Simulation Experiments for TEMPO Air Quality Objectives

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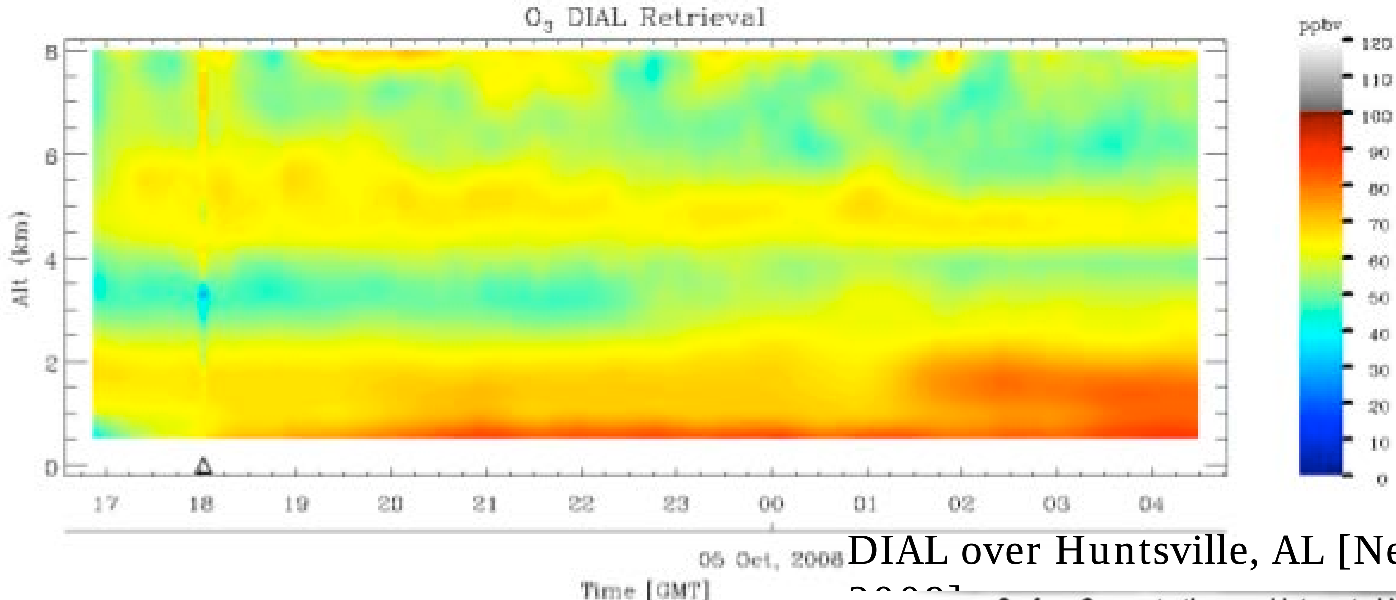
TEMPO Science Team Meeting
July 24, 2013

The Difficulty of Ozone Air Quality from Space

- Ozone concentrations very heterogeneous both spatially and temporally

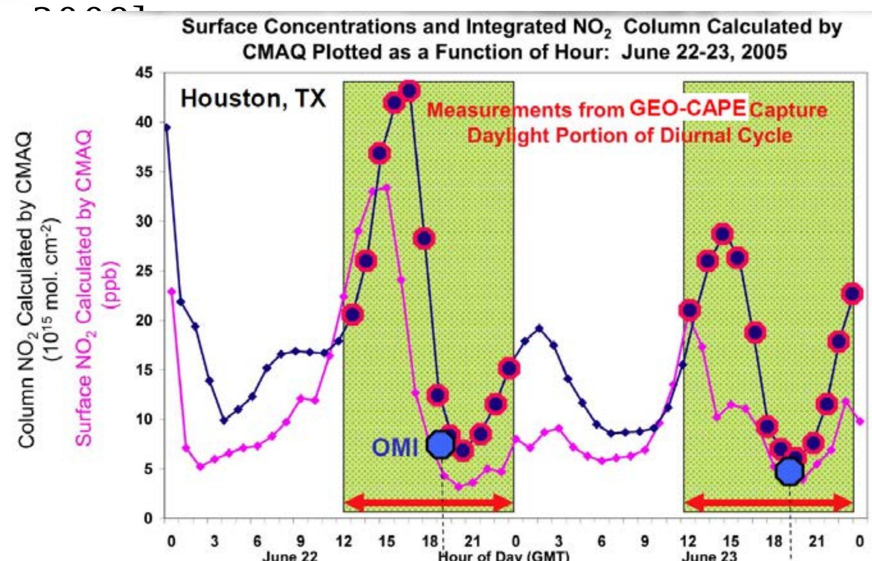


DIAL over Huntsville, AL [Newchurch et al,

Ozone chemistry complex and non-linear

Short timescales → large diurnal variation

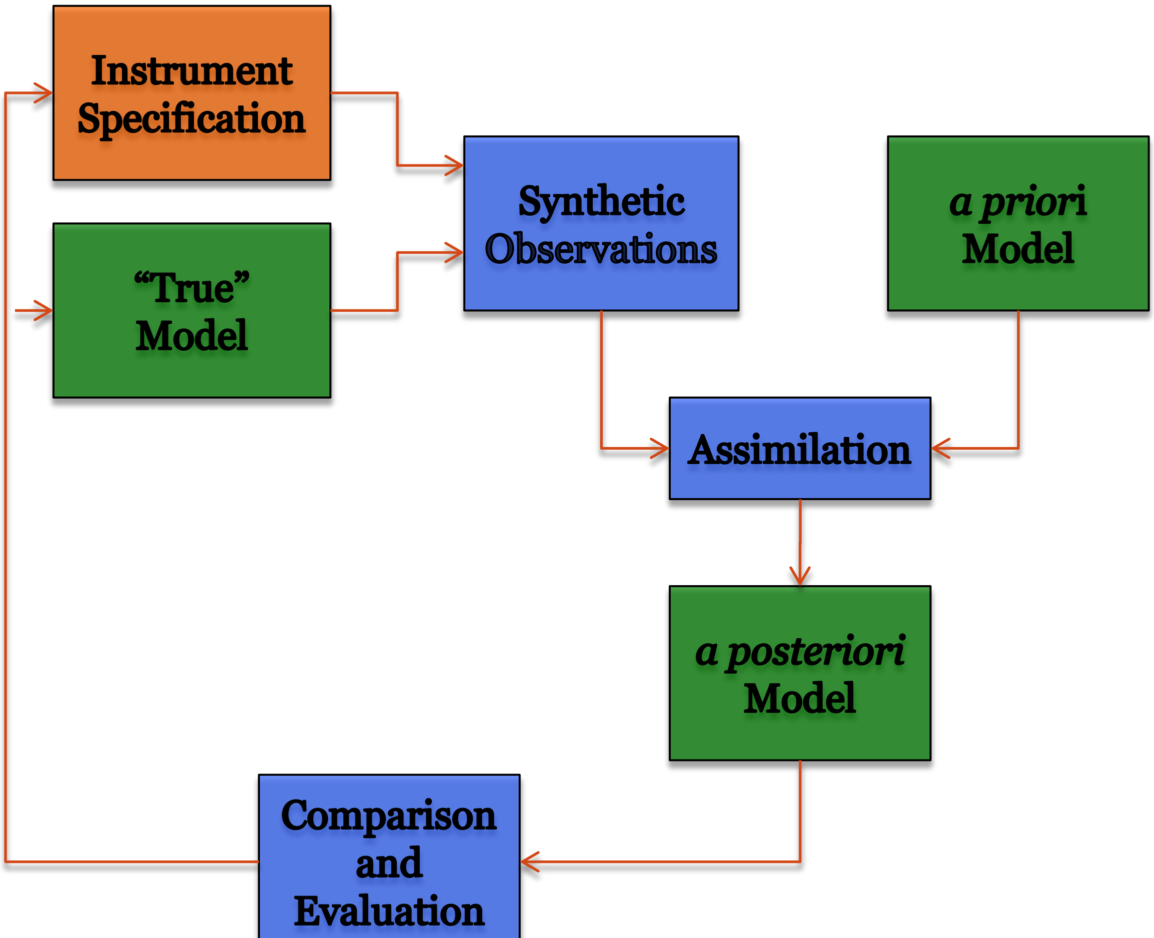
NAS/EPA: current ground/sonde network inadequate for air quality monitoring



[Fishman et al. 2008]

Observing System Simulation Experiment

- What additional information is provided by addition of a new instrument?



