Satellite NO_2 for the Evaluation of U.S. NO_X Emissions

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LADCO

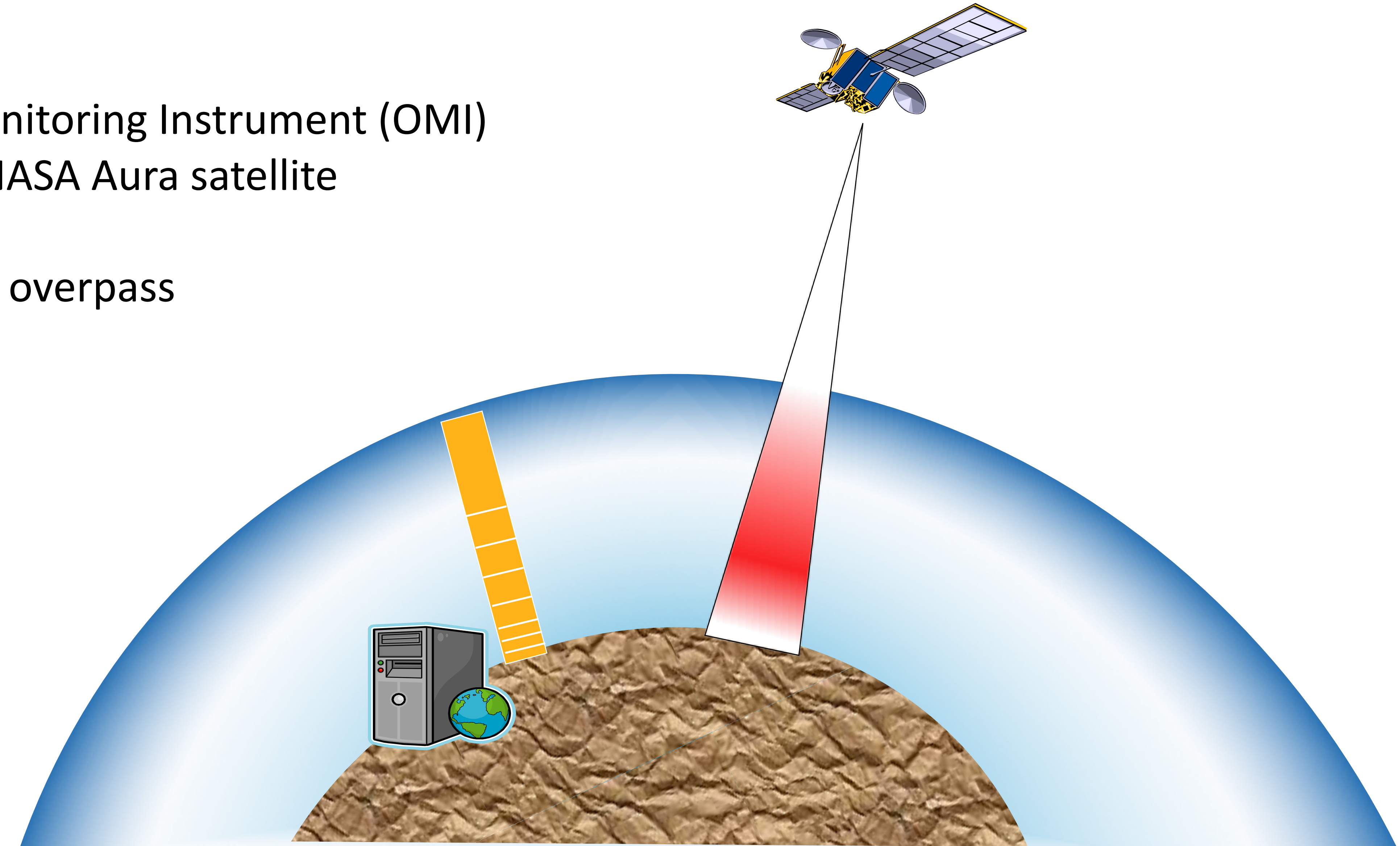
Satellites:

- continuous, global coverage: NO_2, SO_2, AOD (particulates), HCHO (VOCs)
- daily, seasonal patterns and multi-year trends

Satellite-based NO_2:

Ozone Monitoring Instrument (OMI) onboard NASA Aura satellite

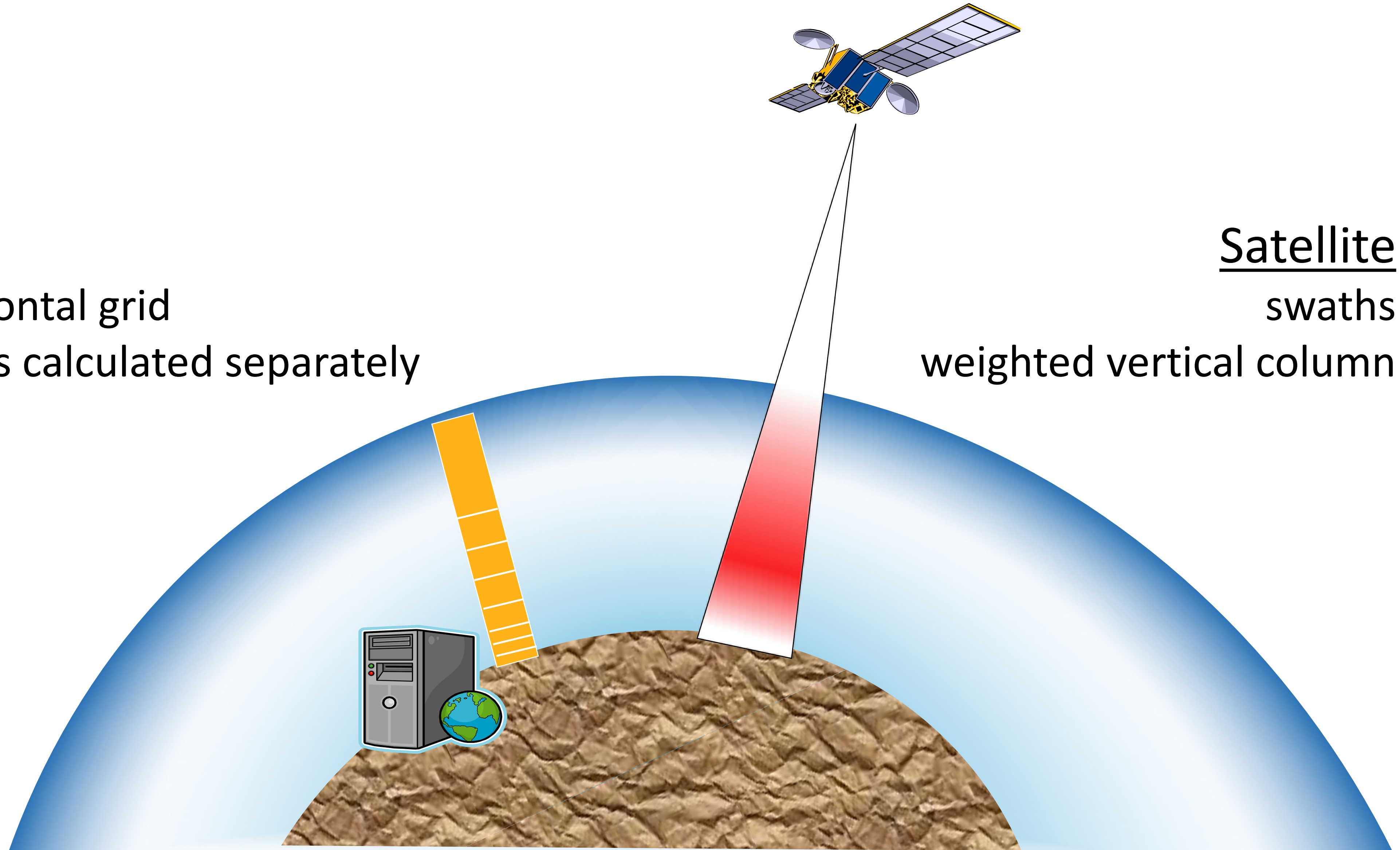
~1 pm LST overpass



Satellite-based NO_2:

<u>Model</u>
regular horizontal grid
vertical layers calculated separately

<u>Satellite</u>
swaths
weighted vertical column



Satellite-based NO_2:

