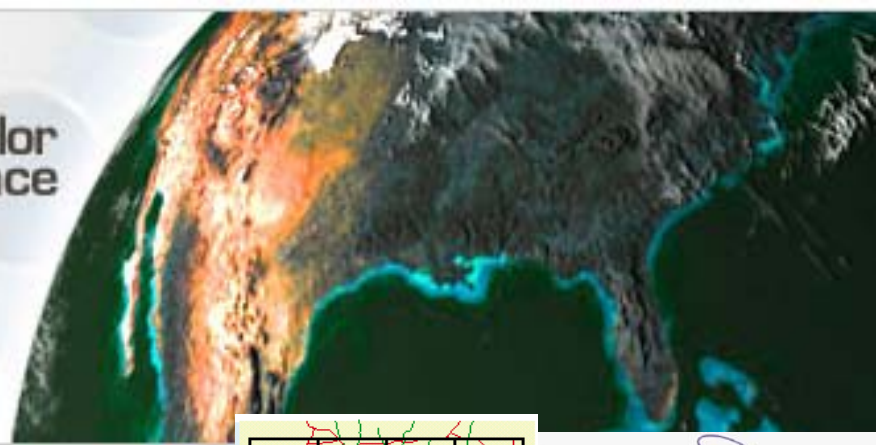
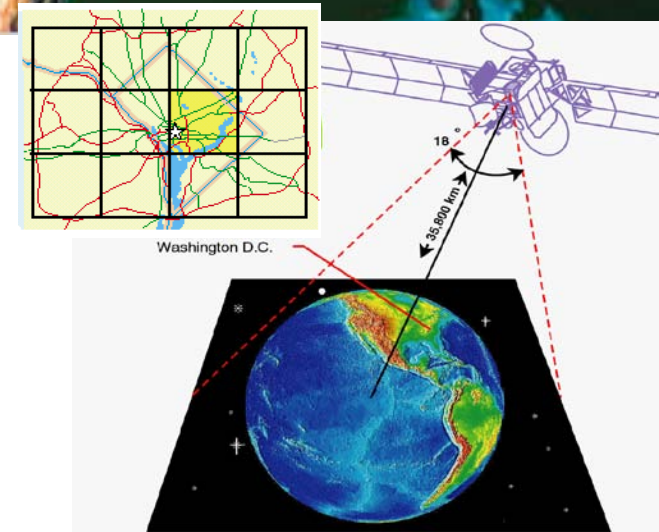


Air quality &
Ocean color
from space

GEO-CAPE



GEO-CAPE Science Goals and Requirements - Atmosphere



Daniel J. Jacob

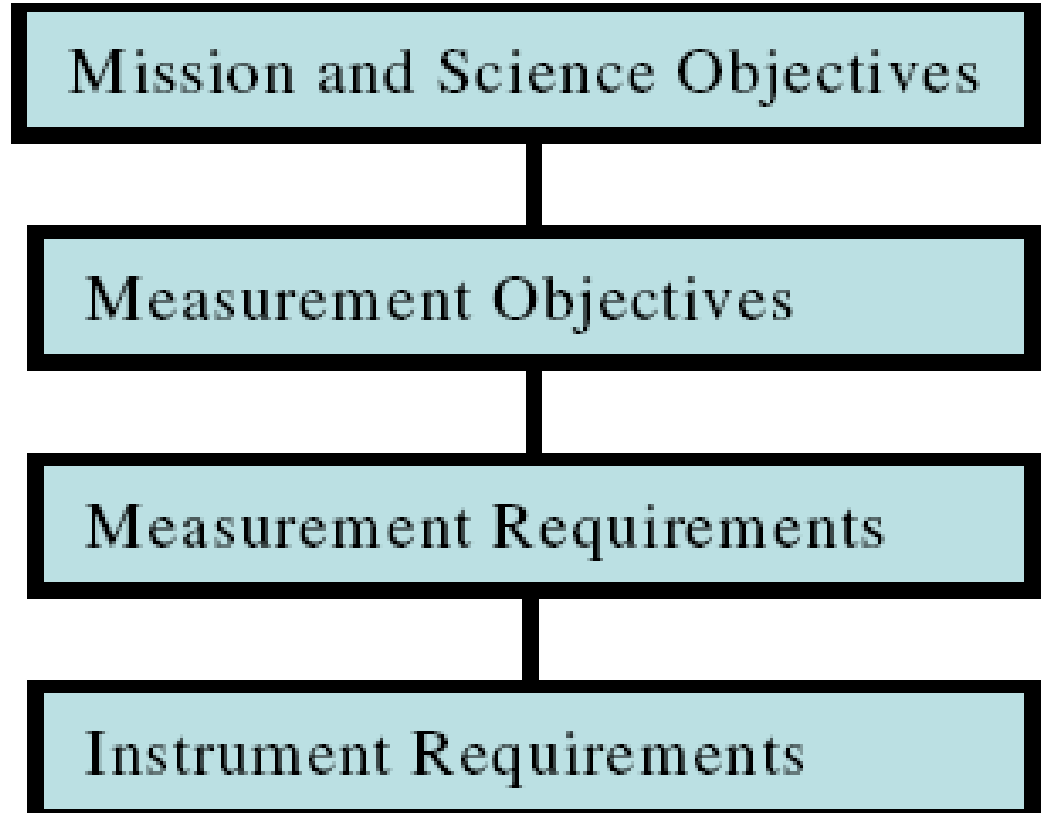
Co-Lead, GEO-CAPE Atmosphere Science Working Group