a priori = GEOS-Chem model

"True" = independent model

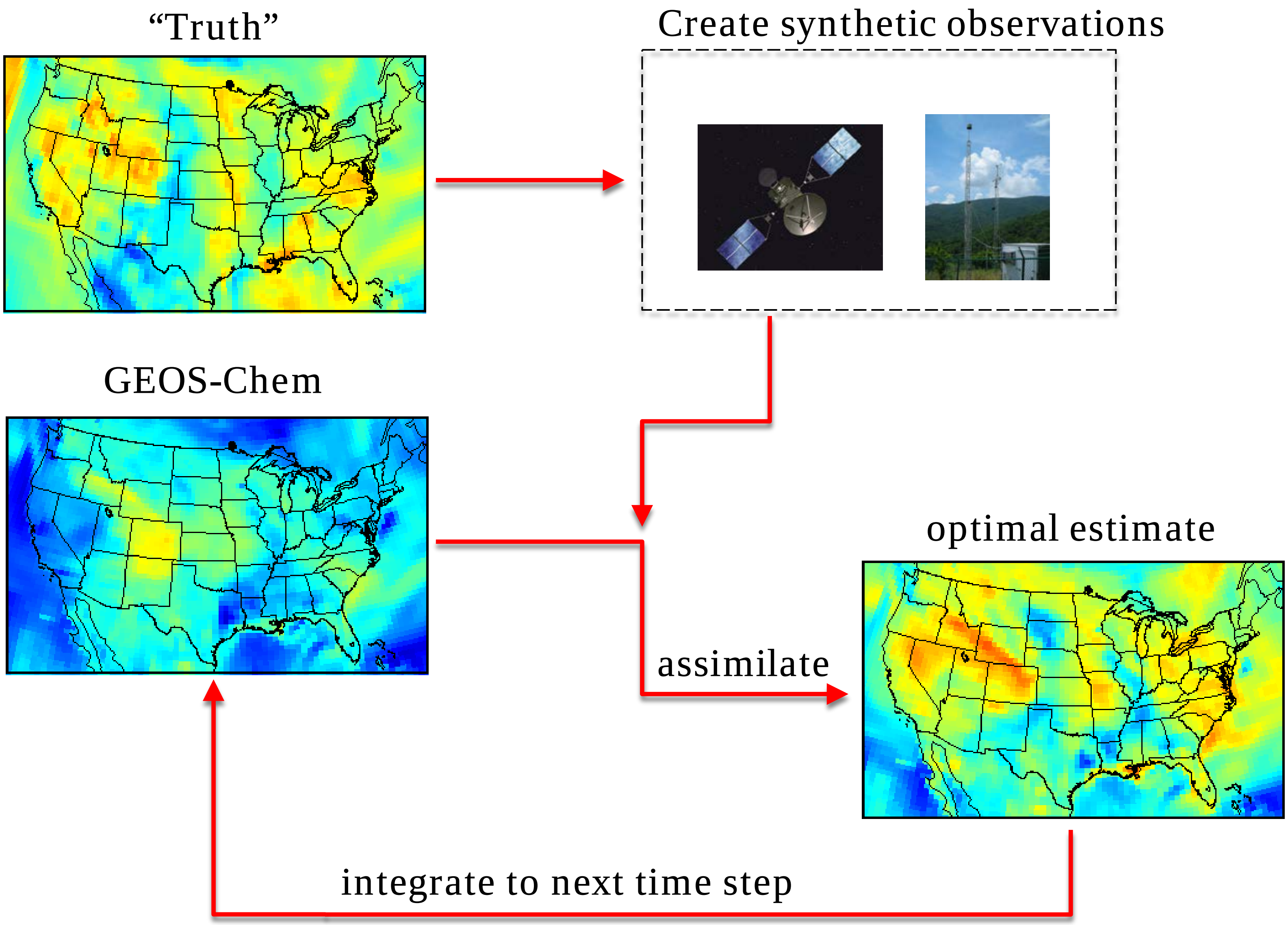
a posteriori = GEOS-Chem + assimilation of synthetic observations

→ attempt to reproduce "true" atmosphere

Science Questions

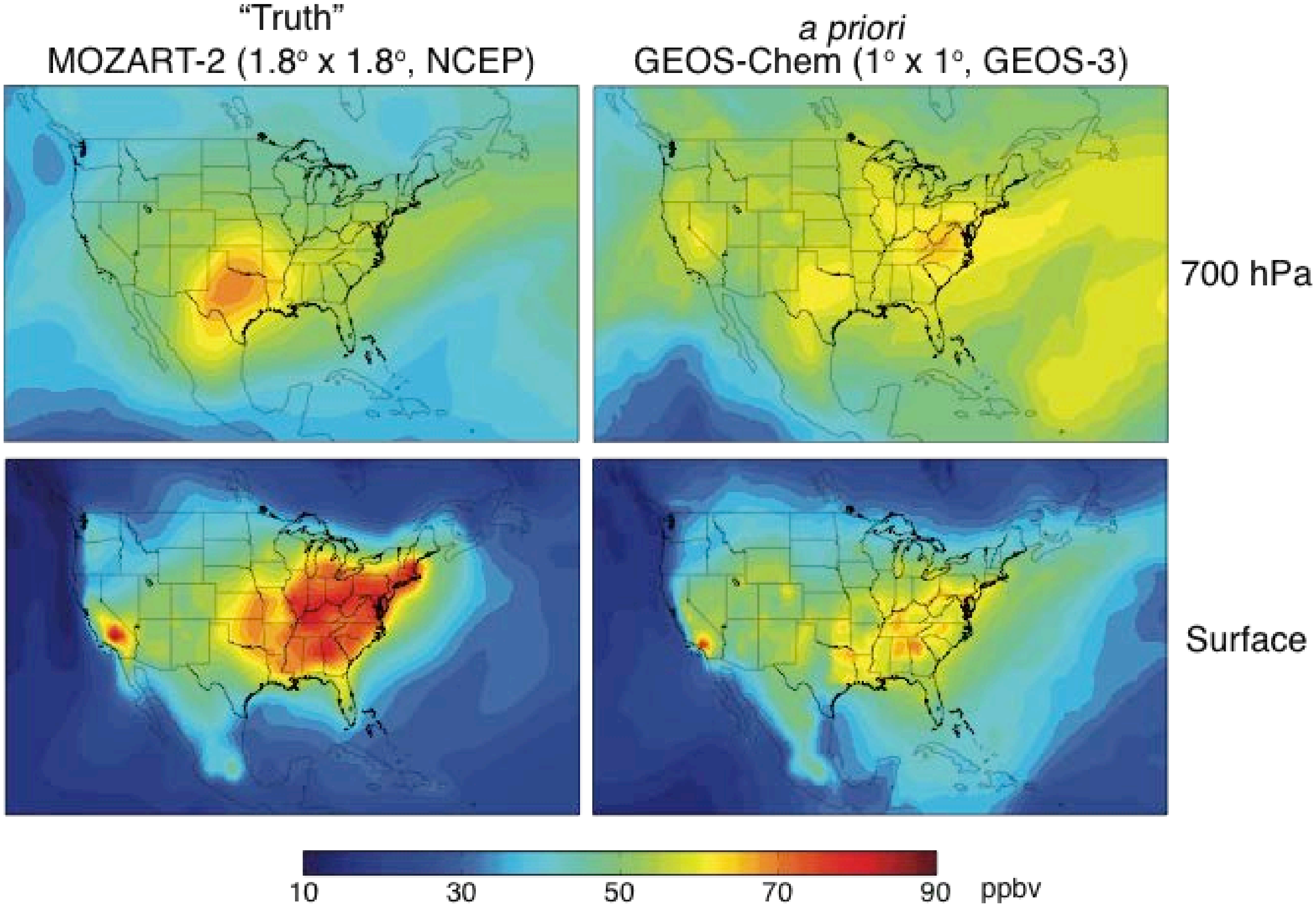
- What are the measurement requirements for geostationary observations to constrain ozone in the boundary layer?
- How can we use TEMPO observations to monitor and attribute air quality exceedances?
- Can concurrent geostationary measurements of CO improve monitoring of surface ozone air quality through a joint assimilation?

