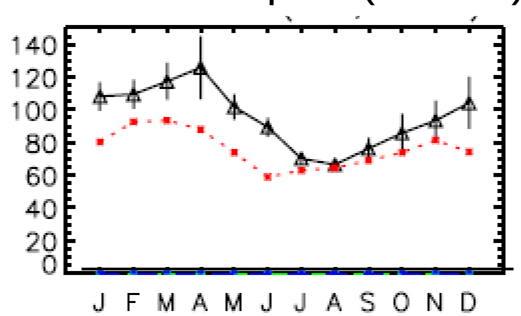
surface

GMD

Northern midlatitudes (Ireland)



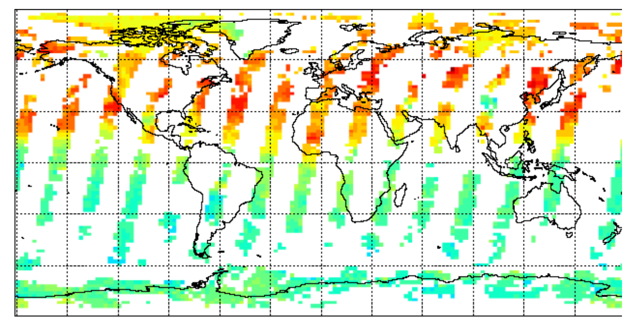
Northern tropics (Hawaii)



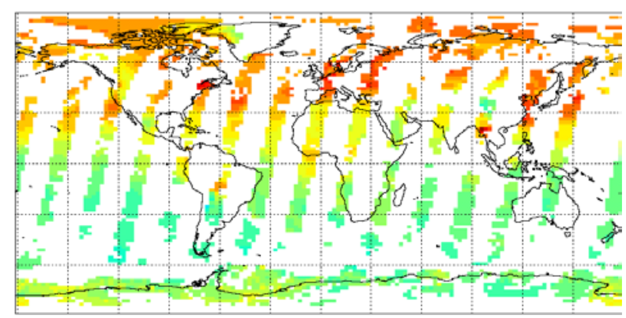
Compare with satellite data

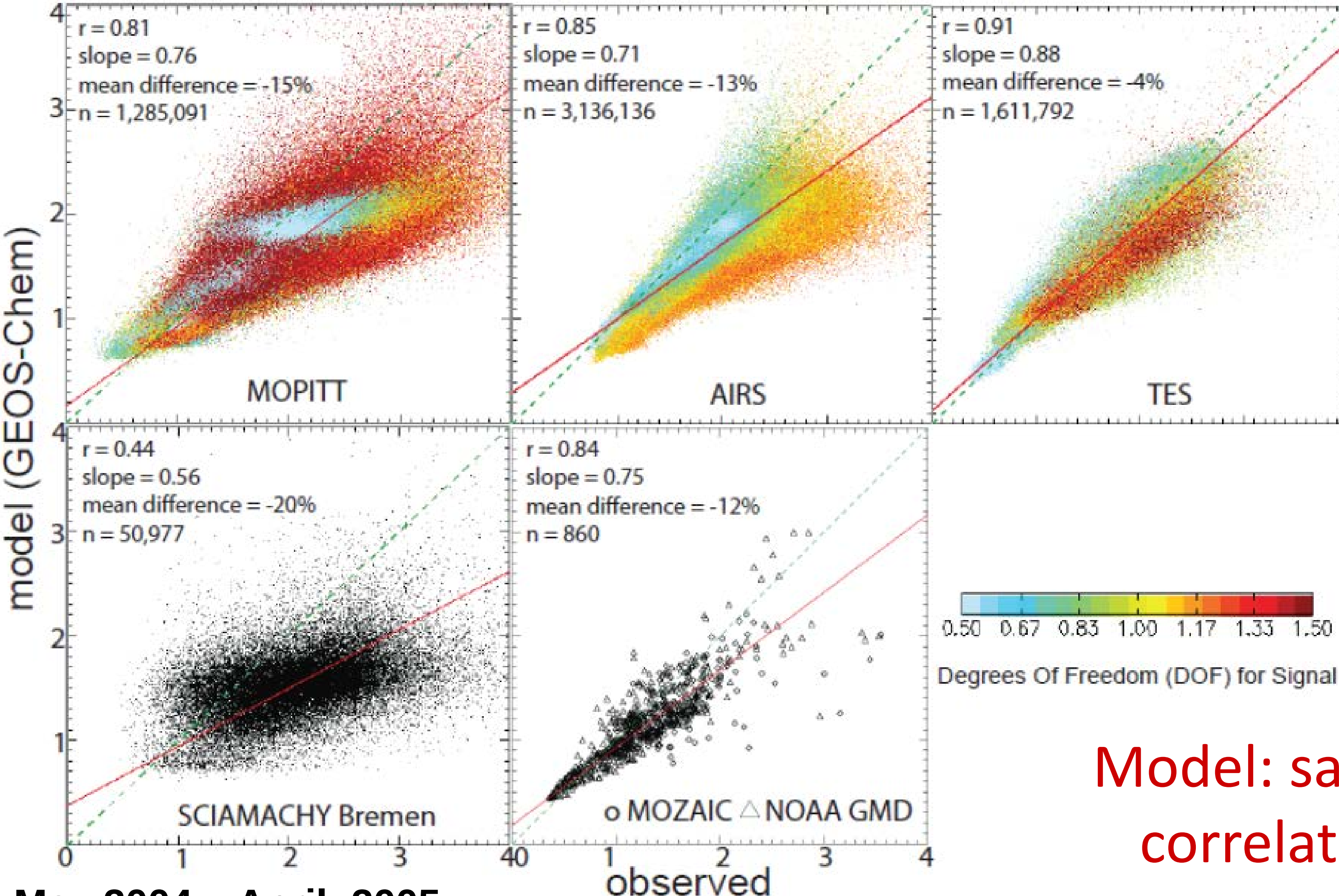
$$\hat{\mathbf{y}} = \mathbf{y}_\mathbf{a} + \mathbf{A}(\mathbf{y} - \mathbf{y}_\mathbf{a})$$

MOPITT CO columns



GEOS-Chem+ MOPITT AK





Model: satellite correlations

May 2004 – April 2005 global daytime columns (averaged on 2°x2.5° resolution of GEOS-Chem)