Model

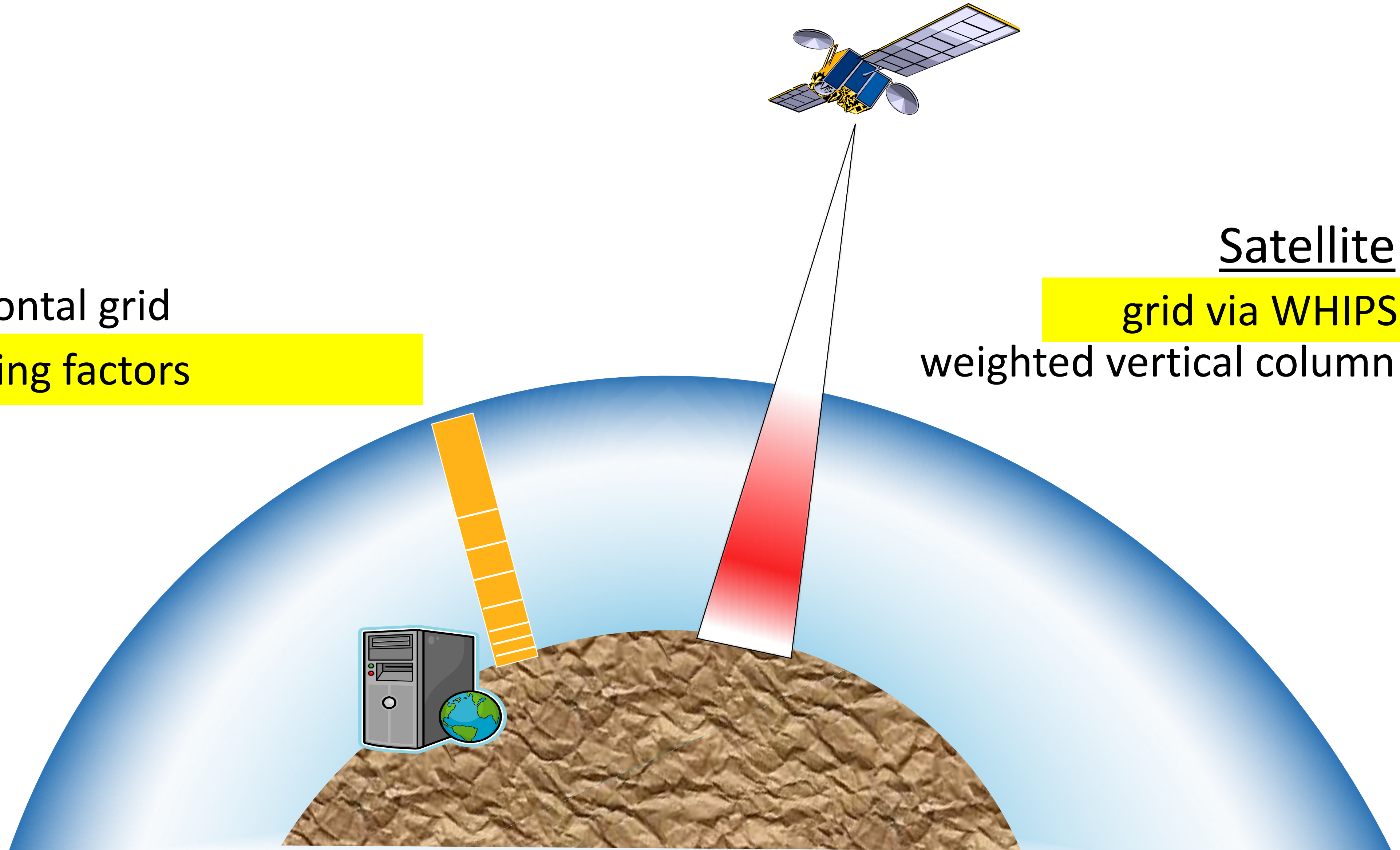
regular horizontal grid

apply weighting factors

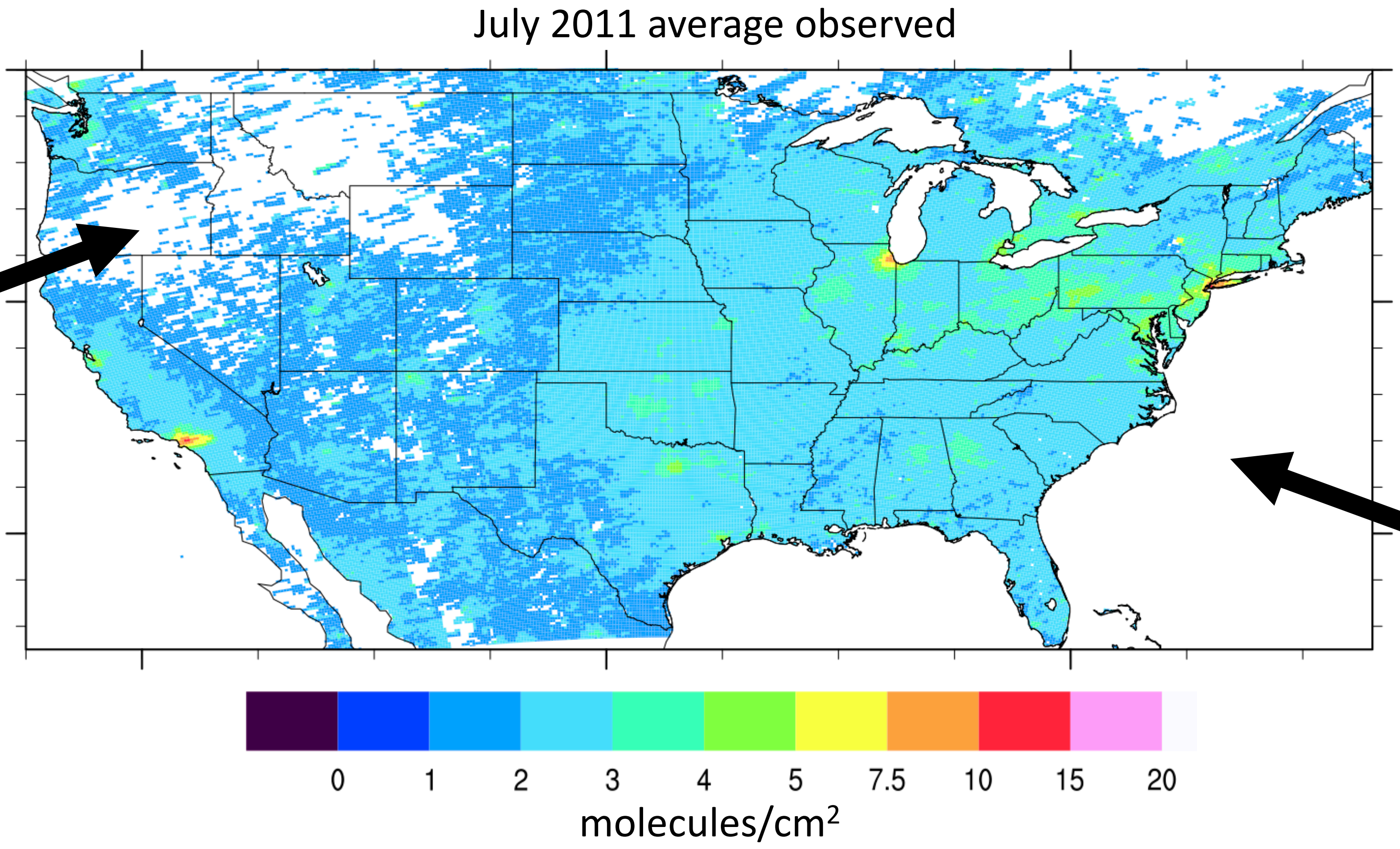
Satellite

grid via WHIPS

weighted vertical column



Satellite-based NO_2:



screen out values $< 1.5 \times 10^{15}$ molecules/cm^2

landmask

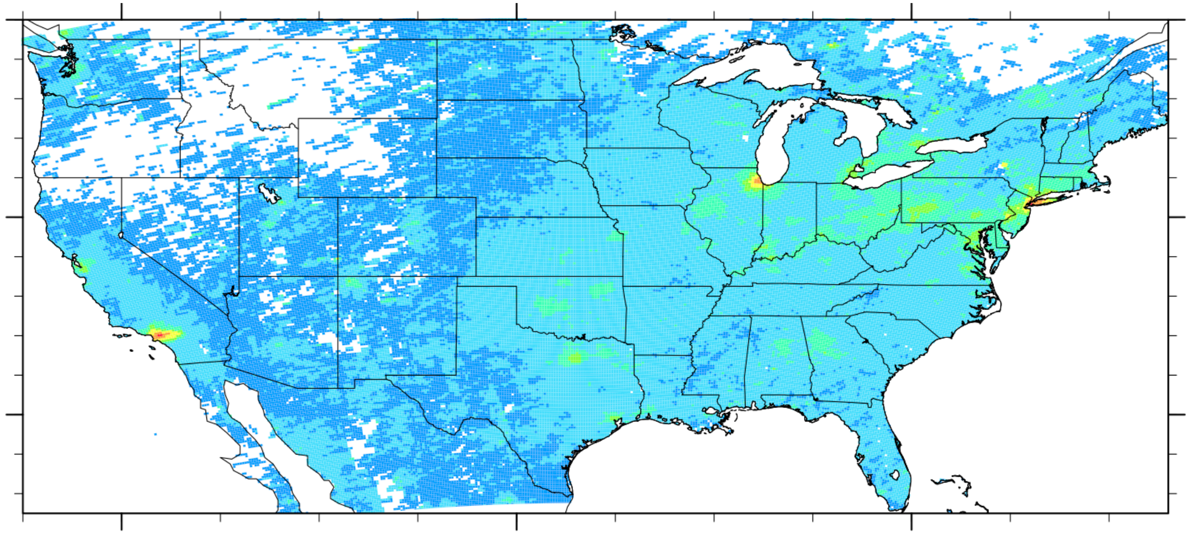
How can OMI NO_2 help us learn…

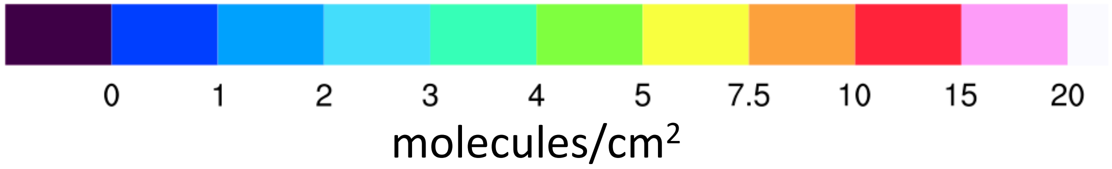
- about urban-rural gradients?
- from scaling for near-surface amounts?
- from assimilating OMI NO_2 observations?