Data Assimilation



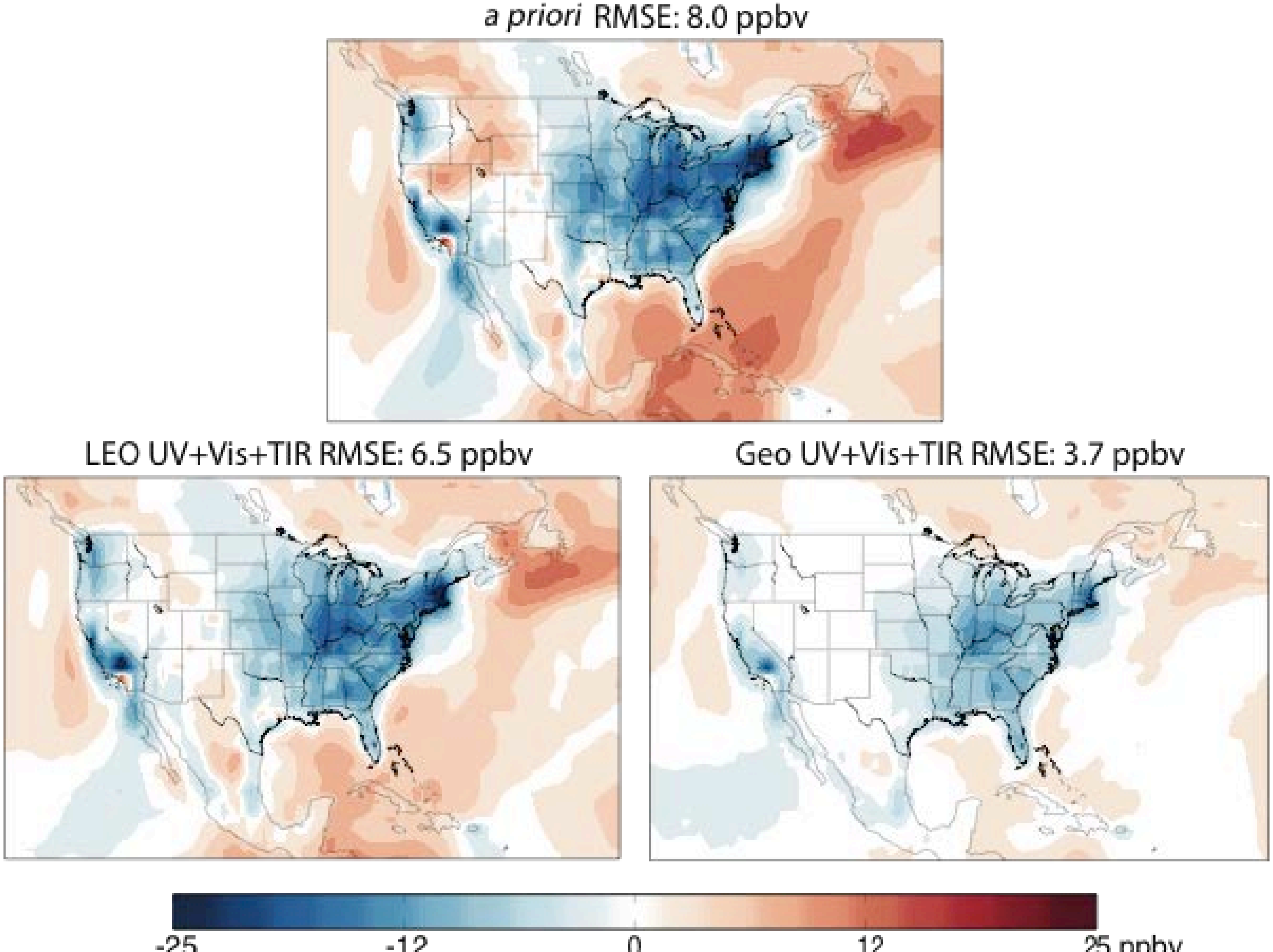
Simulation Models

- "Truth" and GEOS-Chem are completely different
  - Meteorology, Chemistry, Emissions



Air Quality Information from GEO

Error in Surface MDA8 Ozone averaged for July 2001

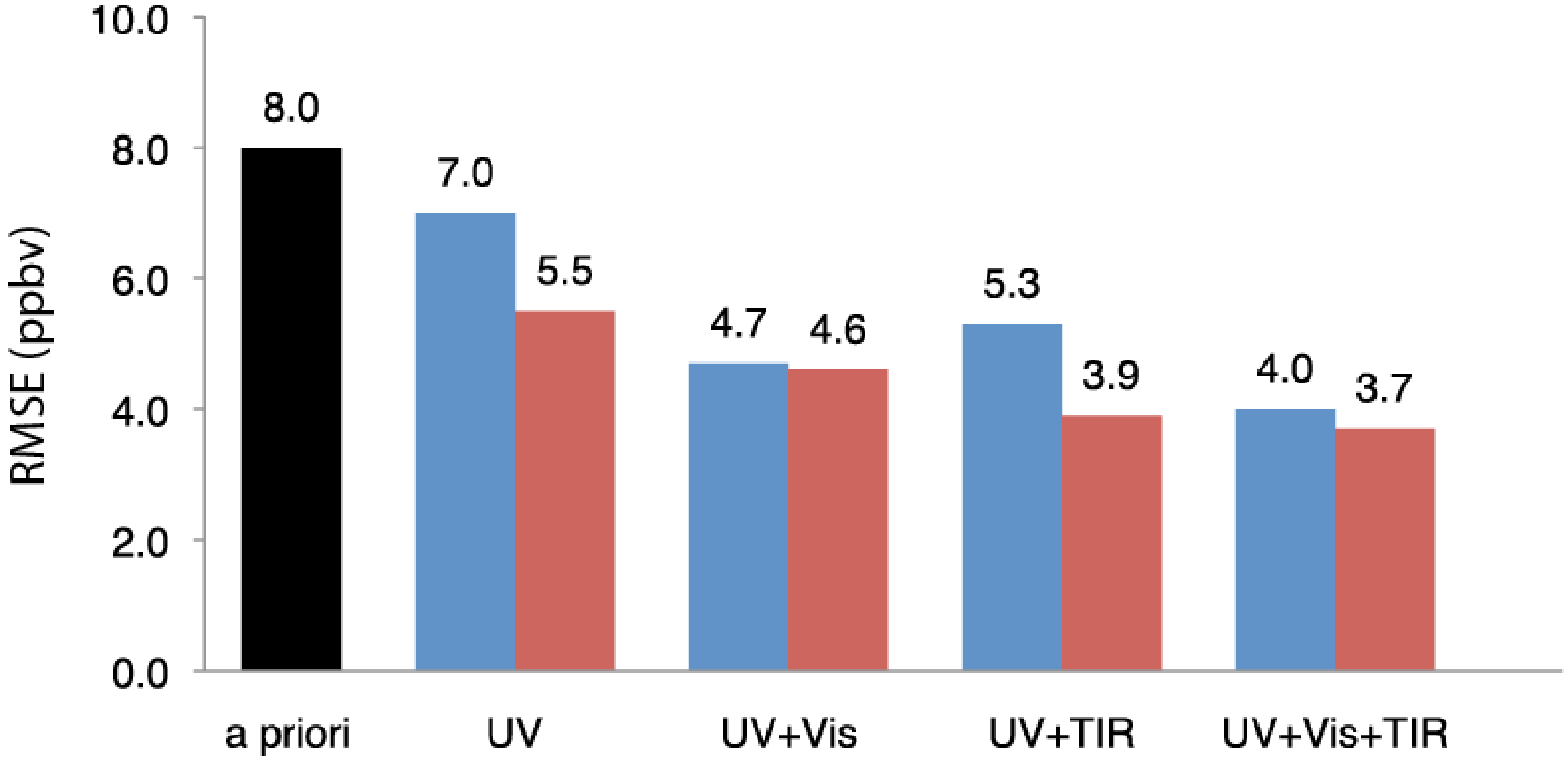


[Zoogman et al, 2011]

Need to combine observations in multiple spectral regions at high temporal resolution to constrain ozone air quality