**TES data for 2005-2006*

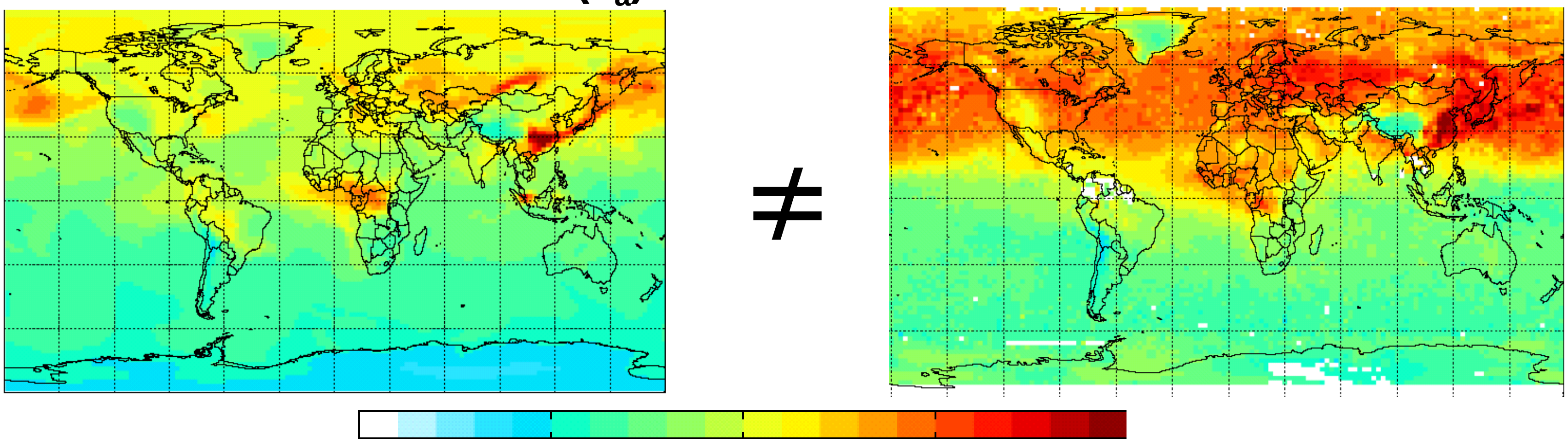
Measure of information content: degrees of freedom (DOFs) ← color dimension

Unit: 10^{18} molec/cm^2

Kopacz et al. *2010*

Is the data useful?
Inverse estimates of CO sources

GEOS-Chem CO column: $F(x_a)$ **satellite CO column: y**



***a priori* sources:** $x_a + \varepsilon_a$

satellite data (MOPITT, AIRS, SCIAMACHY Bremen) : $y + \varepsilon_o$

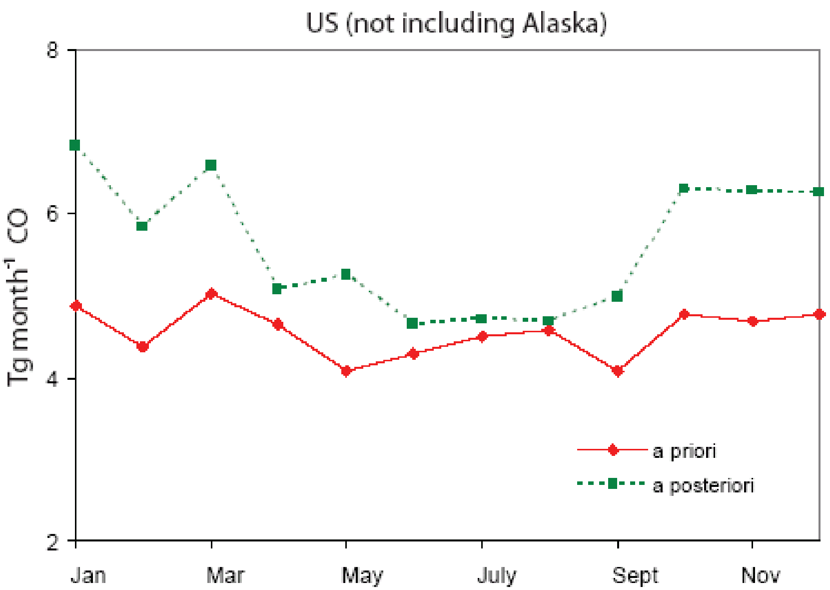
model concentrations: $F(x) + \varepsilon_m$

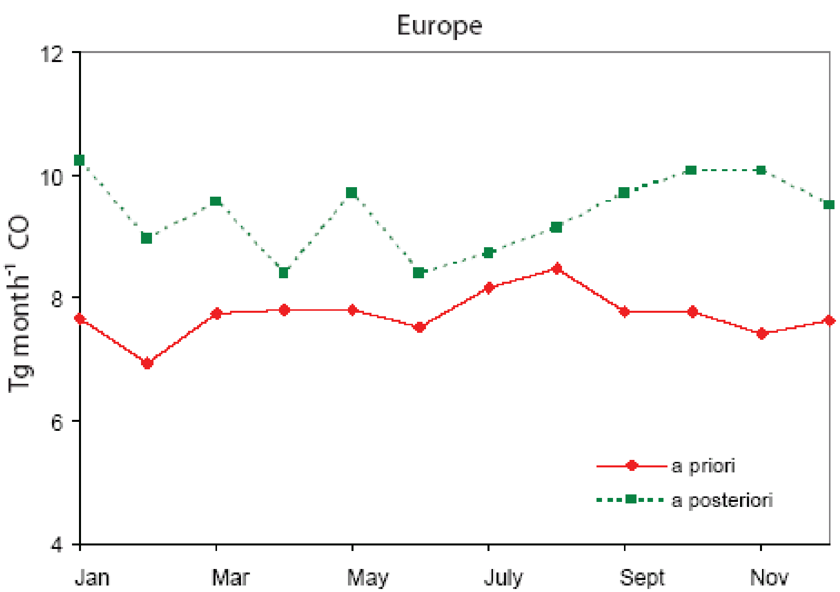
observation error: $\varepsilon_e = \varepsilon_o + \varepsilon_m + \varepsilon_r$