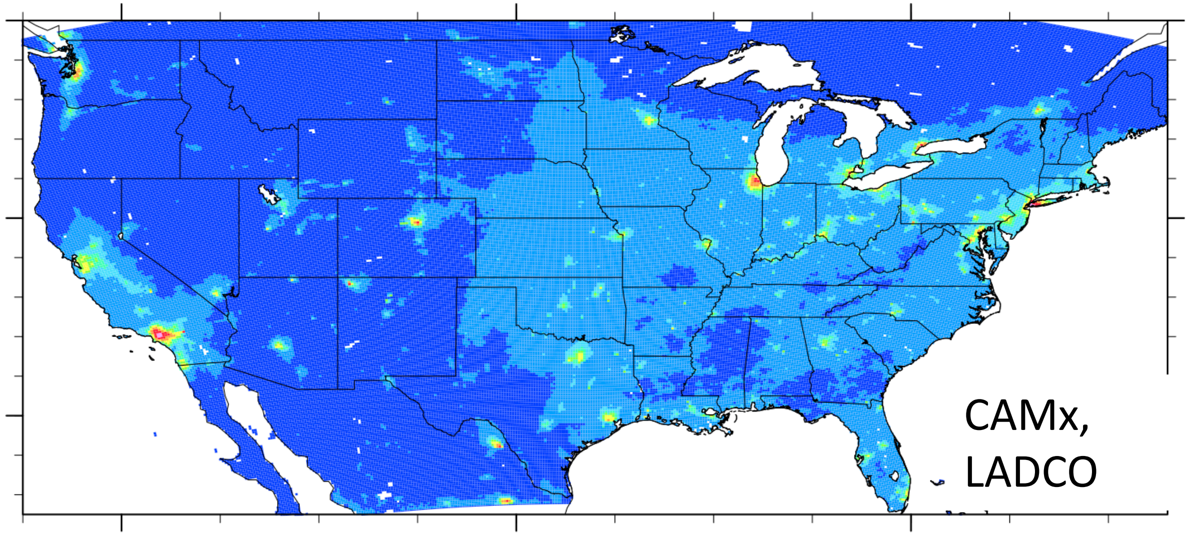
urban-rural gradients

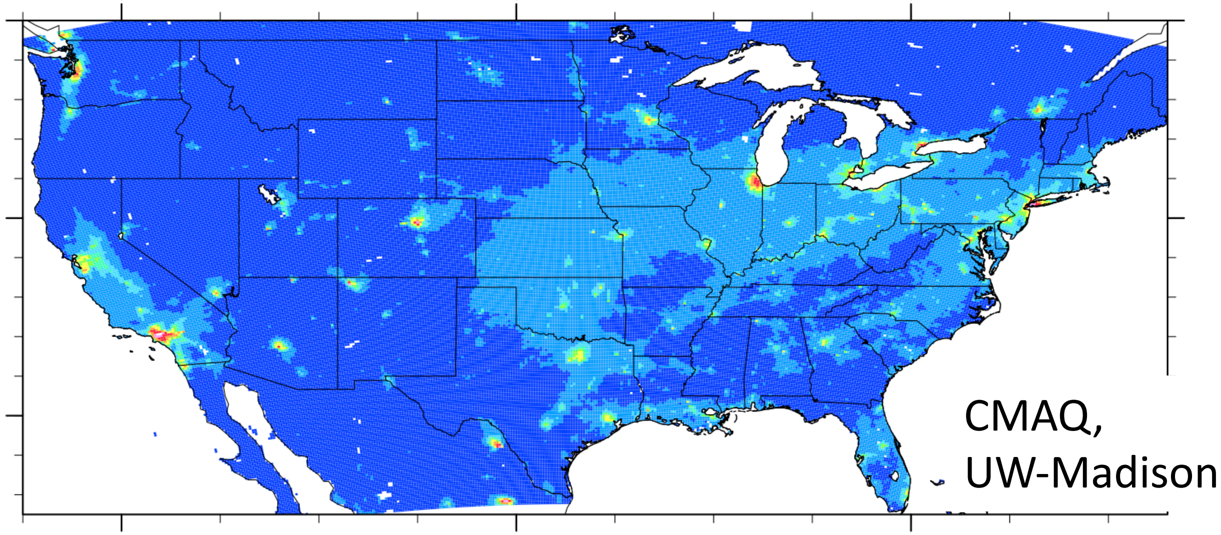
July 2011 average modeled

July 2011 average observed



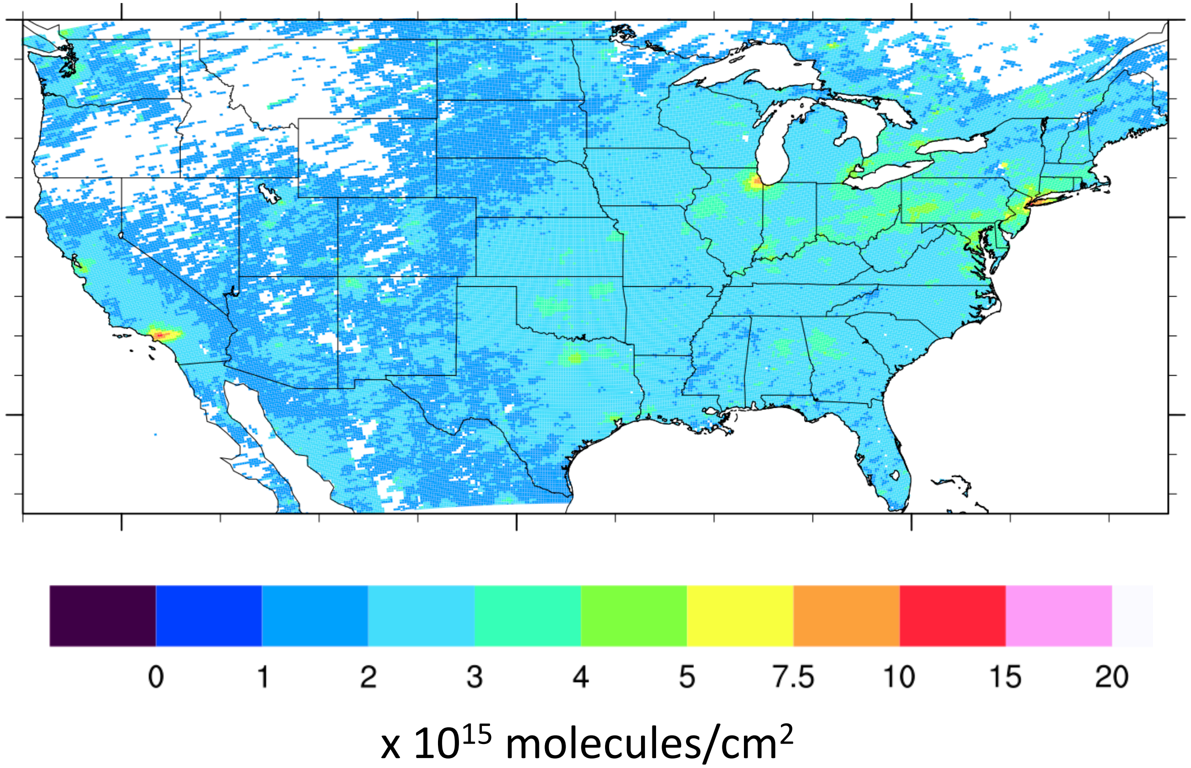




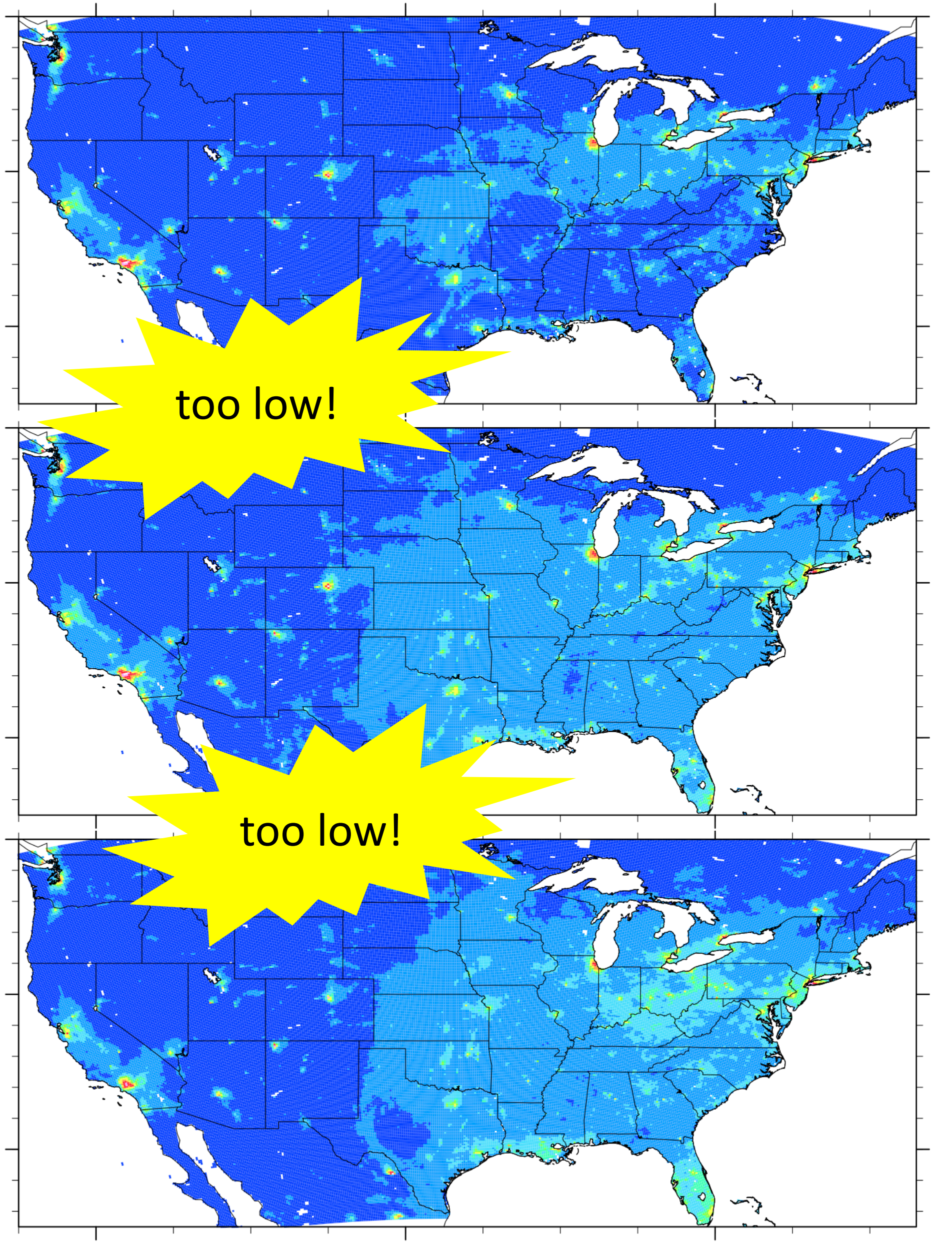


urban-rural gradients

July 2011 average observed



CMAQ:

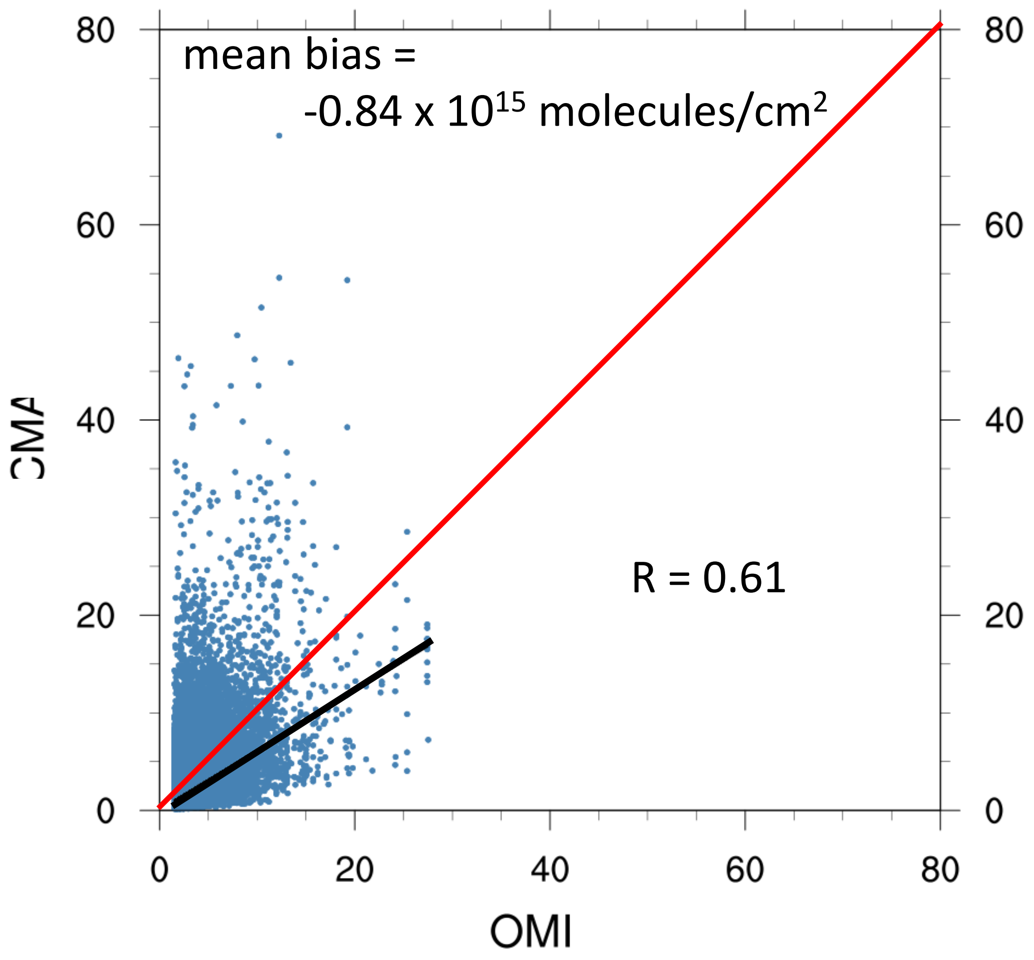


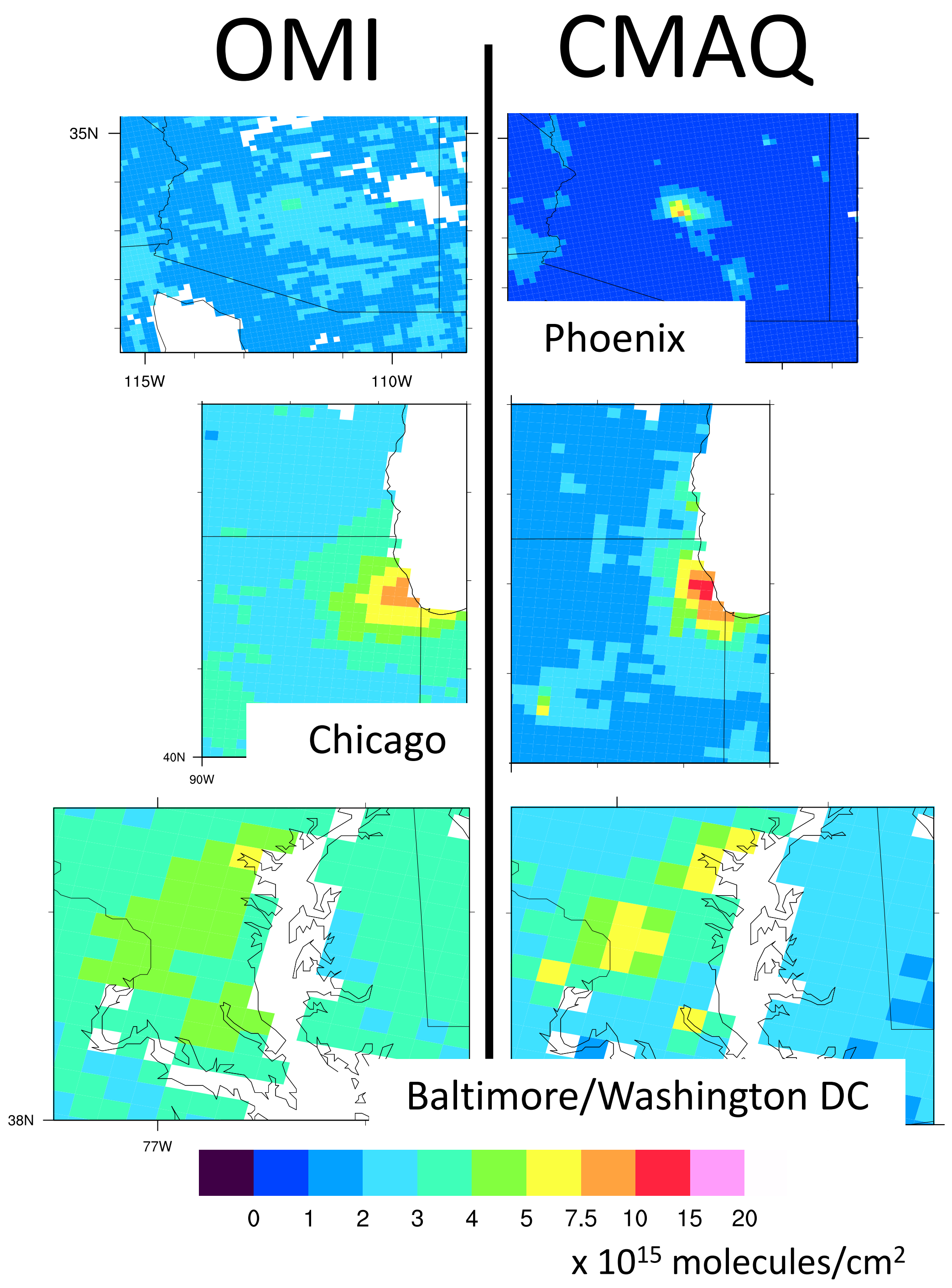
with emissions from fires

with emissions from fires and lightning

with emissions from fires and lightning, different meteorology

urban-rural gradients





How can OMI NO_2 help us learn…

- about urban-rural gradients?

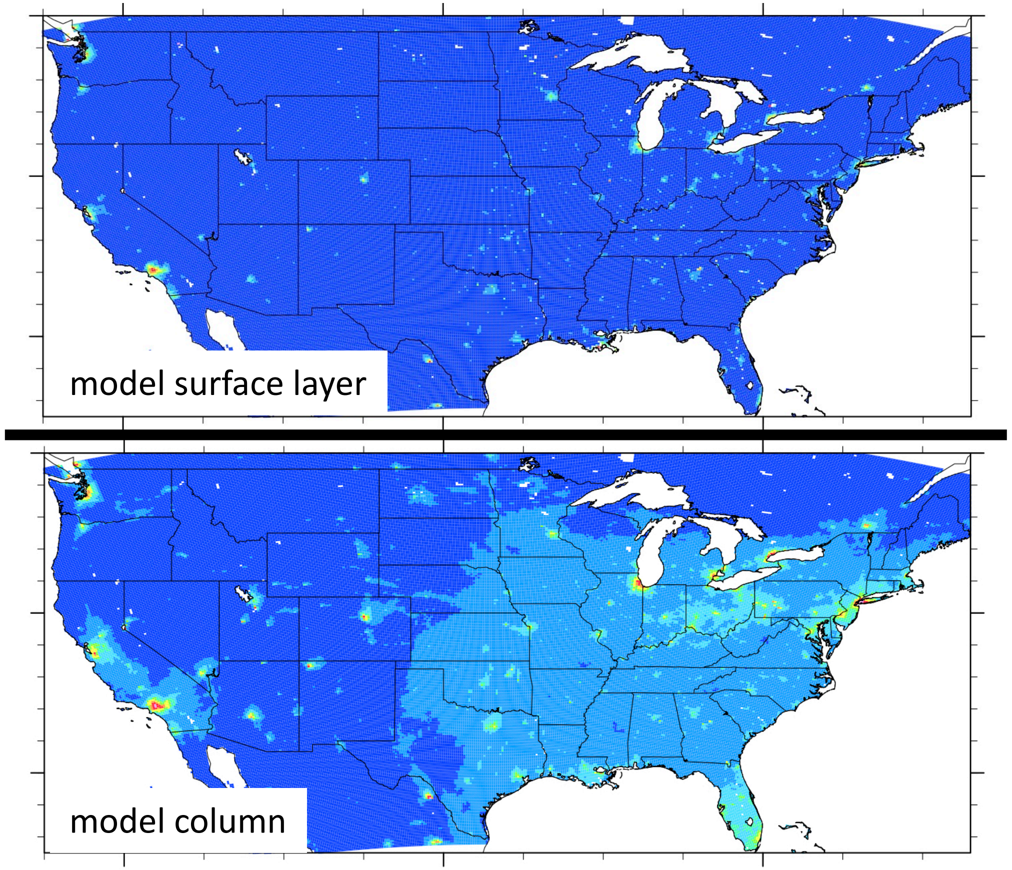
  modeled column NO_2 too low in non-urban areas; too high in urban areas
  uncertainties in LNOx? aviation emissions?

- from scaling for near-surface amounts?

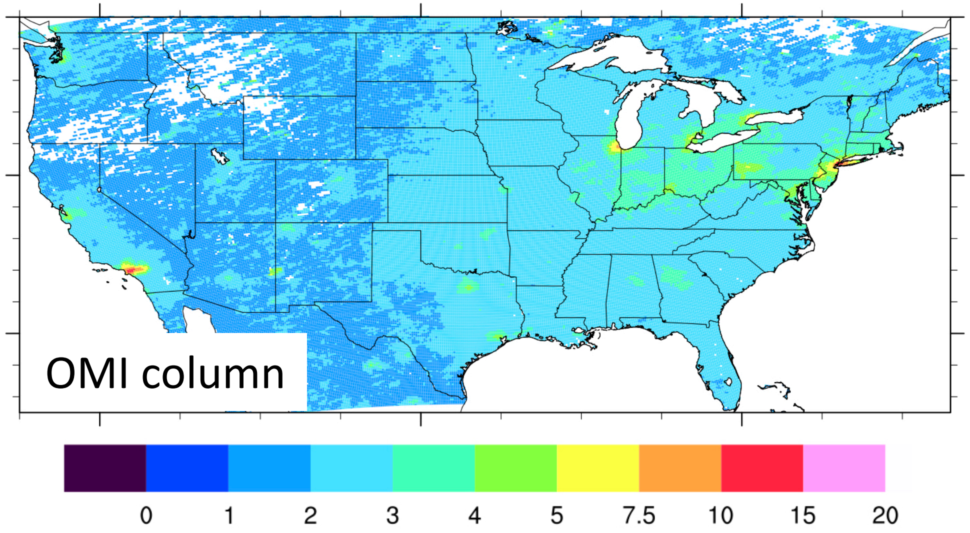
- from assimilating OMI NO_2 observations?

scaling OMI NO_2 for near-surface amounts

$$\frac{\text{model surface layer}}{\text{model column}} = \frac{\text{scaled OMI surface layer}}{\text{OMI column}}$$