Building the Science Traceability Matrix for GEO-CAPE

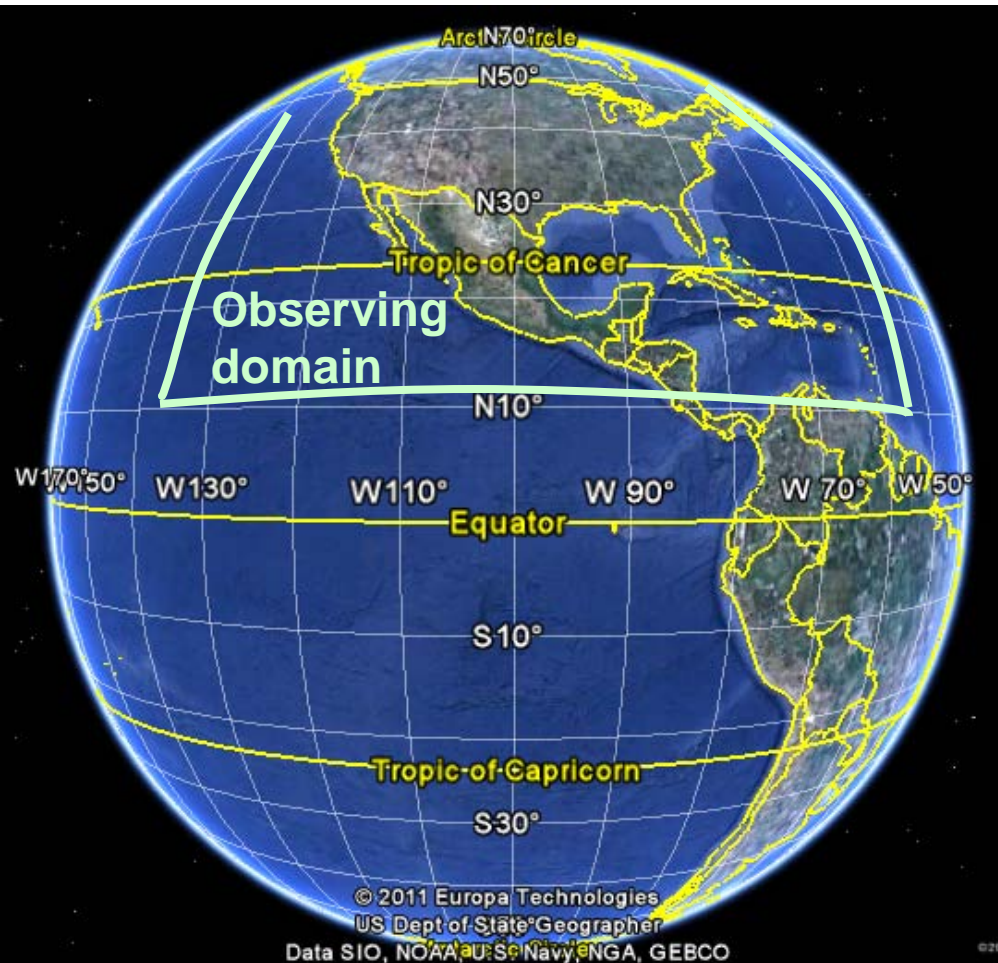
Flow from science objectives
to requirements



Trace requirements
to their objectives;
define “trade space”

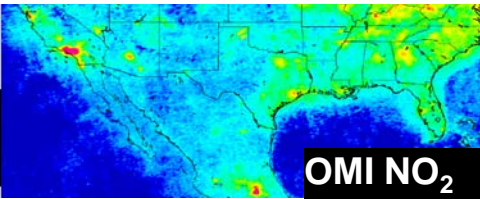


Atmospheric Mission Objective: To Observe, Understand, and Predict Air Quality and Climate Forcing in North America

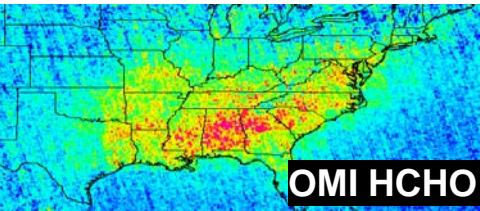


- Orbit centered at 100° W
- Observe North America and adjacent oceans with hourly repeat time
- Pixel resolution: 1x1 km² (aerosols), 4x4 km² (gases) at 40° N

Science Questions for GEO-CAPE - Atmosphere



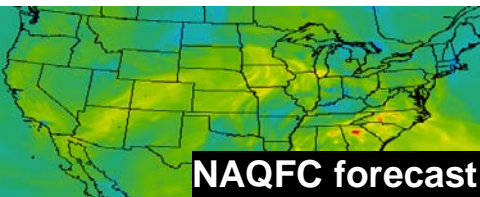
1. What are the temporal and spatial variations of emissions of gases and aerosols important for air quality and climate?