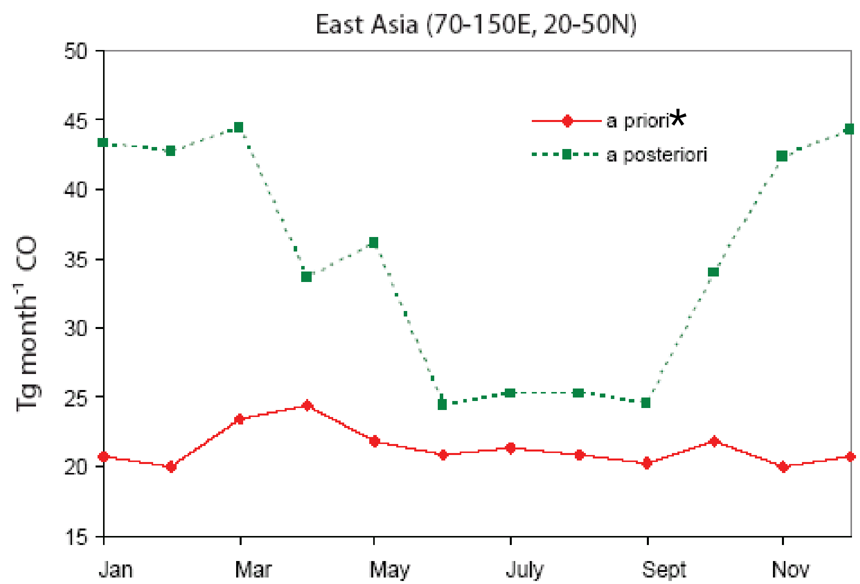
$$\min\ J(\mathbf{x}) = (\mathbf{F}(\mathbf{x}) - \mathbf{y})^T \mathbf{S}_\varepsilon^{-1} (\mathbf{F}(\mathbf{x}) - \mathbf{y}) + (\mathbf{x} - \mathbf{x}_a)^T \mathbf{S}_a^{-1} (\mathbf{x} - \mathbf{x}_a)$$

RESULT: monthly CO source estimates at 4º x 5º resolution

Seasonal variability of emissions: largely missing in *a priori* estimates







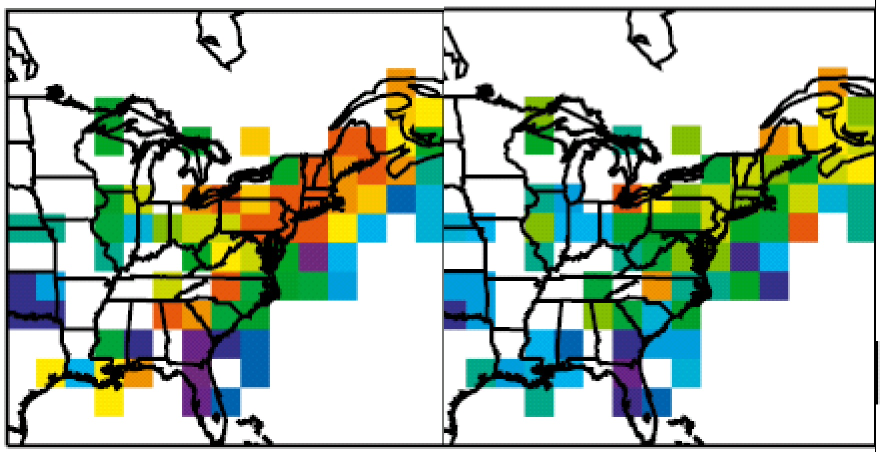
Includes regional inhomogeneity

* *Streets et al.* [2006] did not include *Streets et al.* [2003] seasonality

Regional CO source estimates: N. America

Previous study

GEOS-Chem w/ NEI99 emission inventory > INTEX-A observations

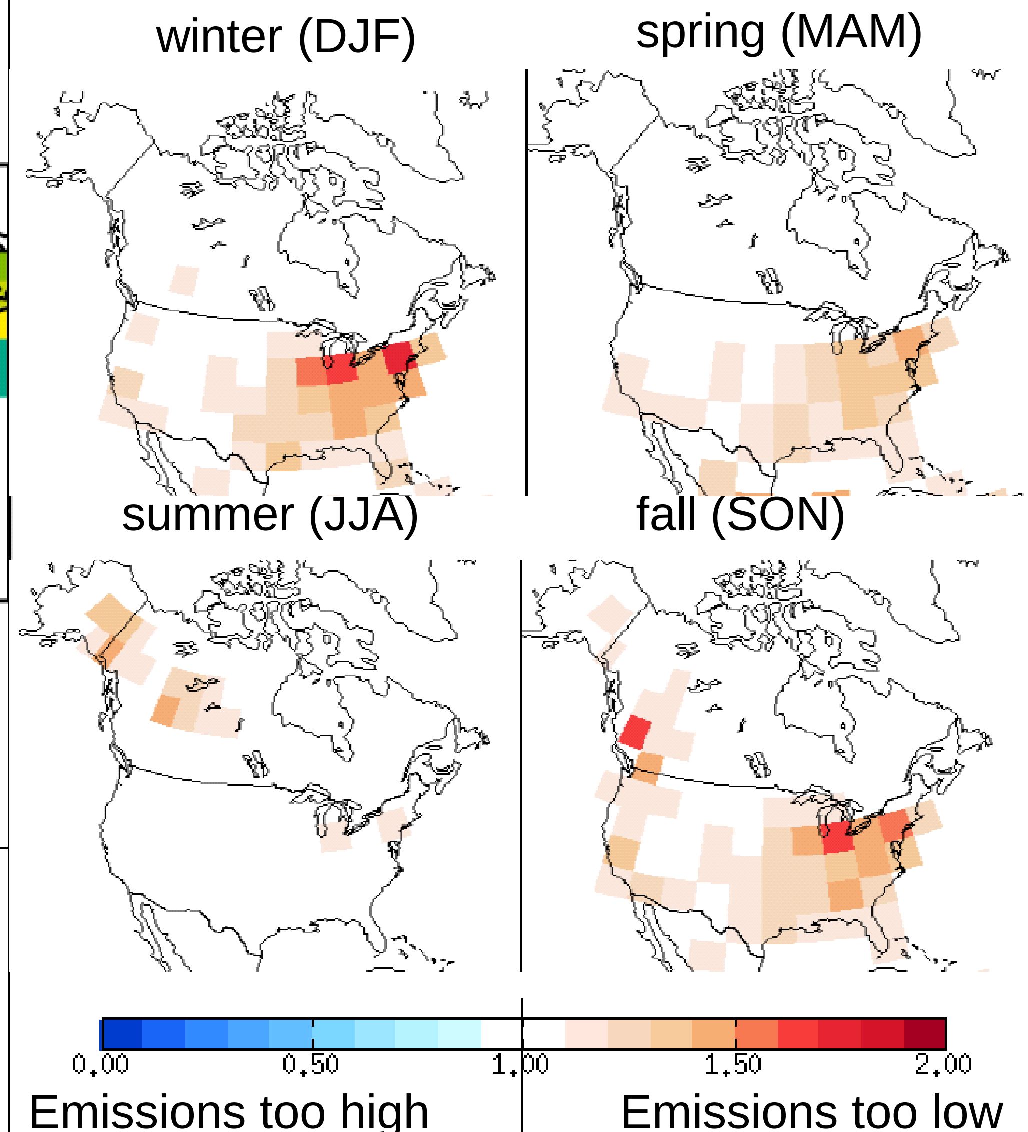


Hudman et al. [2008]