Comparison of Spectral Combinations

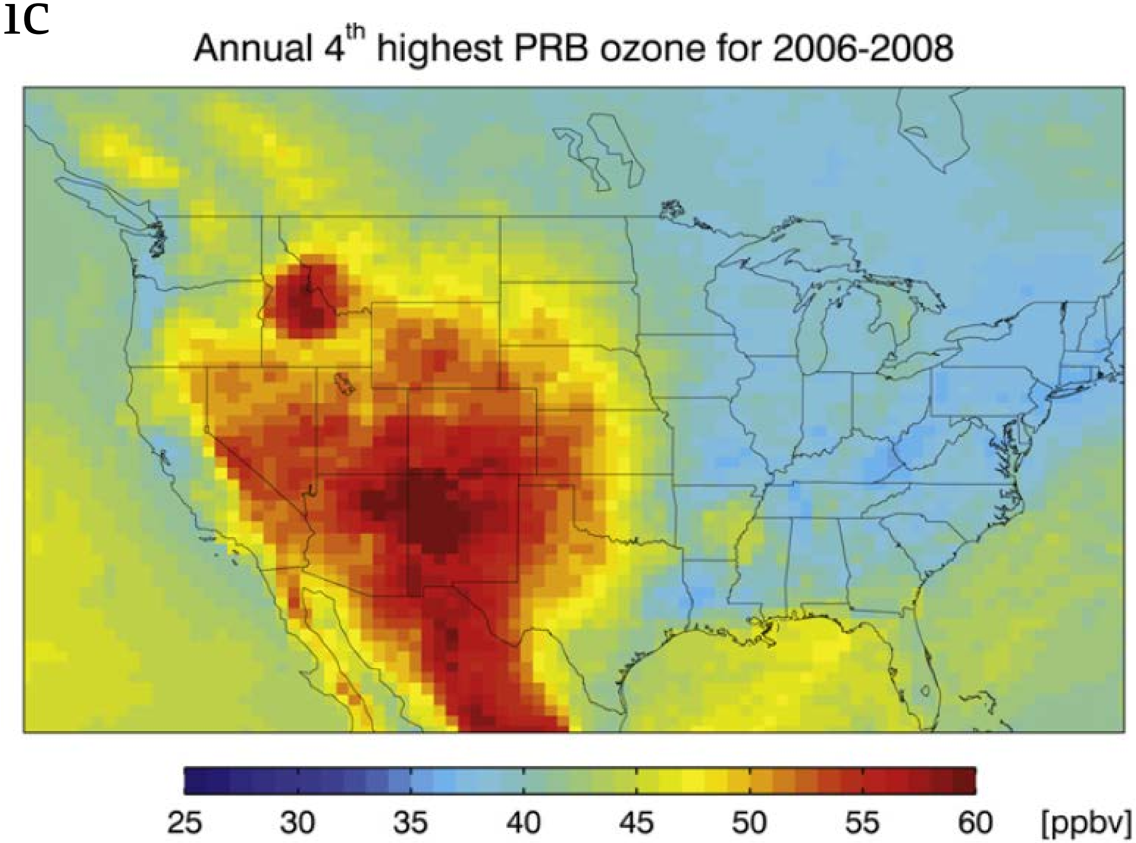
Error in ozone surface air concentration over the US after assimilation of observations in different spectral combinations



[Zoogman et al, 2011]

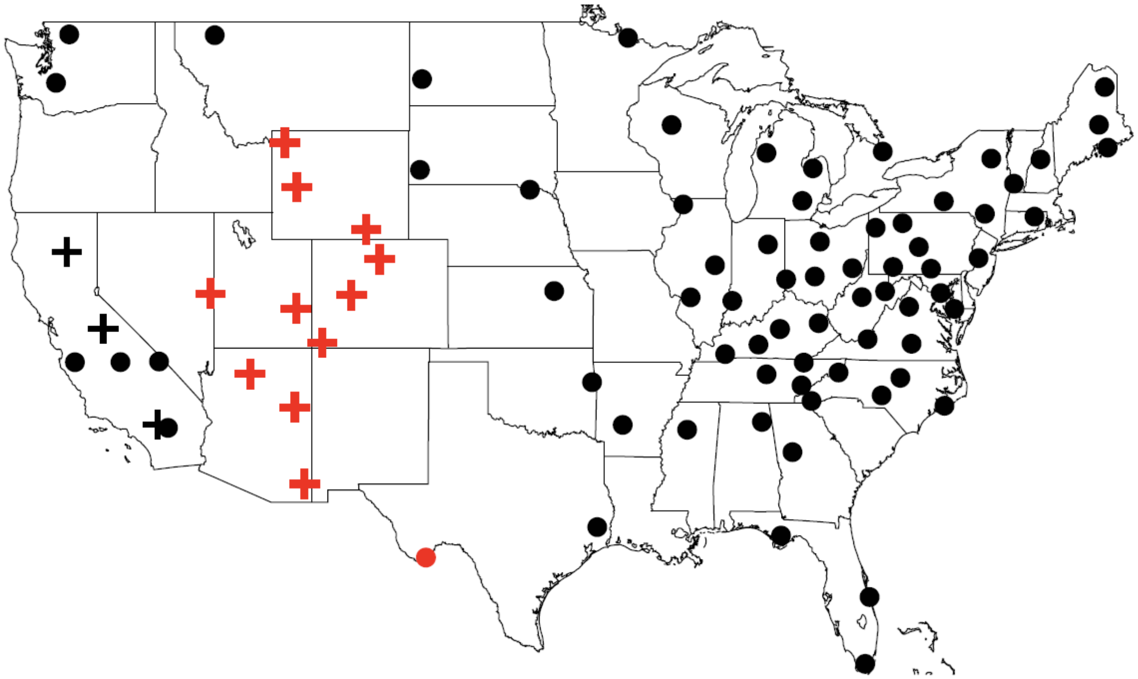
North American Background Ozone

- O_3 that would occur in the absence of anthropogenic emissions in the U.S., Canada, and Mexico.
- Sets limit on levels achievable through domestic controls
- Highest in the intermountain West



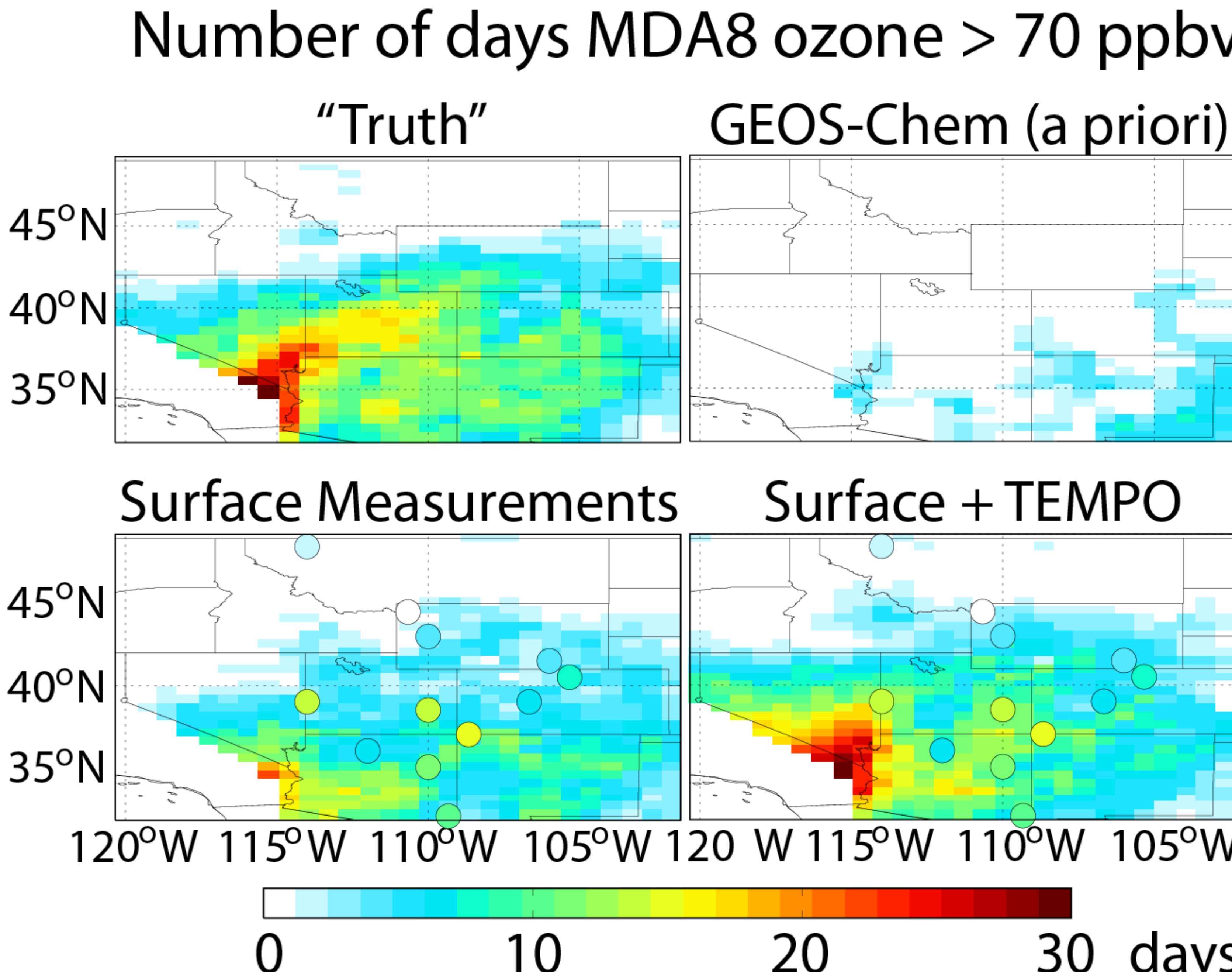
[Zhang et al. 2011]