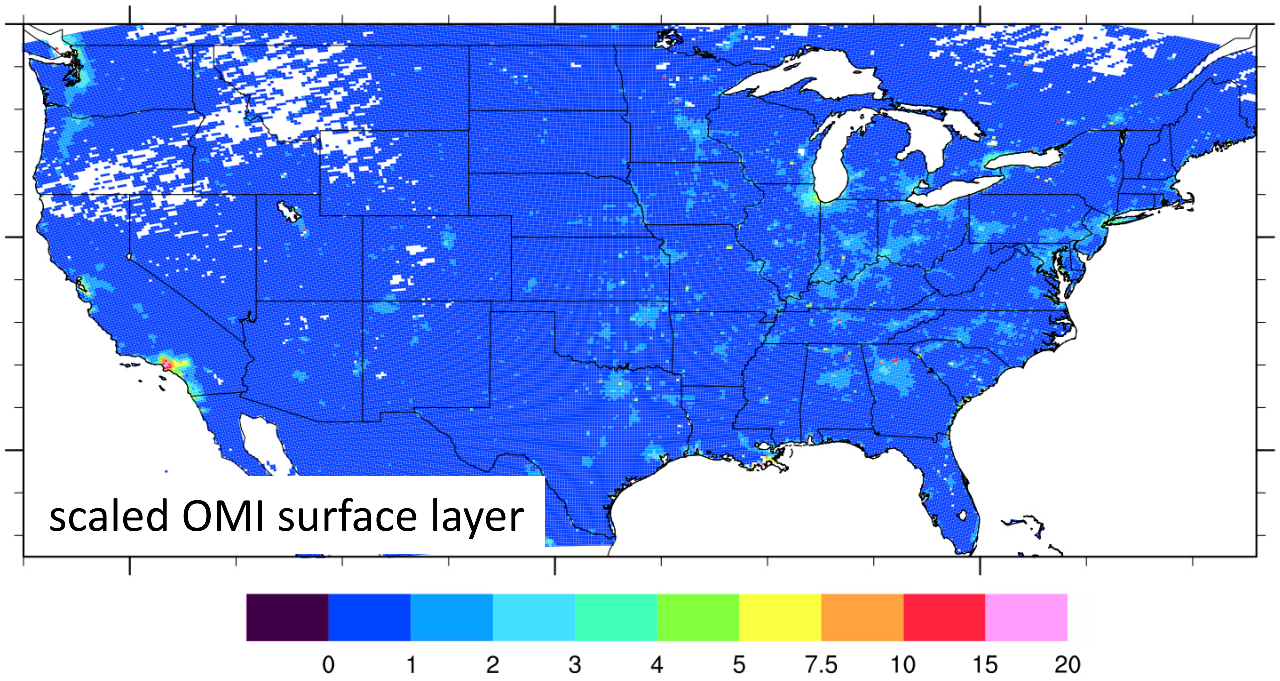


x

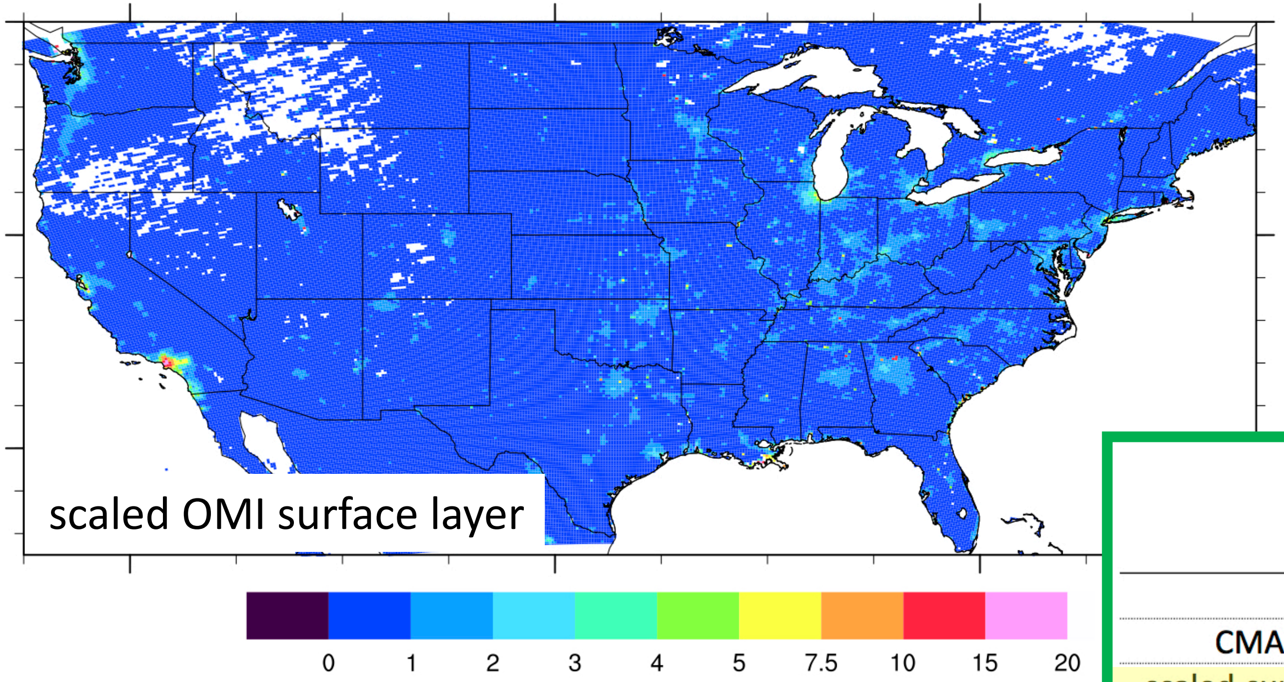


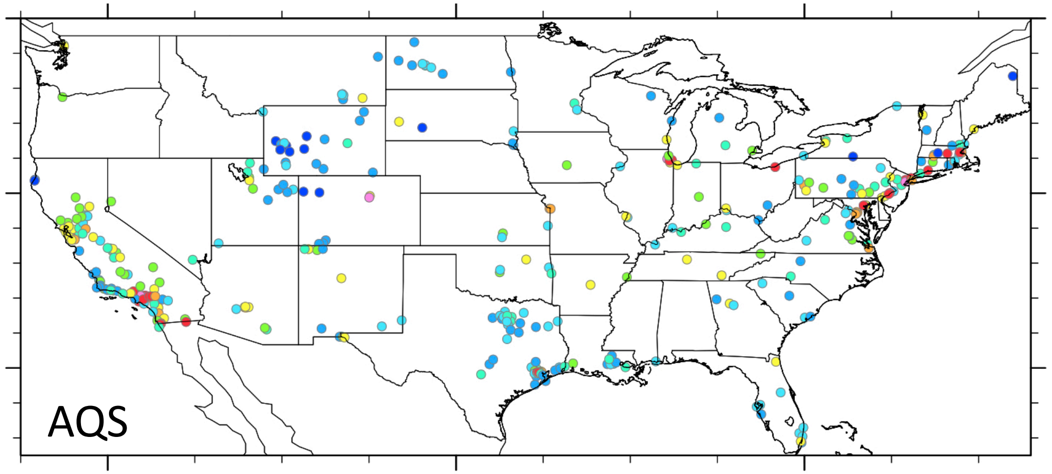
=

scaling OMI NO_2 for near-surface amounts



scaling OMI NO_2 for near-surface amounts





	average	RMSE	Mean Error	Mean Fractional Error	Mean Bias	Mean Fractional Bias
AQS	4.590					
CMAQ surface	1.946	3.807	3.016	95.707	-2.534	-84.565
scaled-surface OMI	3.216	4.541	1.343	28.685	-0.614	-21.278

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- about urban-rural gradients?

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    uncertainties in LNOx? aviation emissions?

- from scaling for near-surface amounts?

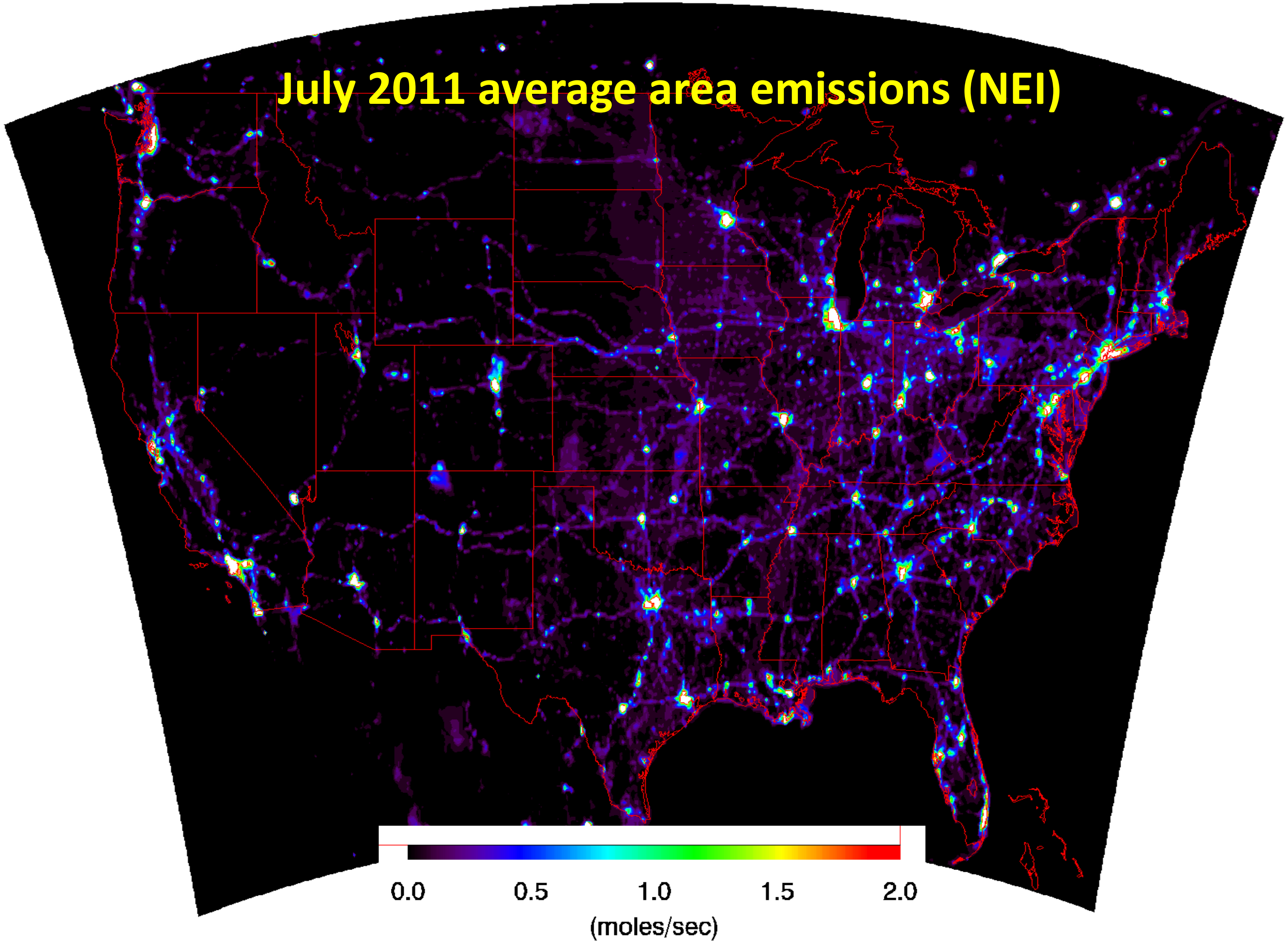
    low-bias technique useful for "filling in the gaps"
    results using month averages similar to using daily values

- from assimilating OMI NO_2 observations?

assimilating OMI NO_2 observations

adjust area NO_X *emissions*

(NO_2 lifetime too short to use assimilation to constrain tropospheric column amounts)



assimilating OMI NO_2 observations

adjust area NO_2 emissions

1) calculate monthly mean NO_2 Jacobian (β) from a 15% NO_X reduction perturbation experiment following *Lamsal et al.* 2011

$$\frac{\Delta E}{E} = \boxed{\beta} \times \frac{\Delta \Omega}{\Omega}.$$

2) calculate monthly mean NO_2 analysis increment using CMAQ + OMI NO_2 assimilation

$$\frac{\Delta E}{E} = \beta \times \boxed{\frac{\Delta \Omega}{\Omega}}.$$

3) adjust 2011 NEI NO_2 emissions using Jacobian and analysis increment

$$\boxed{\frac{\Delta E}{E}} = \beta \times \frac{\Delta \Omega}{\Omega}.$$

Lamsal, L. N., et al. (2011), Application of satellite observations for timely updates to global anthropogenic NOx emission inventories, Geophys. Res. Lett., 38, L05810, doi:10.1029/2010GL046476.