NEI99 60% too high (in the summer)

Conclusion: *Hudman et al.* [2007] correction to NEI99 inventory ok in the summer, not in fall-winter

Current study w/ 60% correction

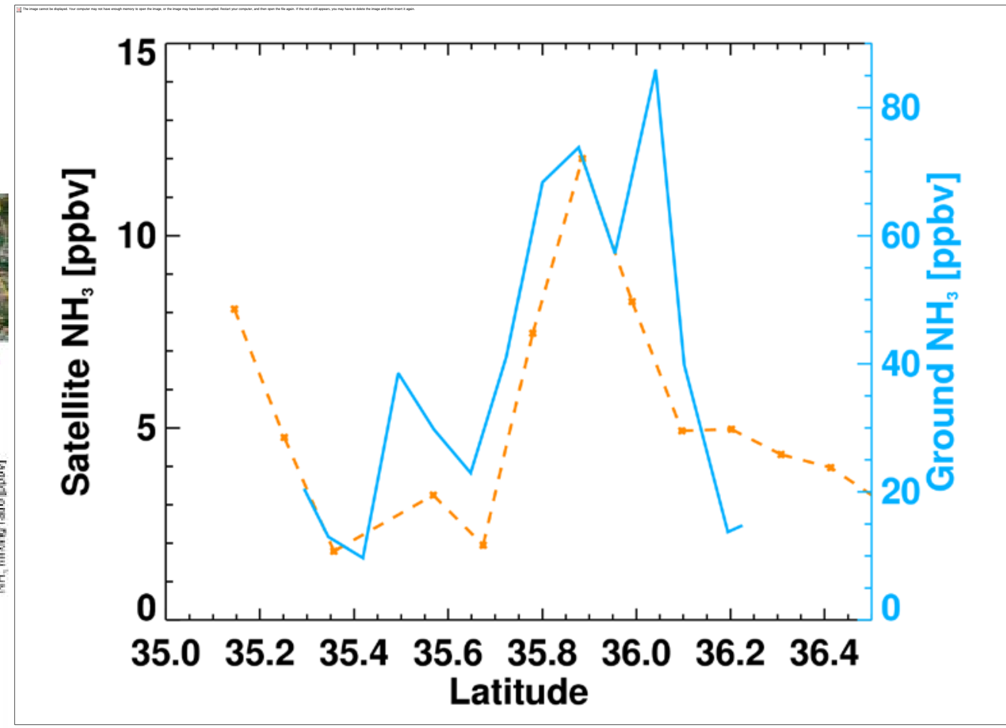


CrIS product (being) developed with AC4 support

Surface and **CrIS NH_3** in DISCOVER-AQ 2013

- Open path Quantum Cascade Laser (QCL) on a moving platform collected data almost directly under TES transect (red symbols) in the San Joaquin Valley on January 28, 2013

- Hotspot measured near Tipton



- Satellite and QCL NH_3 measured in January 2013 are spatially well correlated

Credit: Matt Alvarado and Karen Cady-Pereira

Conclusions

- CrIS needs to provide long term high quality CO retrieval to continue CO monitoring from space, and to continue addressing a large array of air pollution transport, source and chemistry problems
- CrIS should and will provide NH_3 retrievals
- CrIS can and does provide a range of species that are currently being retrieved from TES, AIRS and IASI
- CrIS products need to be developed with averaging kernels for comparison with other data and for validation purposes
- CrIS products need to be and can be validated with future NOAA and other field campaigns

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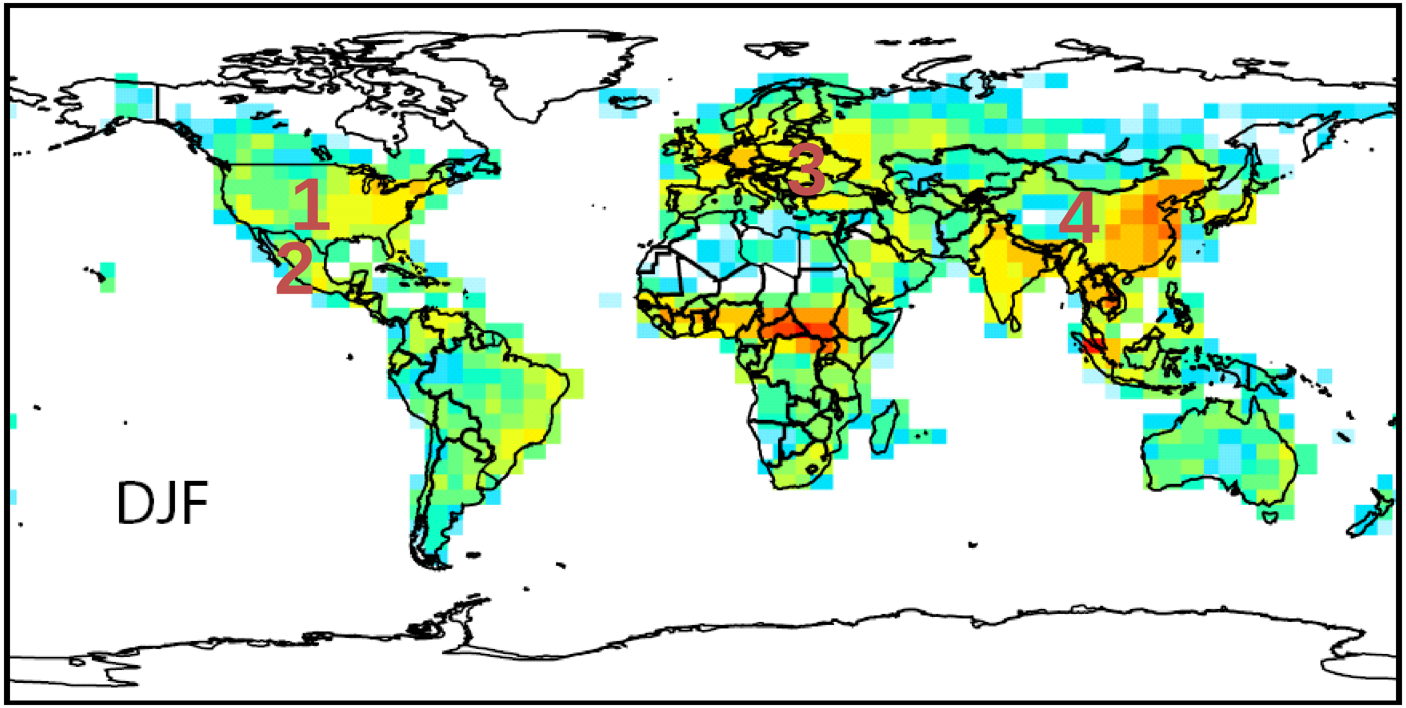
http://cpo.noaa.gov/ClimatePrograms/EarthSystemScience/AtmosphericChemistryCarbonCycleandClimate.aspx