Surface Measurements from CASTNET



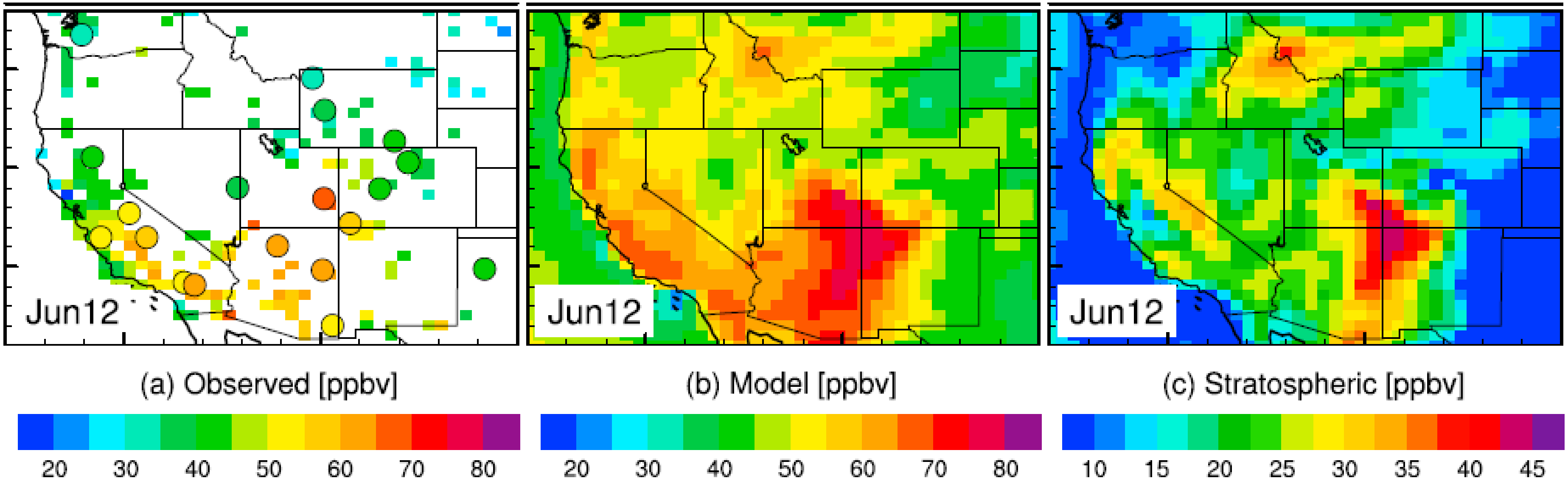
CASTNet ozone monitoring sites in the continental United States
Sites in the intermountain West in red.

- Surface measurements can provide information in their vicinity
  - Horizontal = 510 km, Vertical = 1.7 km



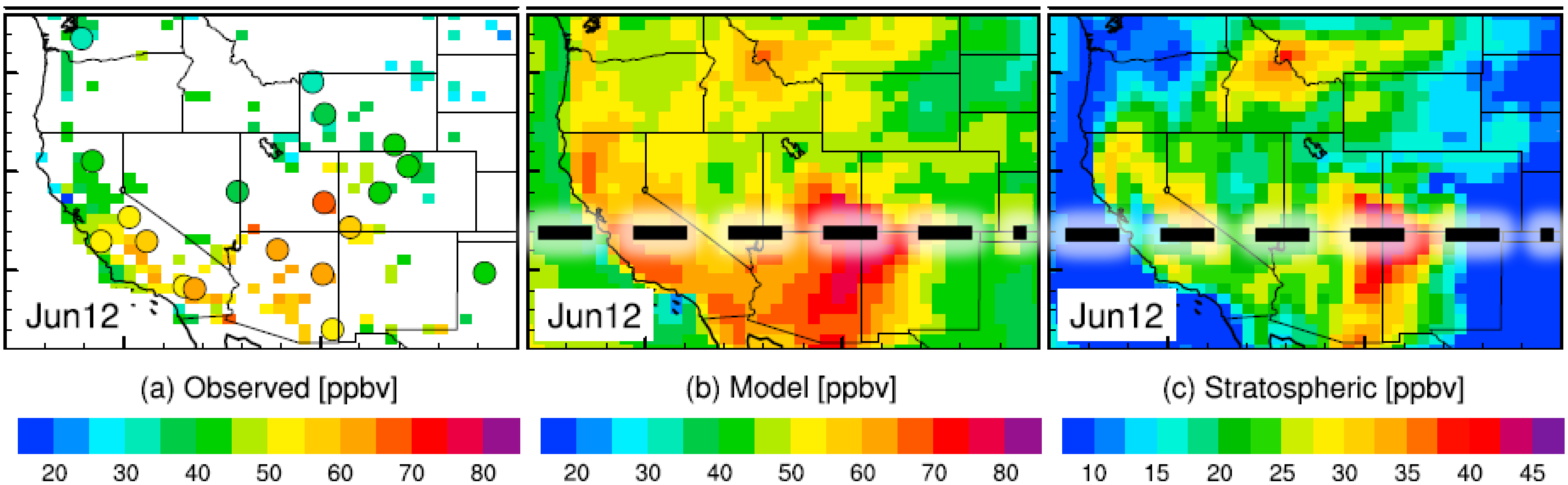
Number of days MDA8 ozone > 70 ppbv
"Truth"
GEOS-Chem (a priori)
Surface Measurements
Surface + TEMPO
45°N
40°N
35°N
120°W 115°W 110°W 105°W
0 10 20 30 days

Seeing a Stratospheric Intrusion



[Lin et al. 2012]

Seeing a Stratospheric Intrusion



[Lin et al. 2012]

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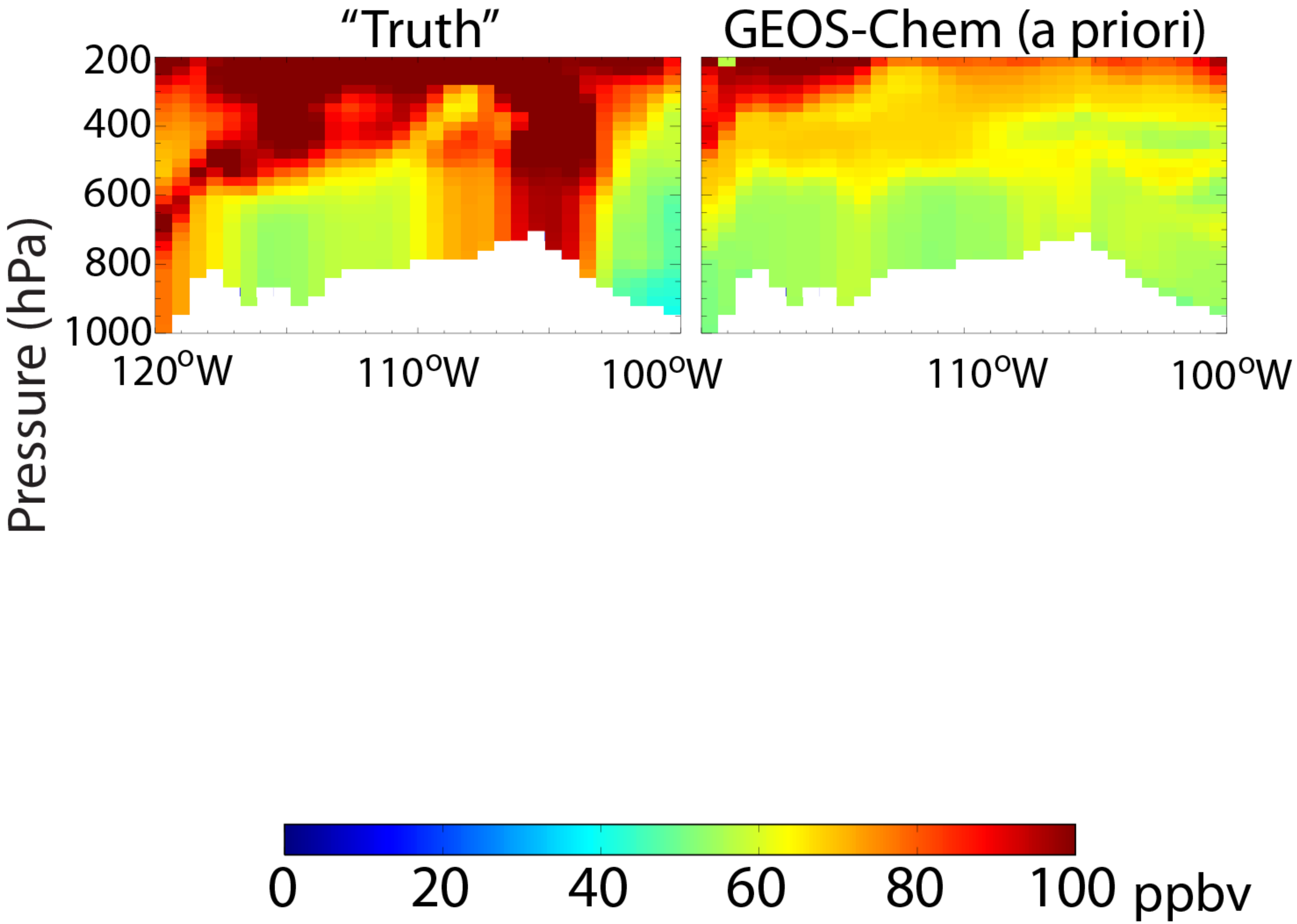