assimilating OMI NO_2 observations

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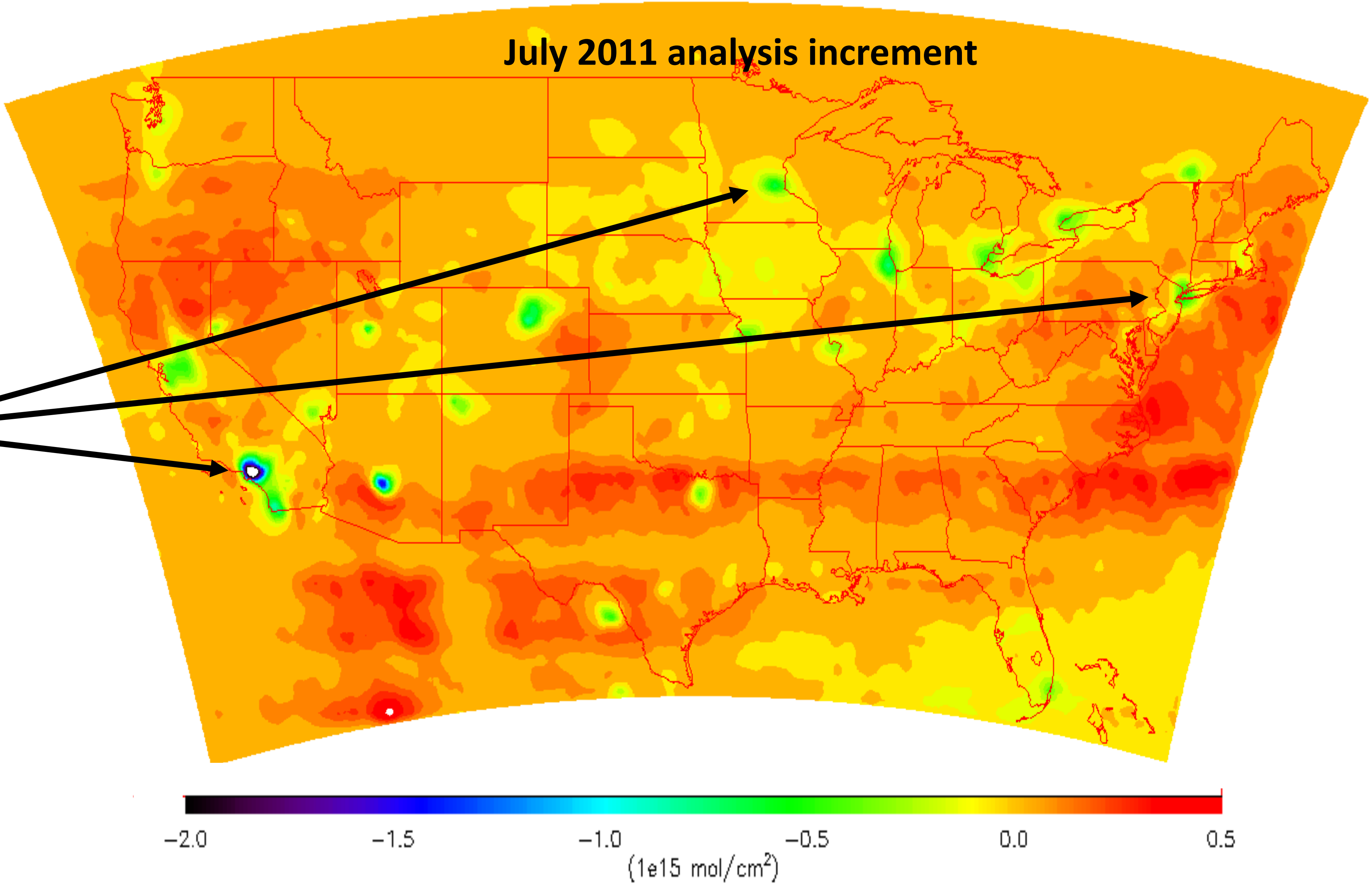
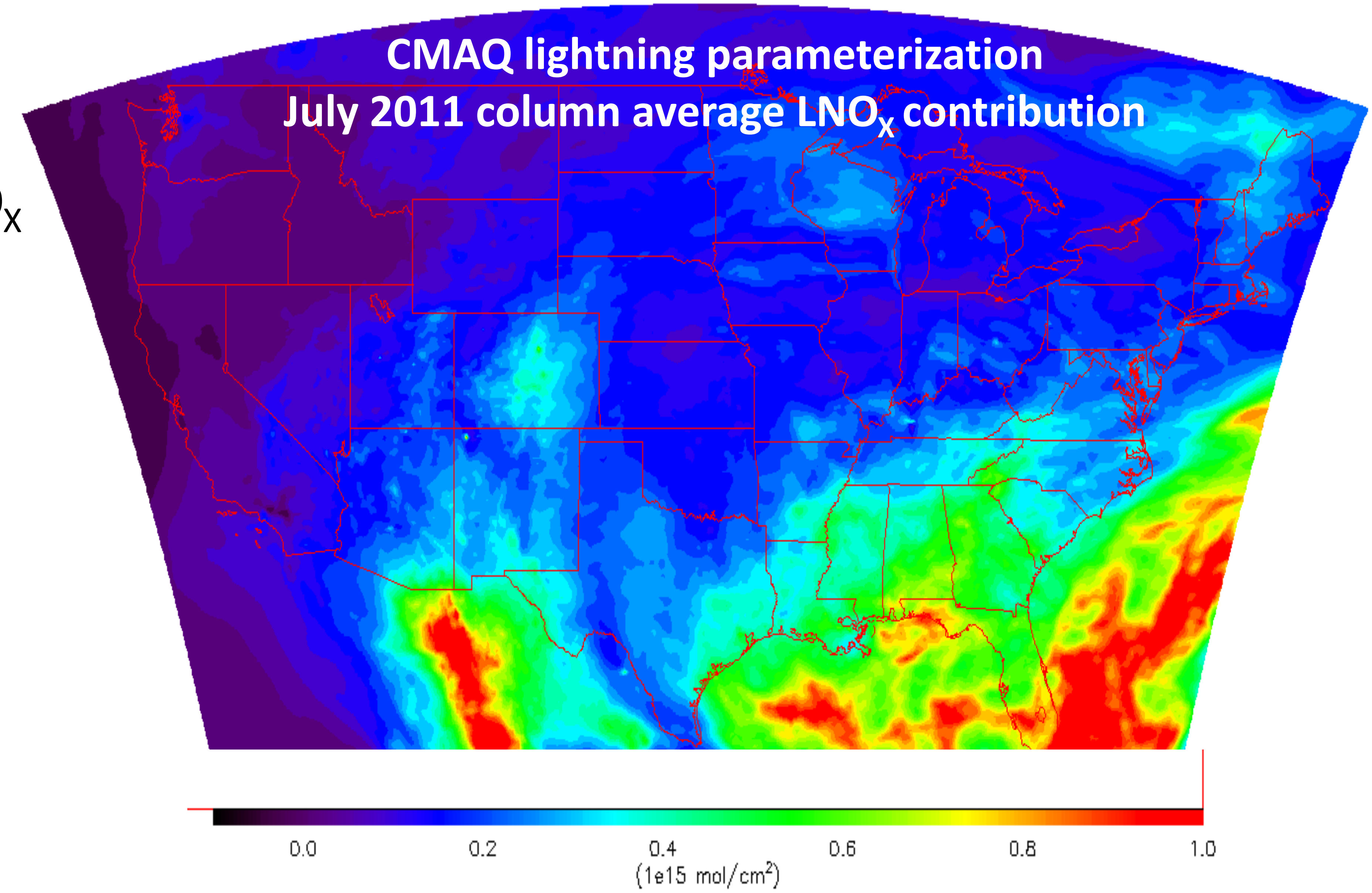
assimilating OMI NO_2 observations