A priori emissions ($\mathbf{x}_a$): fossil fuel, biofuel and biomass burning



Global inventories:

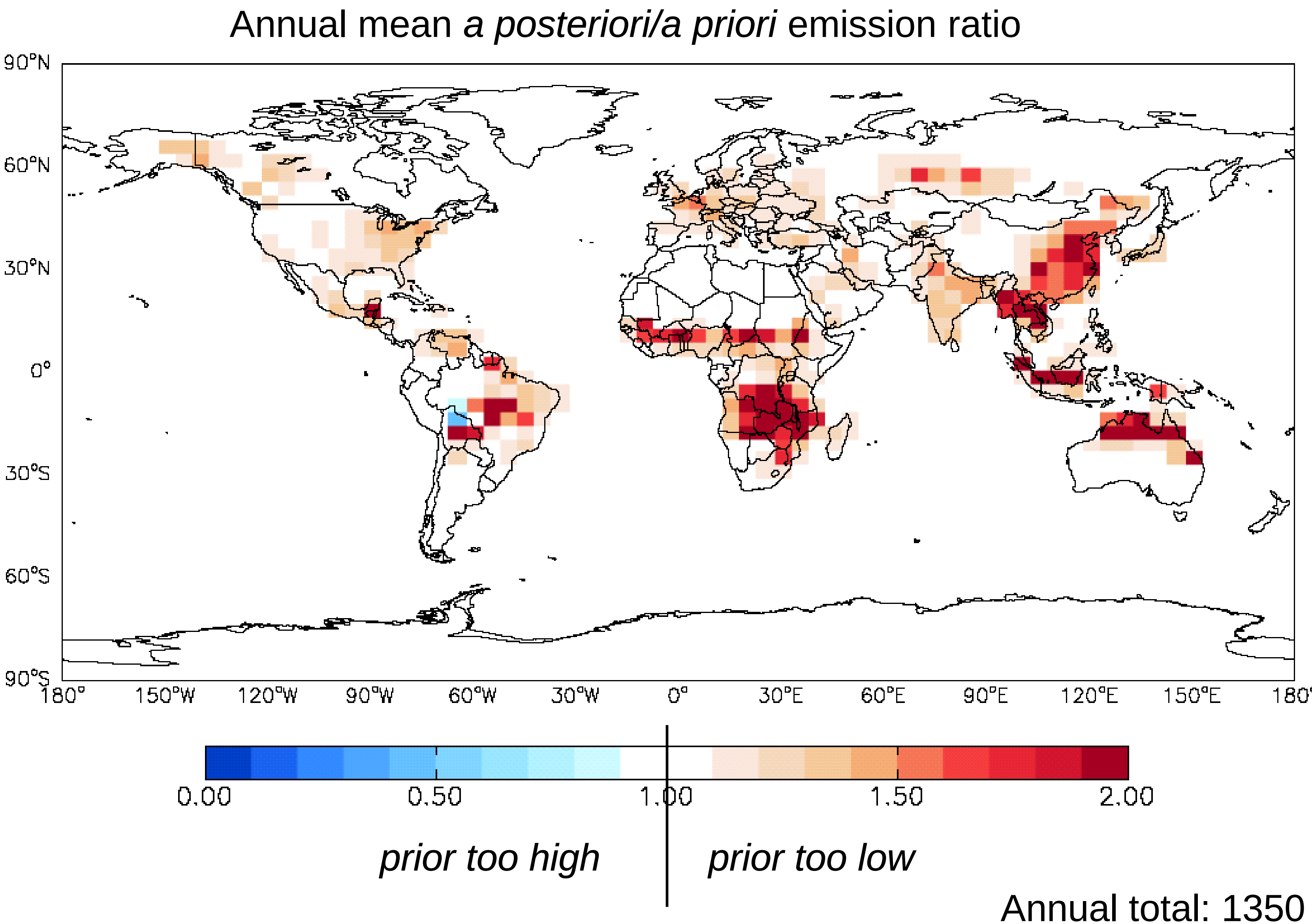
Fossil fuel EDGAR 3.2 (global)

Biomass burning GFED2 (global)

Regional inventories:

1. US fossil fuel: NEI99 – 60%
2. Mexico fossil fuel: BRAVO
3. Europe fossil fuel: EMEP
4. Asia fossil fuel: *Streets et al.* 2006 for China and *Streets et al.* 2003 elsewhere