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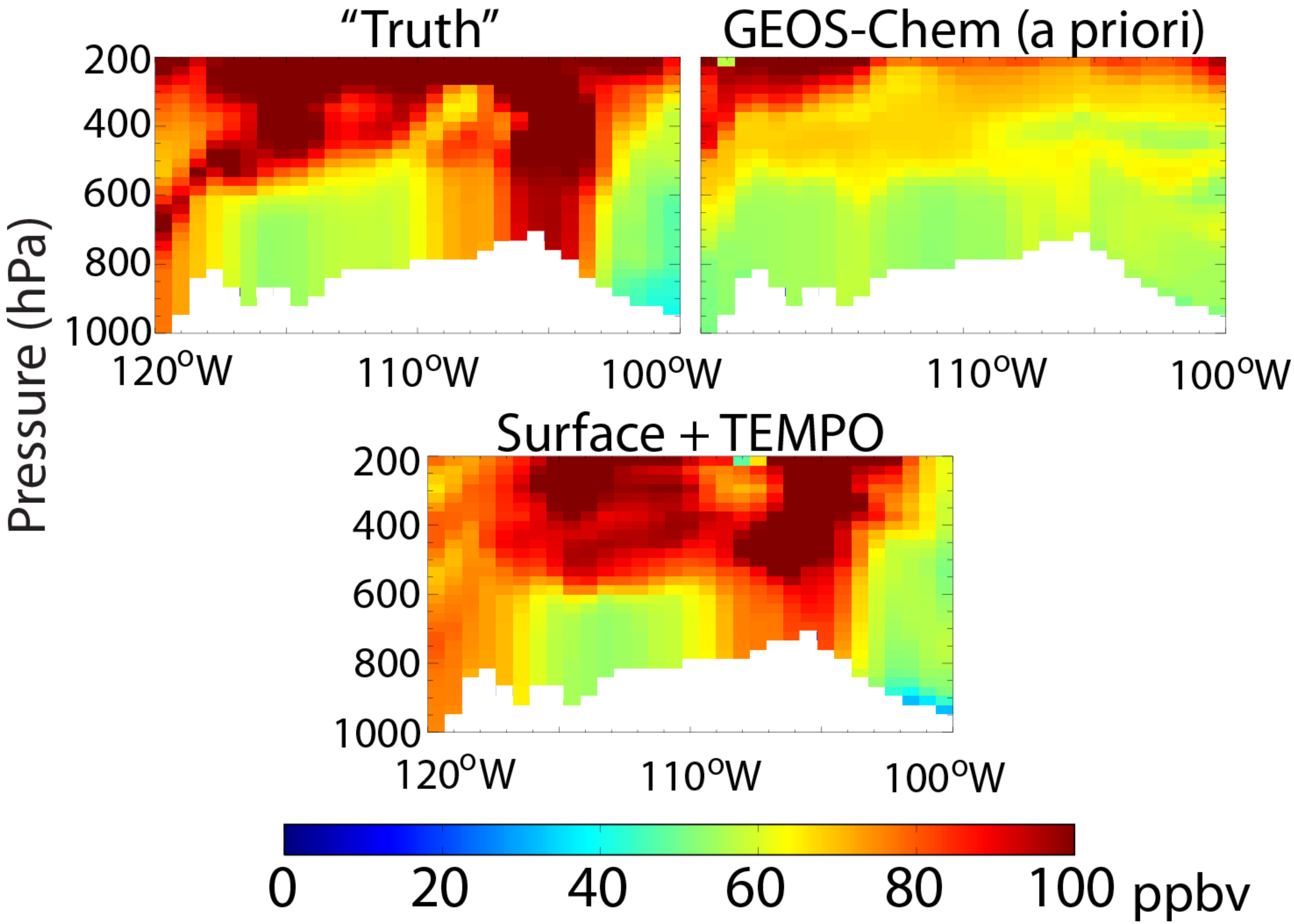
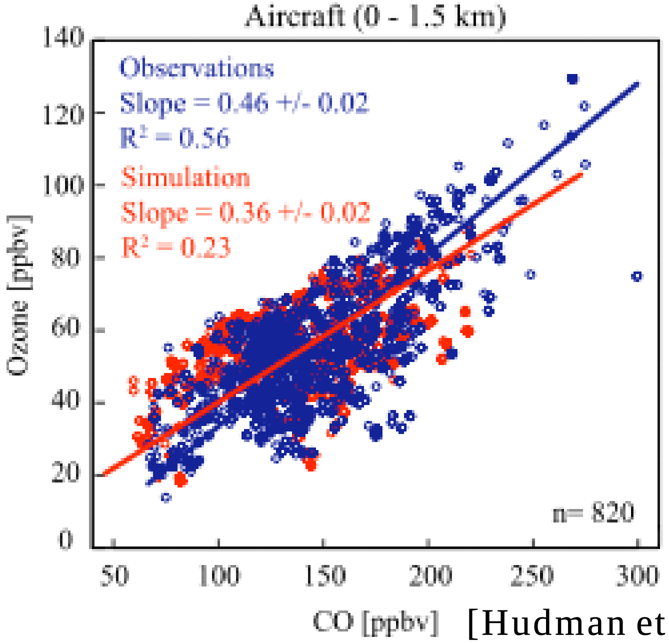


Usefulness of CO Observations

- O_3:CO correlations are well known

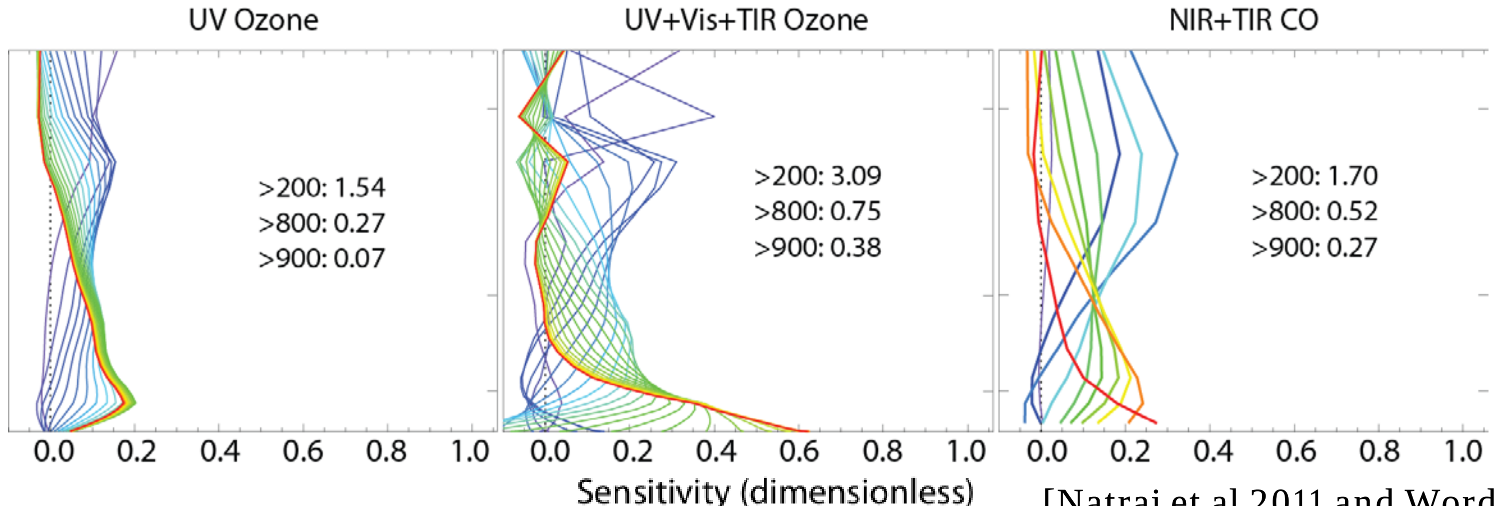
- GCIRI boundary layer sensitivity may be greater for CO than TEMPO ozone