adjust emissions downward in urban areas



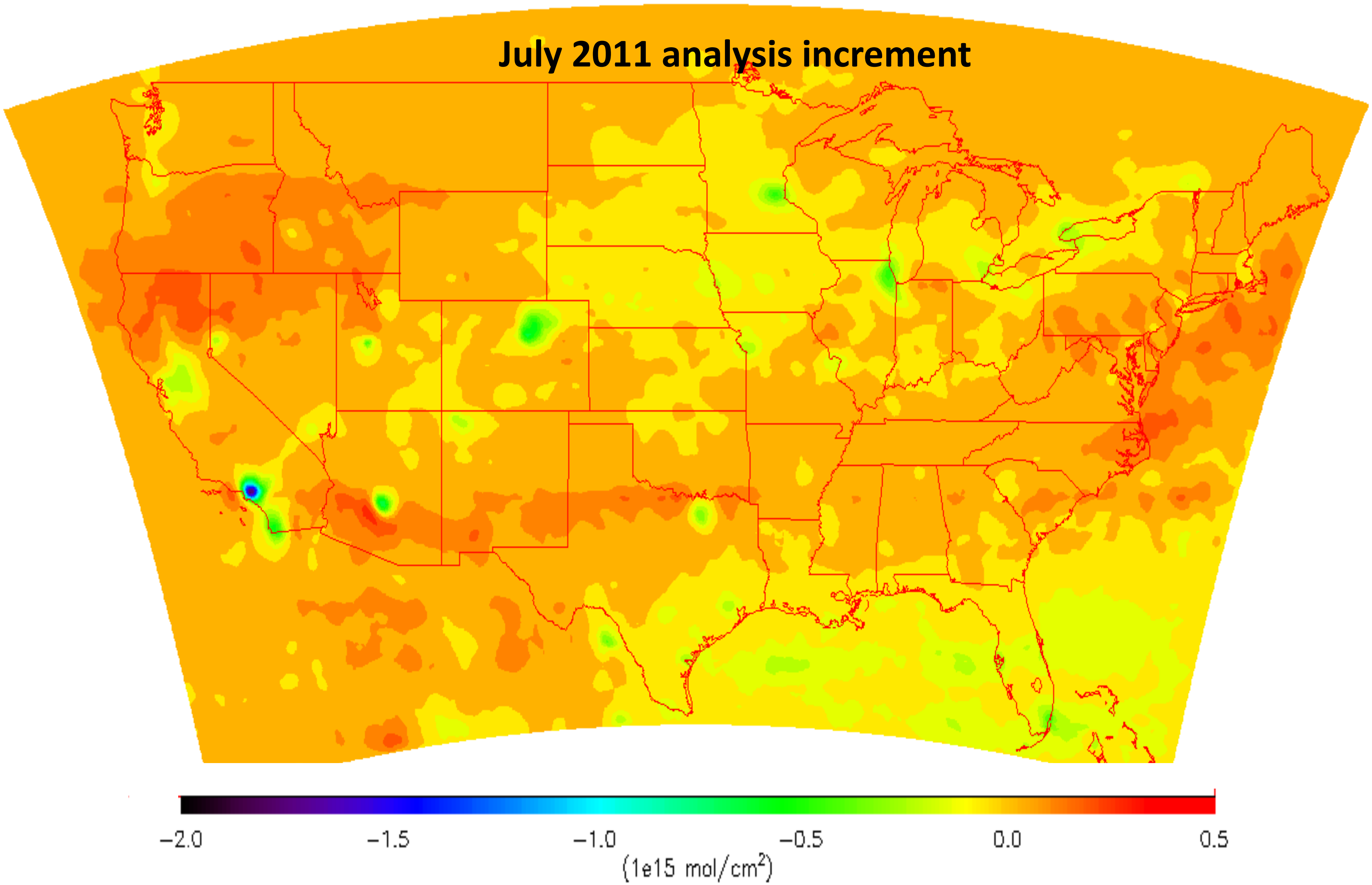
assimilating OMI NO_2 observations

adjust lightning NO_X emissions



assimilating OMI NO_2 observations

adjust lightning NO_X emissions

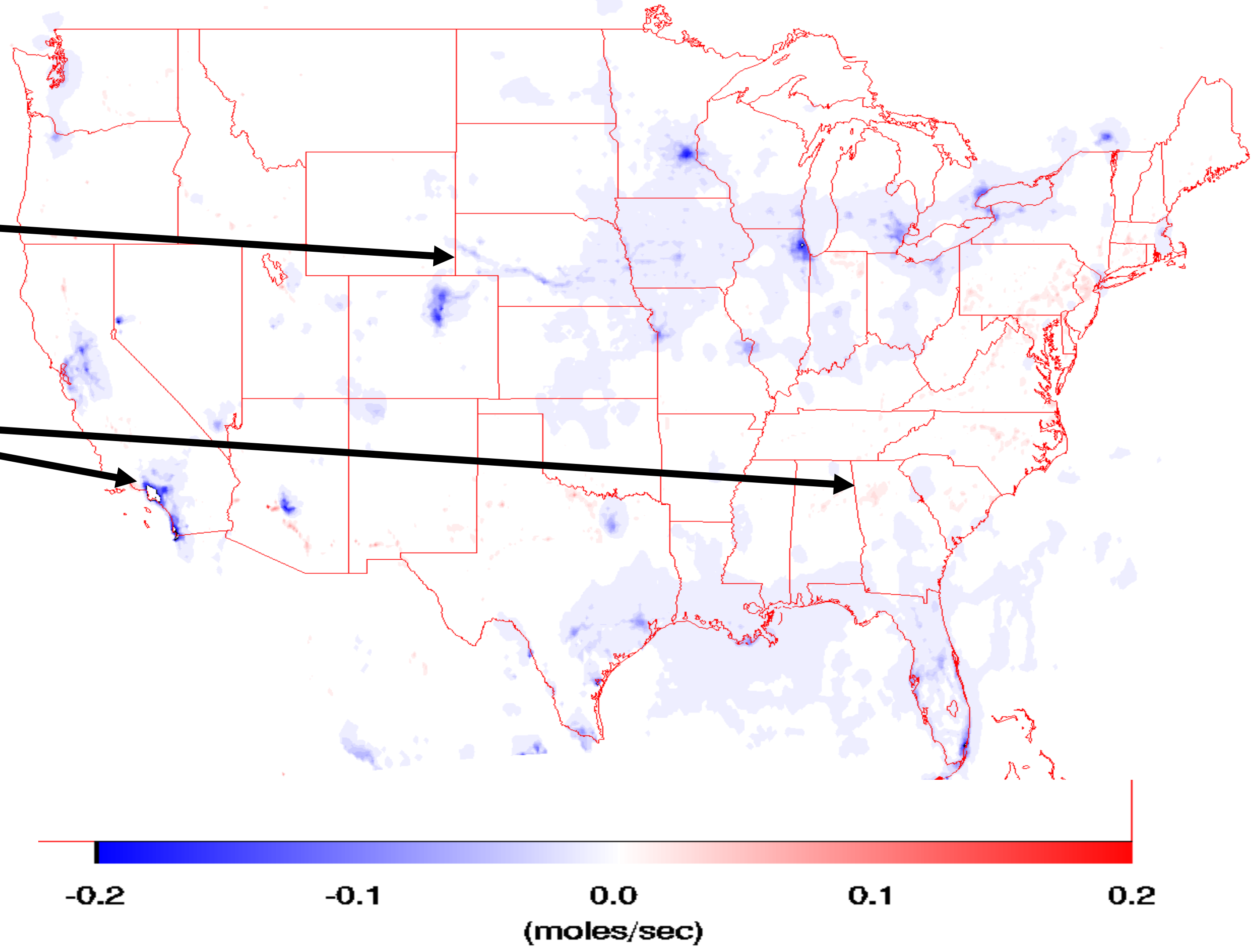


assimilating OMI NO_2 observations

July 2011 area-source emissions adjustment

transportation-related NO_X emissions ~ 0.3 moles/sec

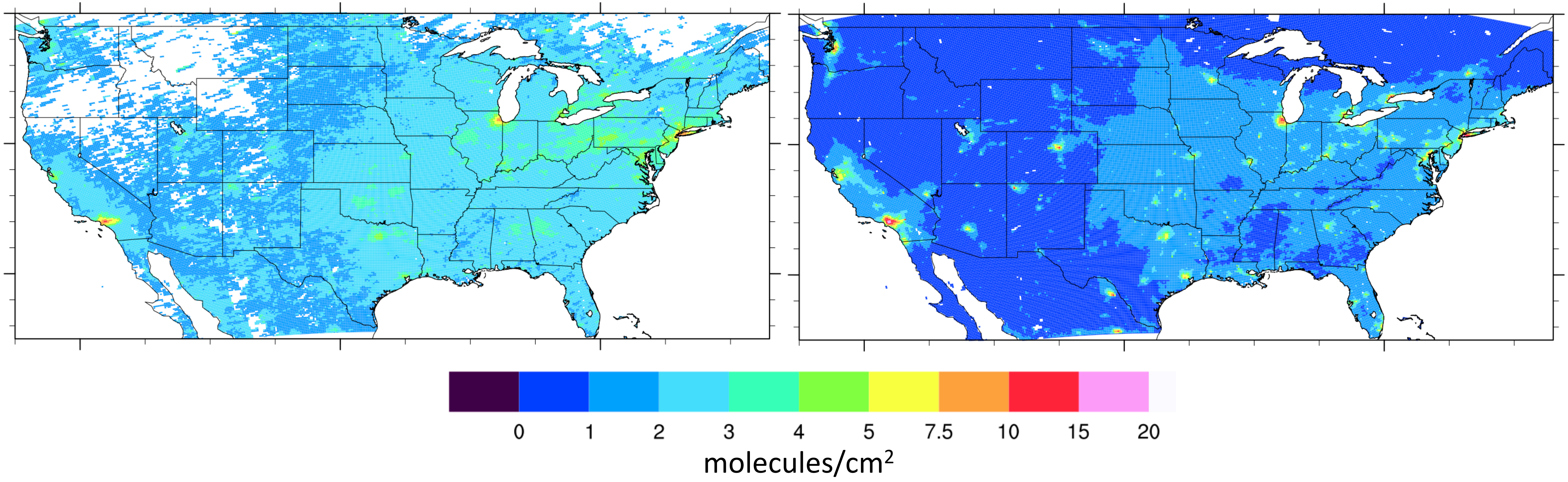
NO_X emissions in urban areas ≥ 2 moles/sec



(not) assimilating OMI NO_2

July 2011 average observed

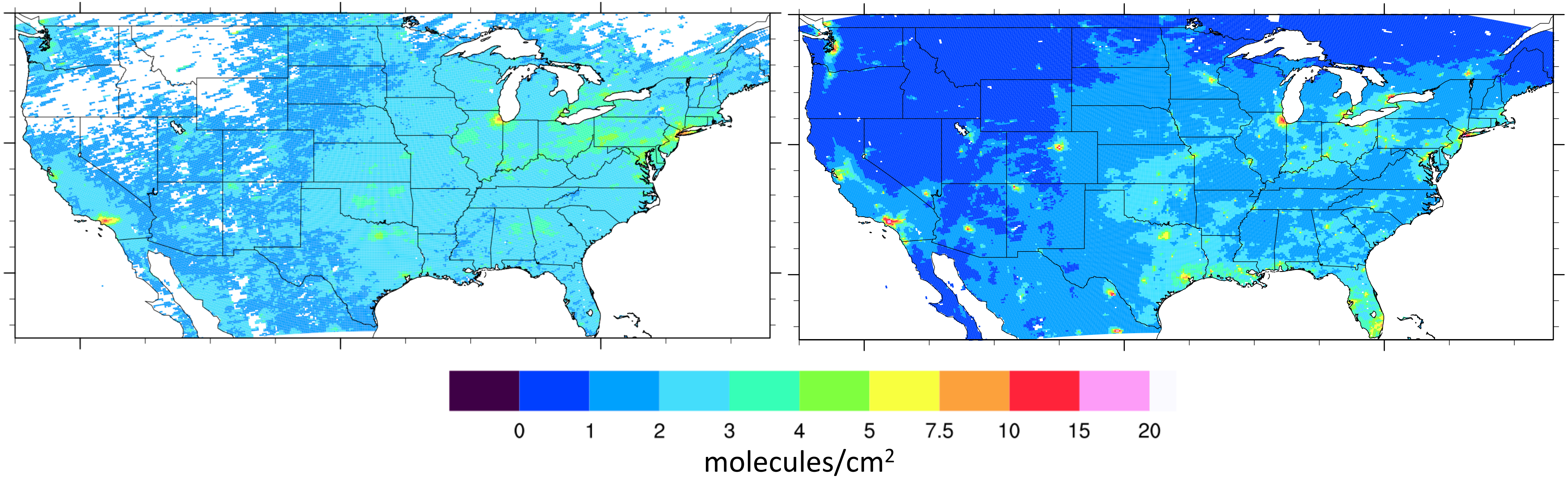
July 2011 average modeled
(original emissions)



assimilating OMI NO_2

July 2011 average observed

July 2011 average modeled
(adjusted emissions)