A posteriori estimates of CO sources: emissions too low

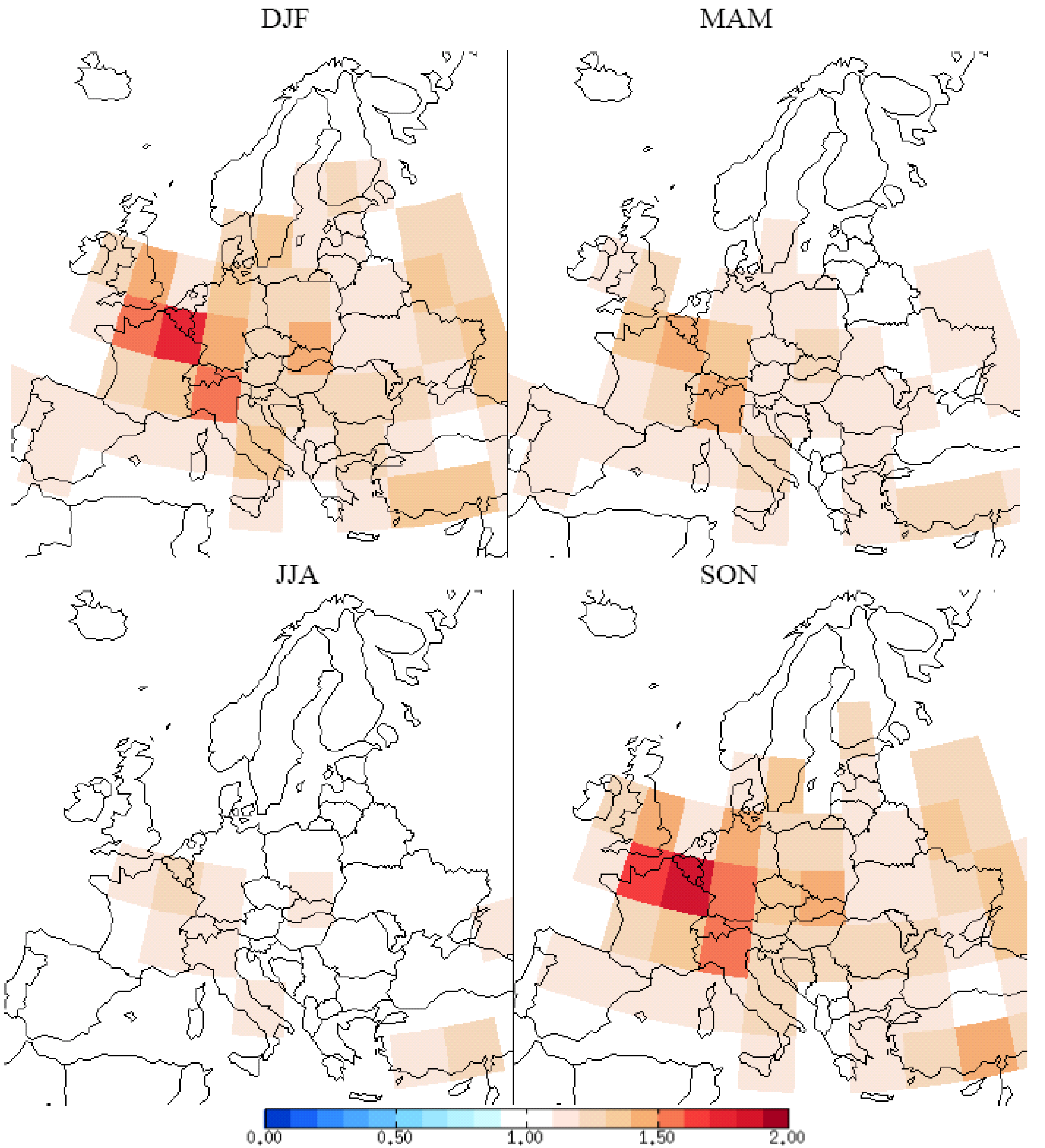


Annual total: 1350 Tg

Regional CO source estimates: Europe

Findings: Similar seasonality and spatial inhomogeneity as in N. America

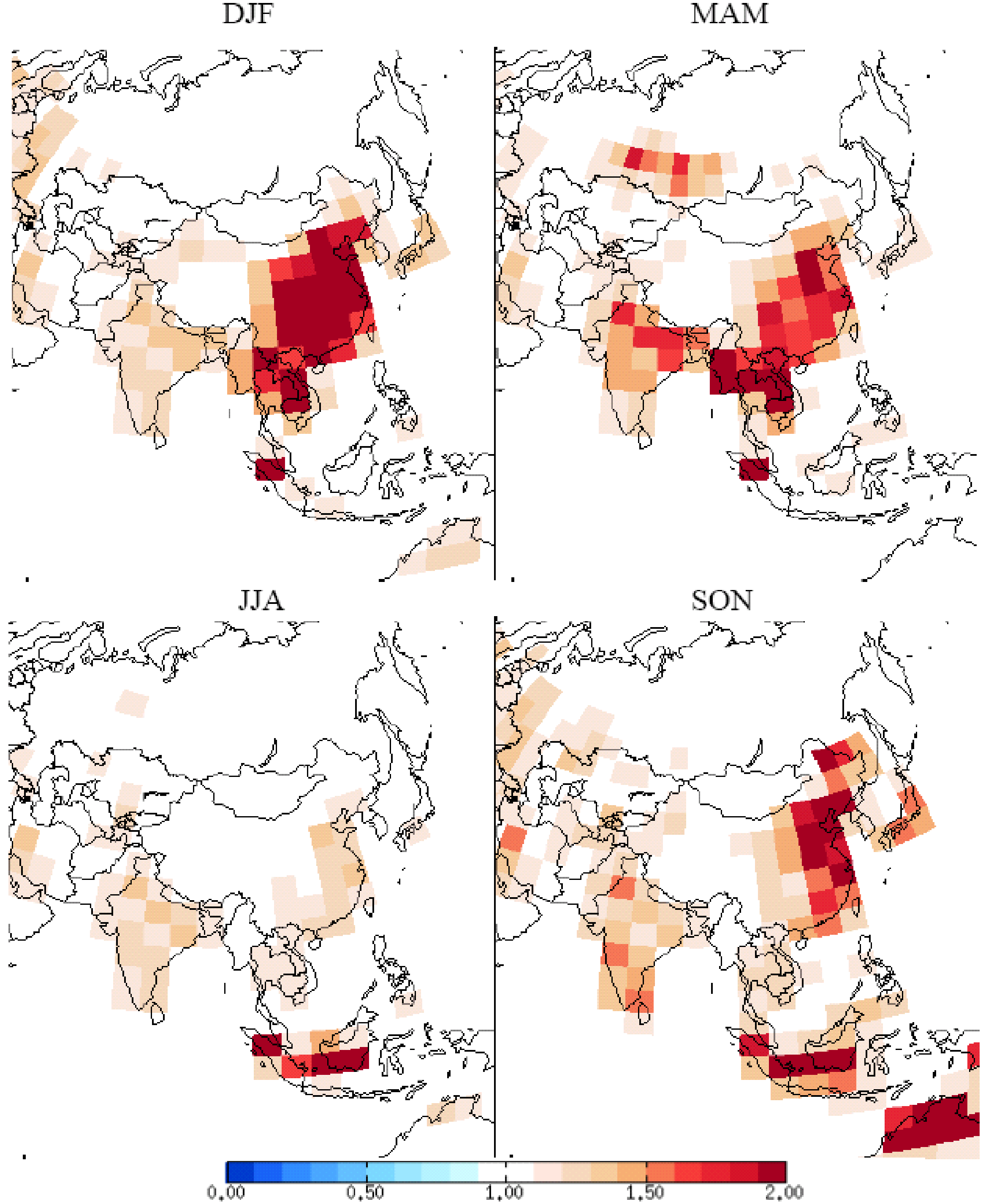
Possible **reasons** for underestimate: residential heating, “cold starts”