[Hudman et al, 2009]

Theoretical Ozone sensitivities

CO sensitivity, MOPITT



[Natraj et al 2011 and Worden et al 2010]

The Case for Error Correlations

- Model errors correlated => CO observations could add information for ozone air quality by constraining model transport error

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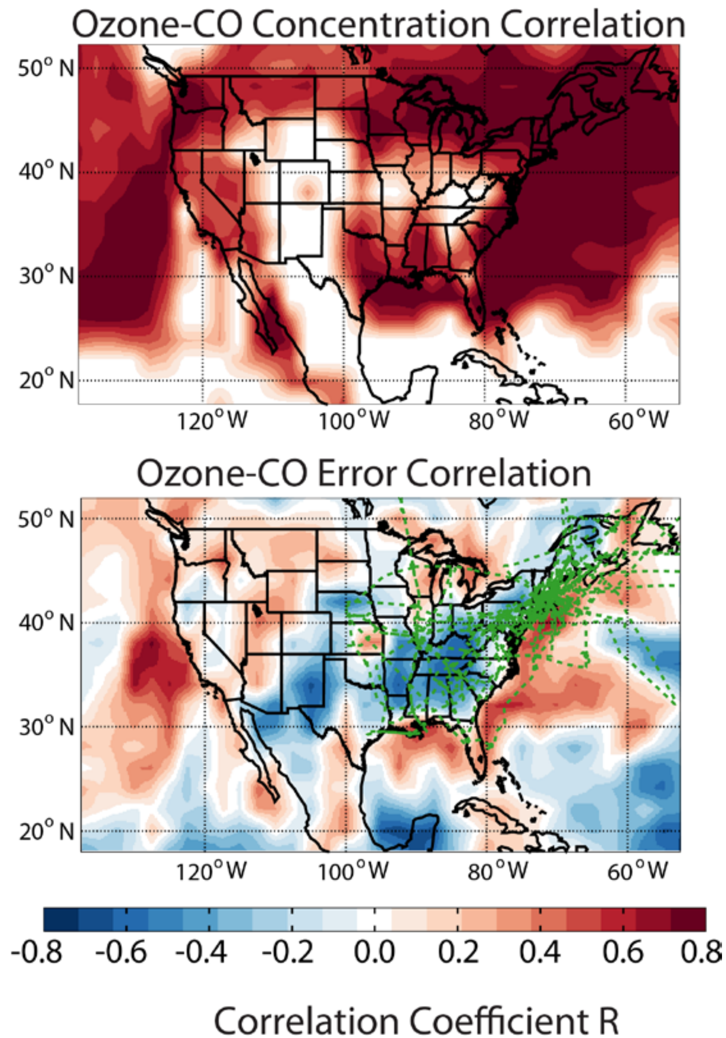
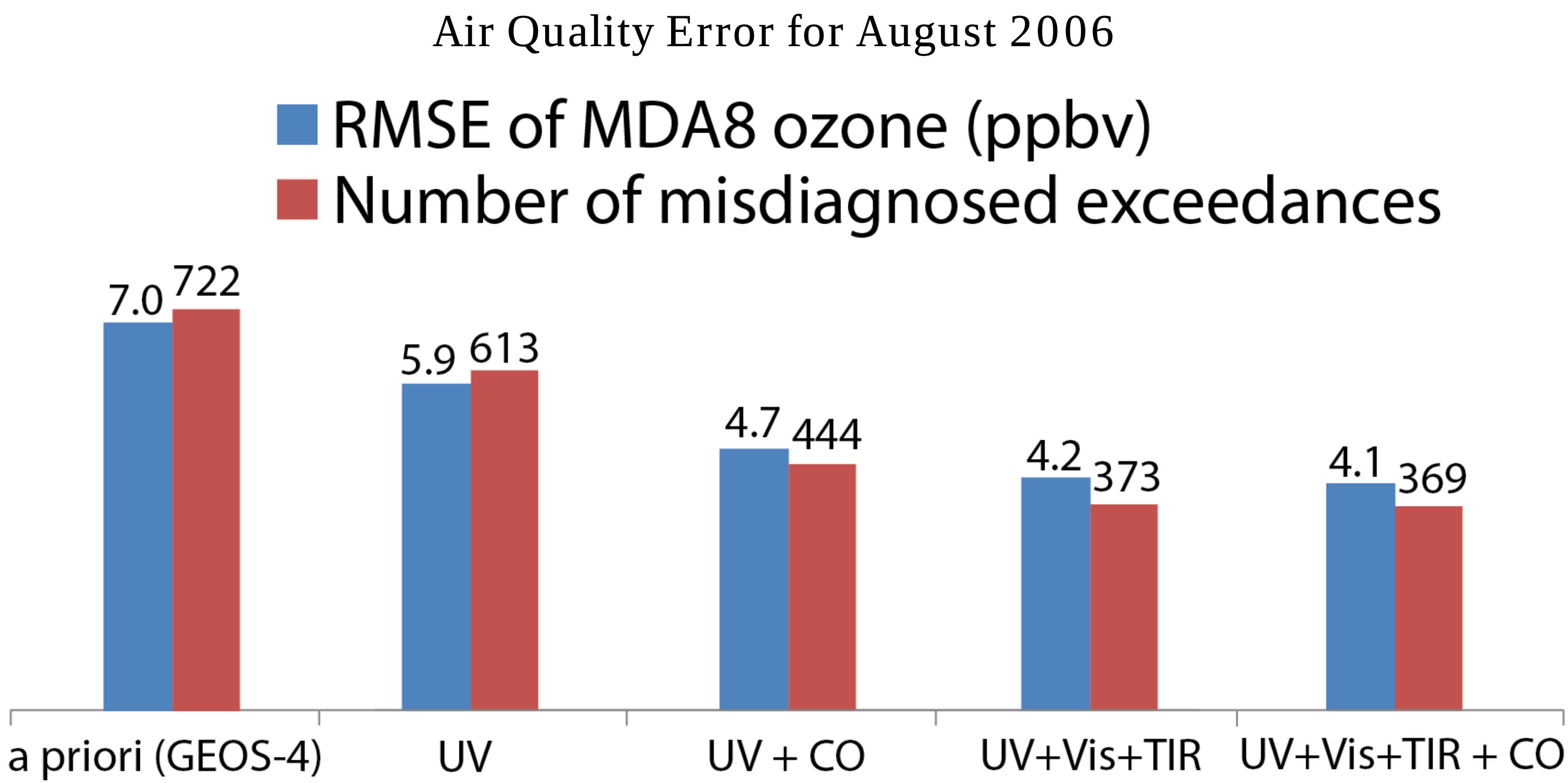


- But! model **error** correlations can differ greatly from **concentration** correlations!

Air Quality Information from Error Correlations



Error Correlations provide additional information for surface ozone (spatial pattern consistent with regions of strong error correlation)

Conclusions

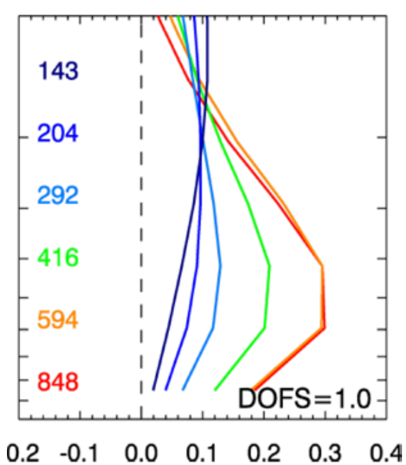
- OSSEs have been used to make the case for GEO UV+Vis design
- TEMPO will provide the capacity to monitor NAAQS exceedances
- High temporal and vertical resolution will allow viewing/attribution of exceptional events
- CO observations from GCIRI could improve on TEMPO near surface ozone

Multispectral Satellite Observations of Ozone

Averaging Kernel matrix **A** quantifies the vertical information provided by a satellite retrieval