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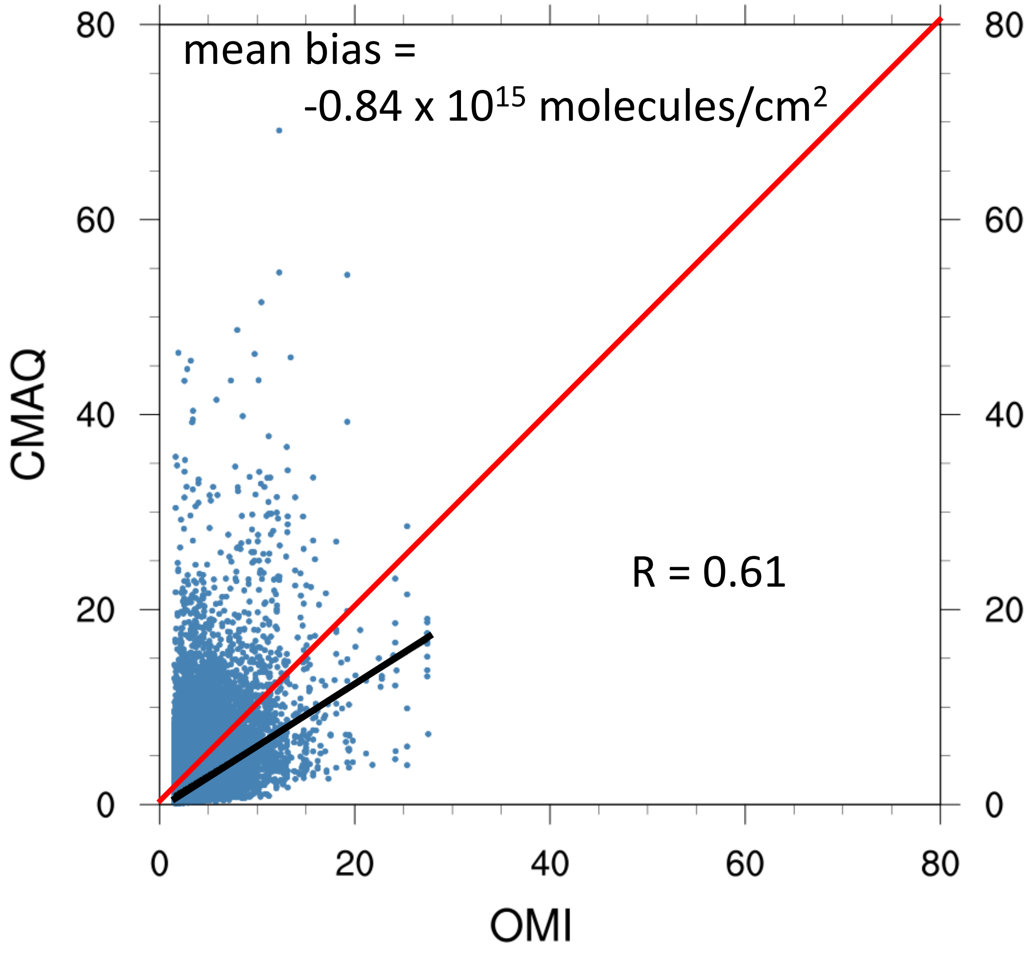
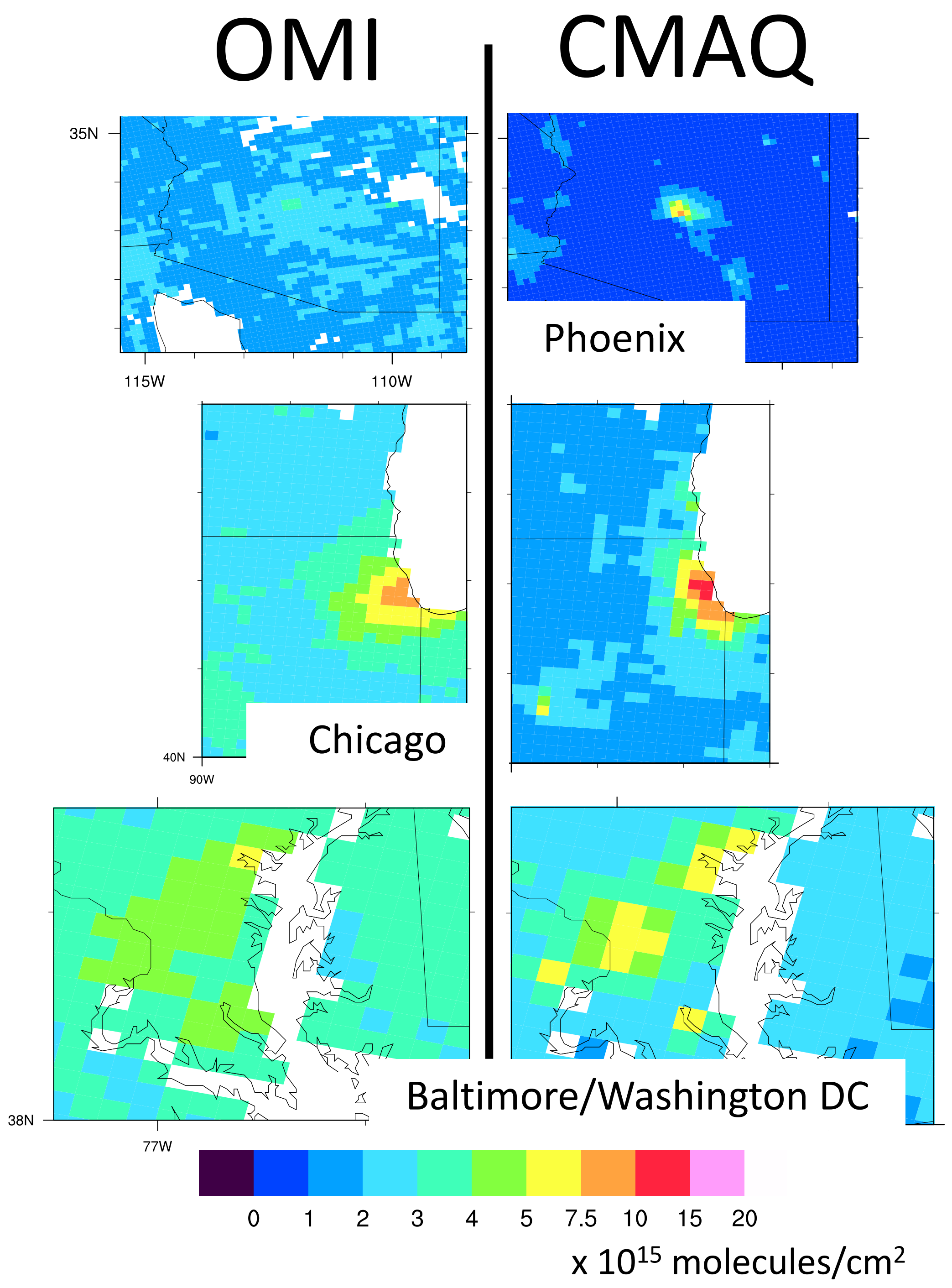
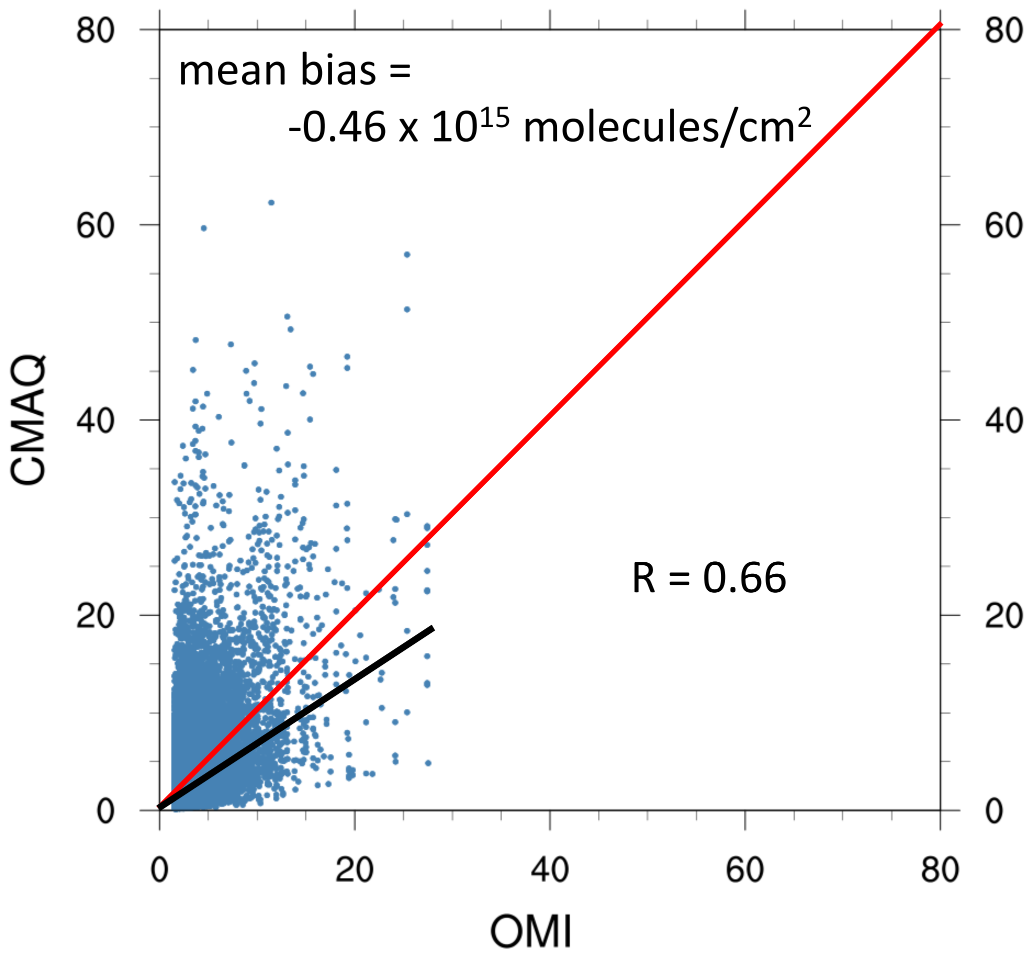
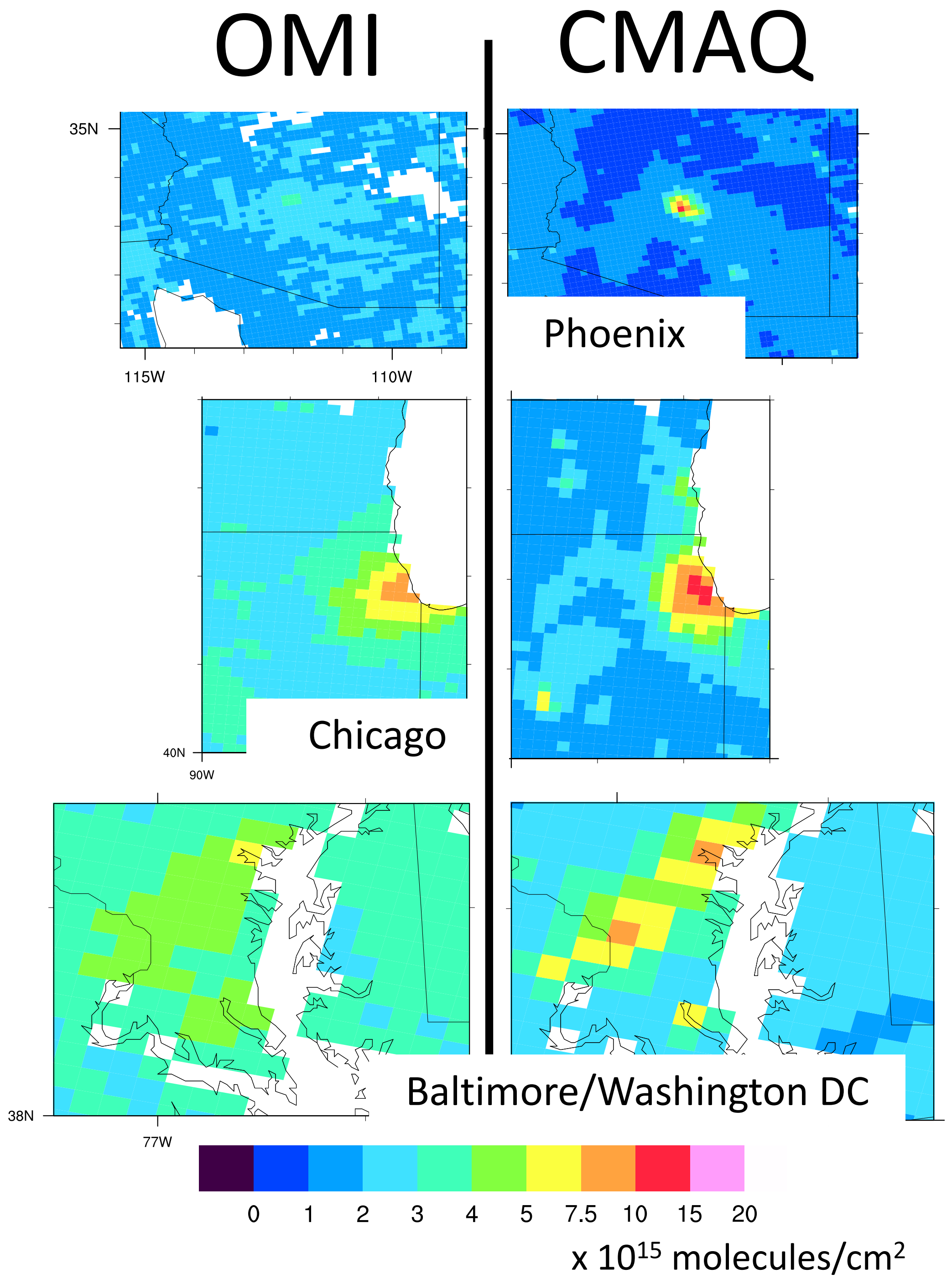




assimilating OMI NO_2





How can OMI NO_2 help us learn…

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  uncertainties in LNOx? aviation emissions?

- from scaling for near-surface amounts?

  low-bias technique useful for "filling in the gaps"
  results using month averages similar to using daily values

- from assimilating OMI NO_2 observations?

  NO_X emissions may be adjusted downward in most large urban areas
  emissions of lightning NO_X important
  adjusted emissions improve model-satellite column NO_2 agreement

What can we learn from OMI NO_2?

- model evaluation and data assimilation show urban NO_X tends to be too high

- uncertainties with lightning NO_X, emissions from aviation at cruising altitude

- scaled-to-surface satellite observations may be helpful in evaluating emissions and trends away from ground-based monitors

More OMI NO_2 utility:


AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE

10.1002/2015JD023316

Key Point:
- CMAQ NO_2 evaluated using observed chemistry-meteorology relationships

Supporting Information:
- Tables S1–S3 and Figures S1–S16

An evaluation of CMAQ NO_2 using observed chemistry-meteorology correlations

Monica Harkey[1], Tracey Holloway[1], Jacob Oberman[1], and Erica Scotty[1]

[1]Nelson Institute Center for Sustainability and the Global Environment, University of Wisconsin-Madison, Madison, Wisconsin, USA

AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE

10.1002/2015JD023250

Key Points:
- NO_2 and HCHO from satellites can characterize O_3 production regimes and trends
- Transitional regime is dominated over eastern China in ozone season
- Cities in China are becoming increasingly VOC limited

Spatial and temporal variability of ozone sensitivity over China observed from the Ozone Monitoring Instrument

Xiaomeng Jin[1] and Tracey Holloway[1]

[1]Center for Sustainable and Global Environment, Nelson Institute of Environmental Studies, University of Wisconsin-Madison, Madison, Wisconsin, USA

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