Regional CO source estimates: Asia

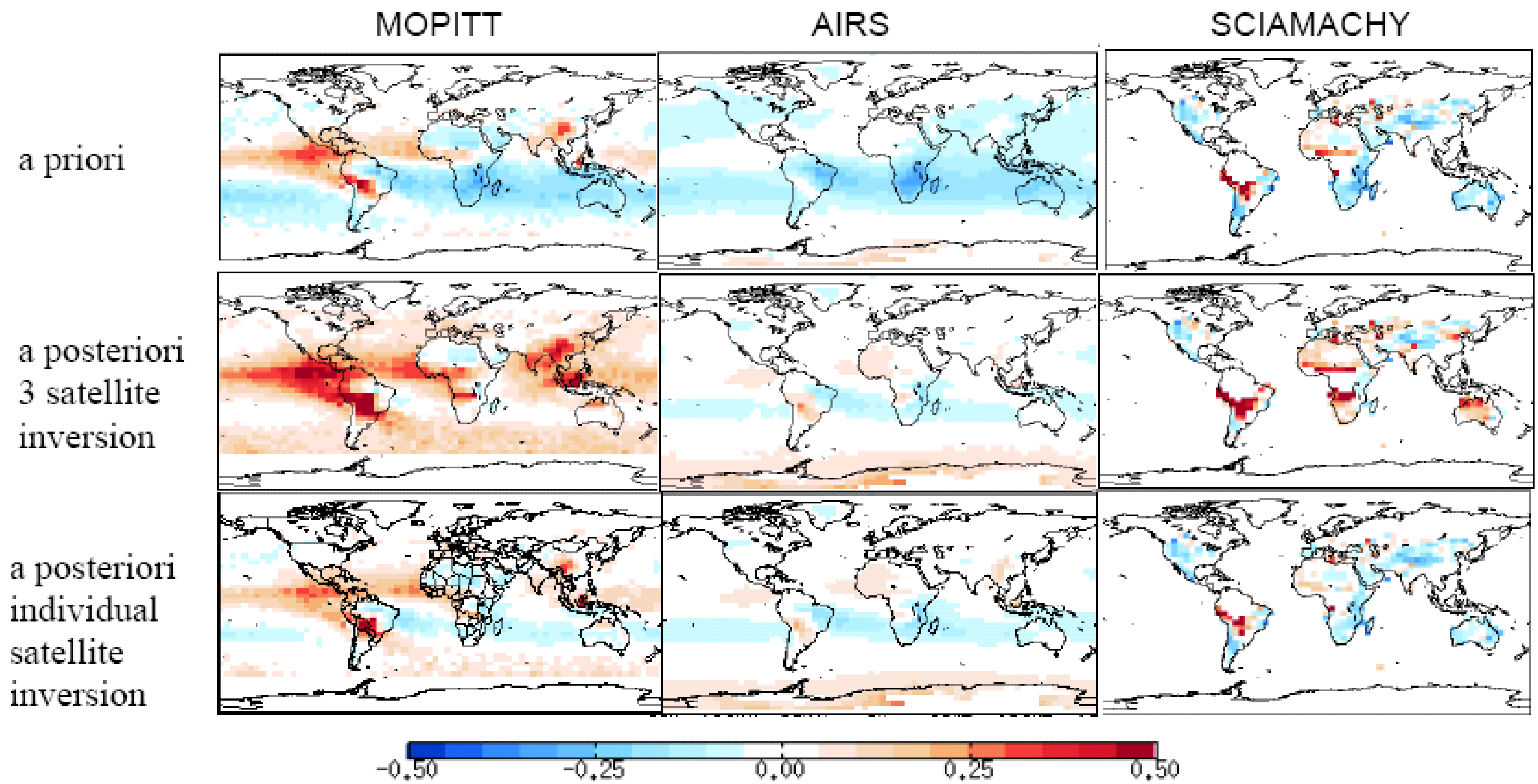
Findings:
Stronger seasonality in China than in N. America, no considerable seasonality in India

Possible **reasons** for underestimate: residential heating, “cold starts”



Improvement in model-data agreement from source inversion

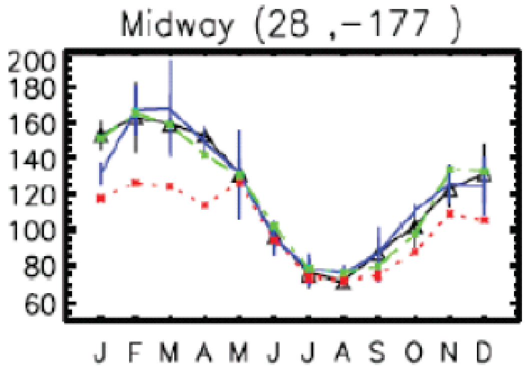
Fractional model bias: **(model-data)/data** during sample period: Sept-Oct-Nov 2004

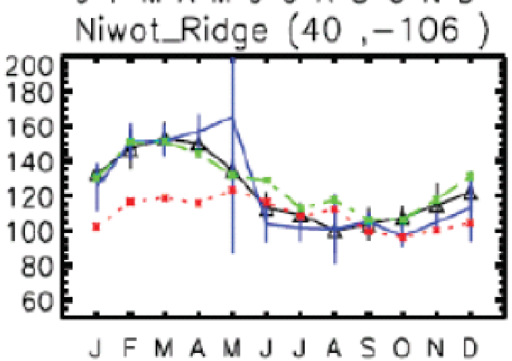


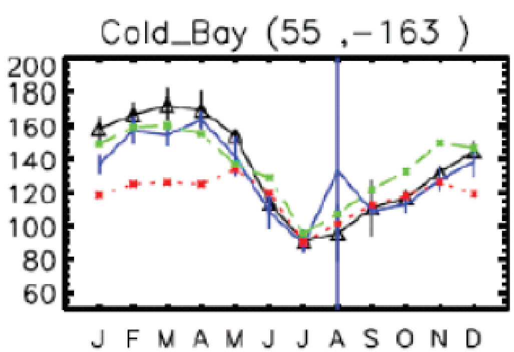
<u>Conclusion:</u> a balance of information, but AIRS dominates due to data density AND regional instrument inconsistencies

Comparison with independent surface measurements (GMD network)