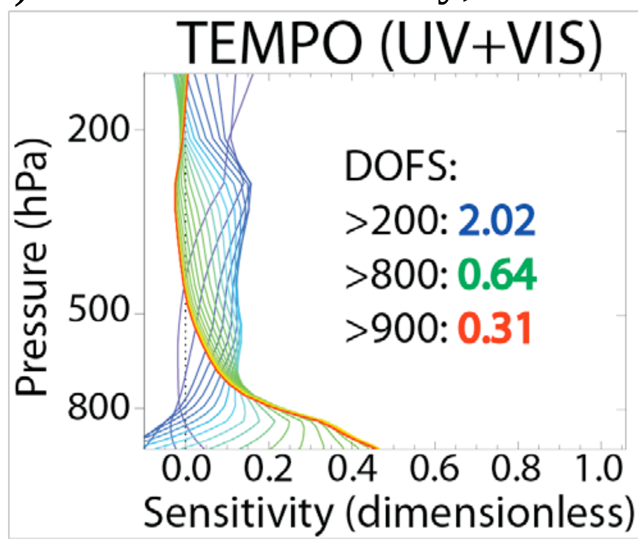
$$\mathbf{x}' = \mathbf{x_a} + \mathbf{A}(\mathbf{x} - \mathbf{x_a}) + \varepsilon \qquad \mathbf{A} = \frac{\partial \mathbf{x}'}{\partial \mathbf{x}}$$

Current ozone sensitivity, OMI (UV)



[Zhang et al. 2010]

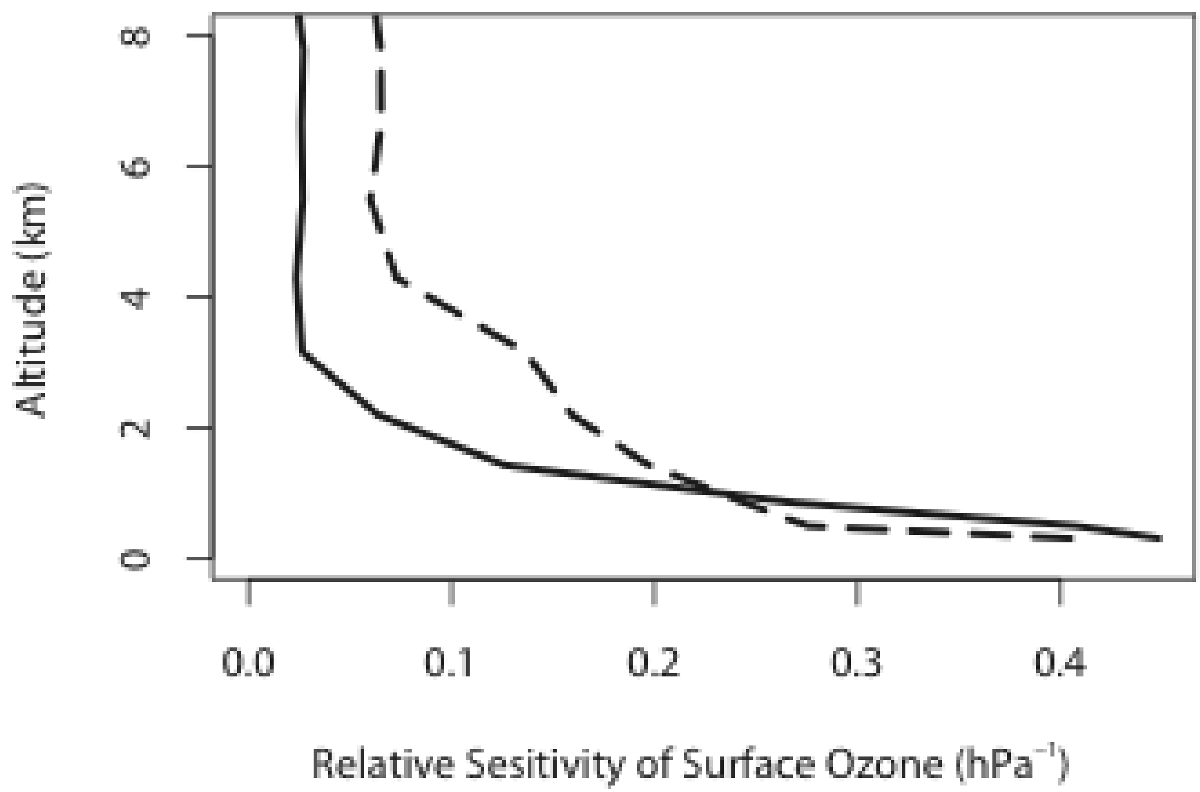
Ozone sensitivity, future



[Natraj et al, 2011]

Surface Ozone Sensitivity

- Adjoint model – receptor based rather than source based approach
- Sensitivity of surface ozone to ozone produced at each vertical layer

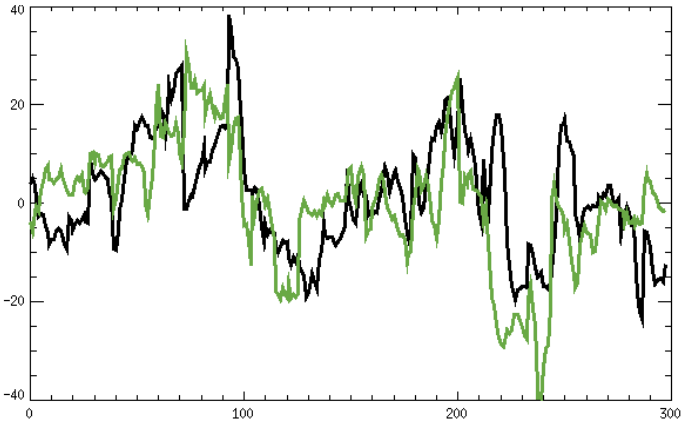


Surface ozone primarily sensitive to production below 2 km

[Zoogman et al, 2011]

Surface Measurements from CASTNET

- Distance/Magnitude of correction is quantified by the ozone error correlation



R=0.50, D=340 km

- Find correlation of model error at each pair of CASTNet sites

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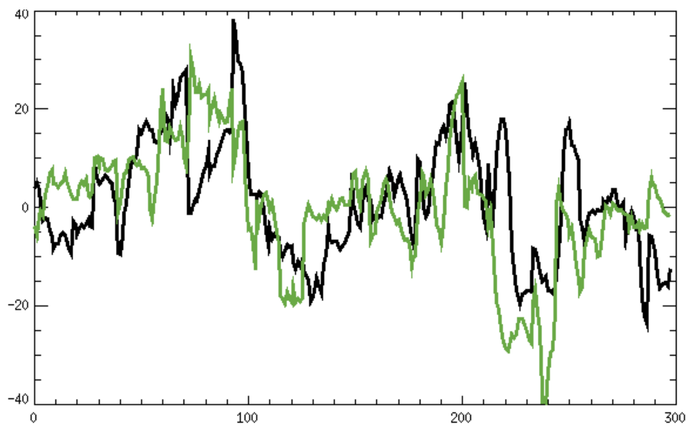

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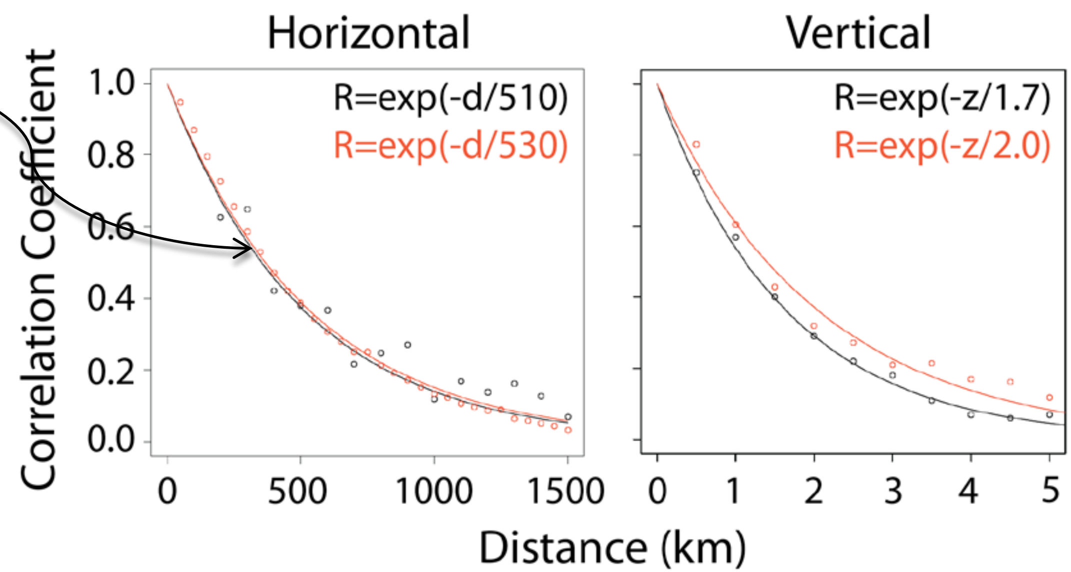

- Plot R vs. distance to find error correlation length scale

The Case for Error Correlations

- Negative model error correlations reproduced when comparing to aircraft observations