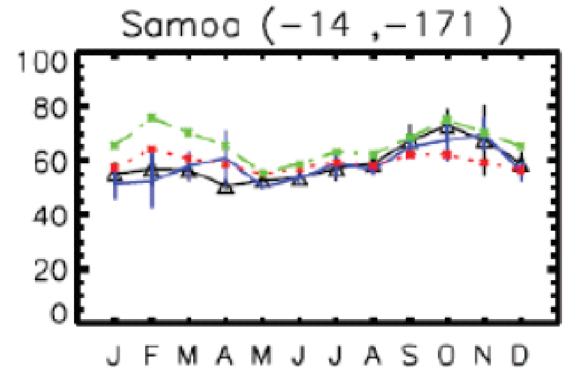
Northern Hemisphere:
great improvement

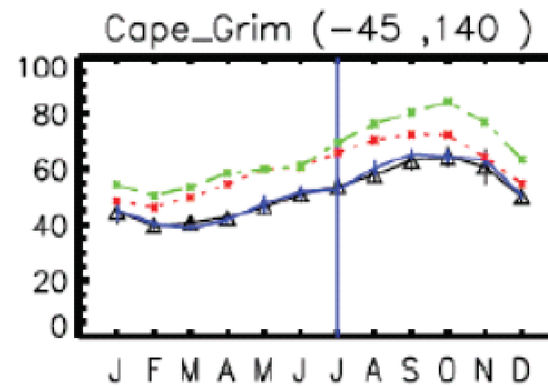






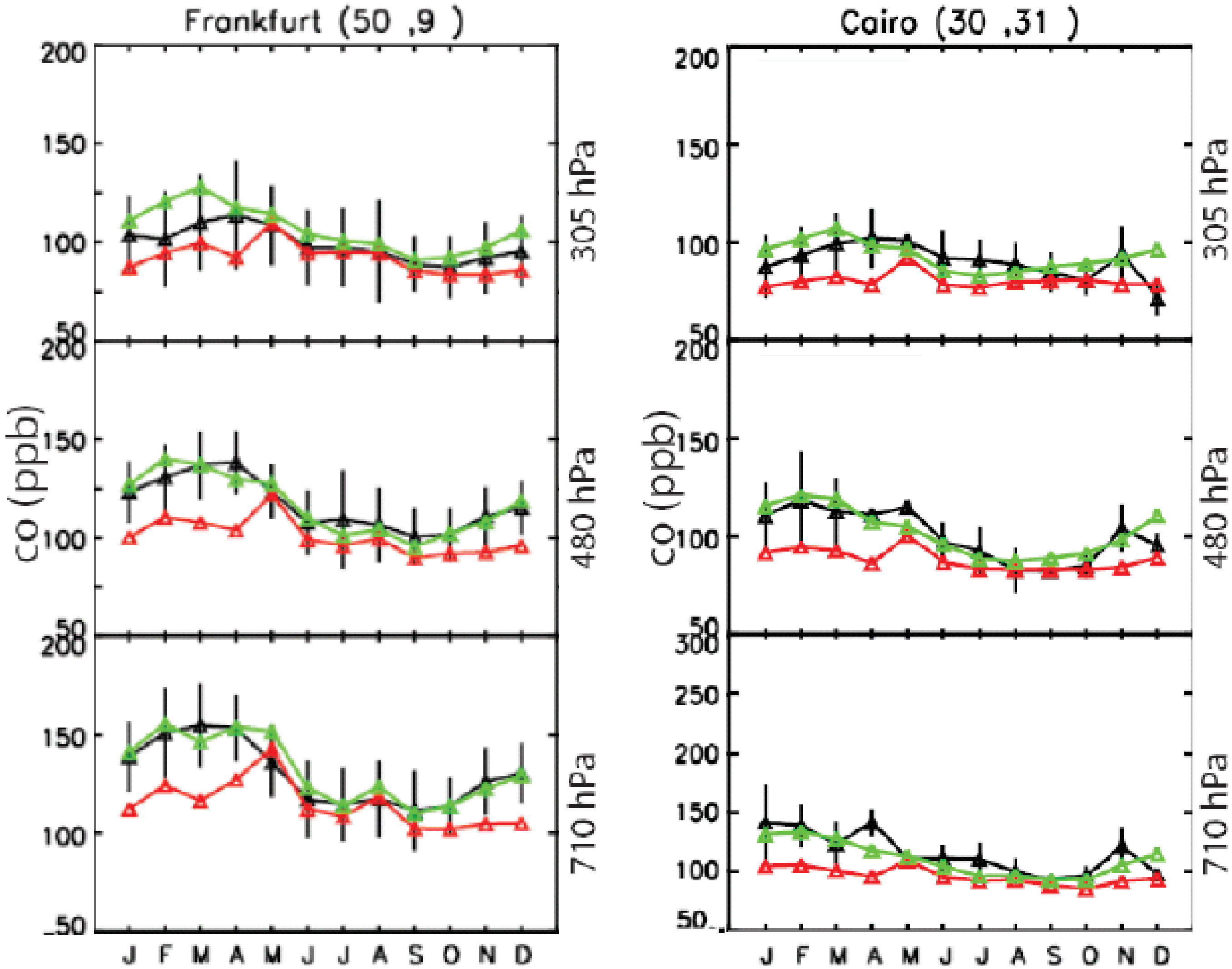
Southern Hemisphere:
still a challenge to match obs.





Model *a priori* Model *a posteriori*
Obs (2004-2005) Obs (climatology)

Comparison with independent aircraft measurements (MOZAIC)



Model *a priori* Model *a posteriori* Obs (climatology)

Major conclusions

1. GEOS-Chem CTM is a useful intercomparison platform for analyzing satellite data consistency
2. MOPITT, AIRS, TES and SCIAMACHY CO concentrations are generally consistent, especially in the northern hemisphere
3. Global annual CO emissions are found to be 1350 Tg
4. CO emissions in N. America, Europe and China exhibit strong seasonality, consistent with surface and aircraft observations
5. Tropical (mostly biomass burning) sources in S. America and Africa are estimated to be 183 and 343 Tg, mostly driven by AIRS data (larger than MOPITT or SCIAMACHY in southern hemisphere)
6. Regional satellite inconsistencies in southern hemisphere result in overestimated sources → motivation for more accurate data

Amount of *a priori* information in model-satellite correlations

Measure of information content: degrees of freedom (DOFs)

Note: DOFs not available for SCIA; reprocessing with MOPITT a priori does not change SCIA correlations