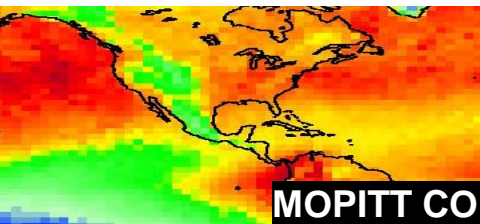
2. How do physical, chemical, and dynamical processes determine tropospheric composition and air quality over scales ranging from urban to continental, diurnal to seasonal?



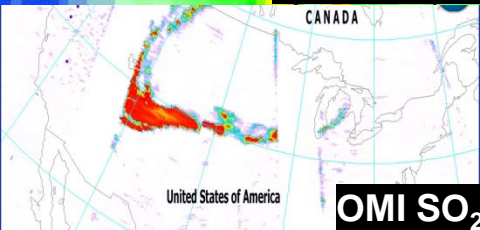
3. How does air pollution drive climate forcing and how does climate change affect air quality on a continental scale?



4. How do we improve air quality forecasts and assessments for societal benefit?



5. How does intercontinental transport affect air quality?



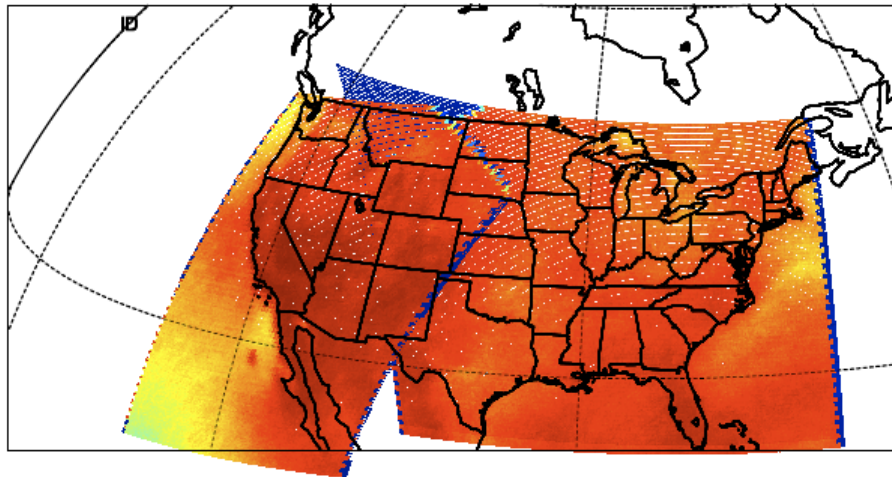
6. How do episodic events such as wild fires, dust outbreaks, and volcanic eruptions affect atmospheric composition and air quality?

Geostationary observation greatly improves probability of observing clear-sky scenes

Geostationary (hourly observation)

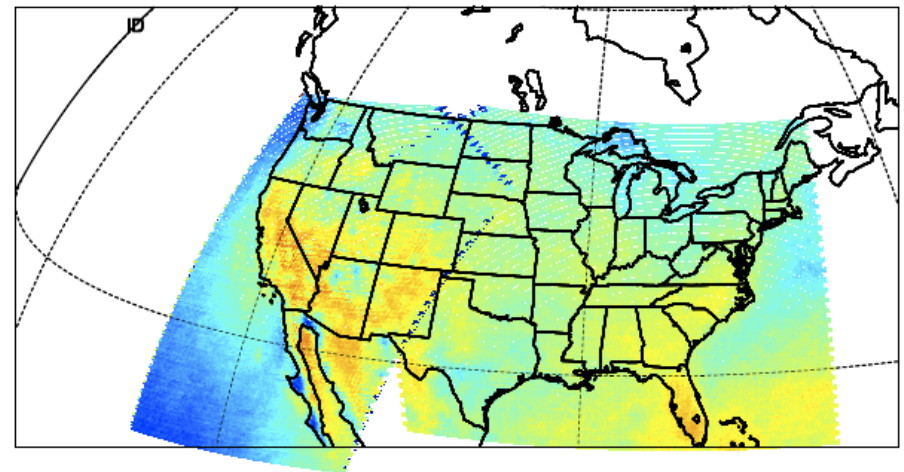
Low-elevation orbit (daily observation)

[Probability of at least 1 clear pixel per day]
0.0 1.0



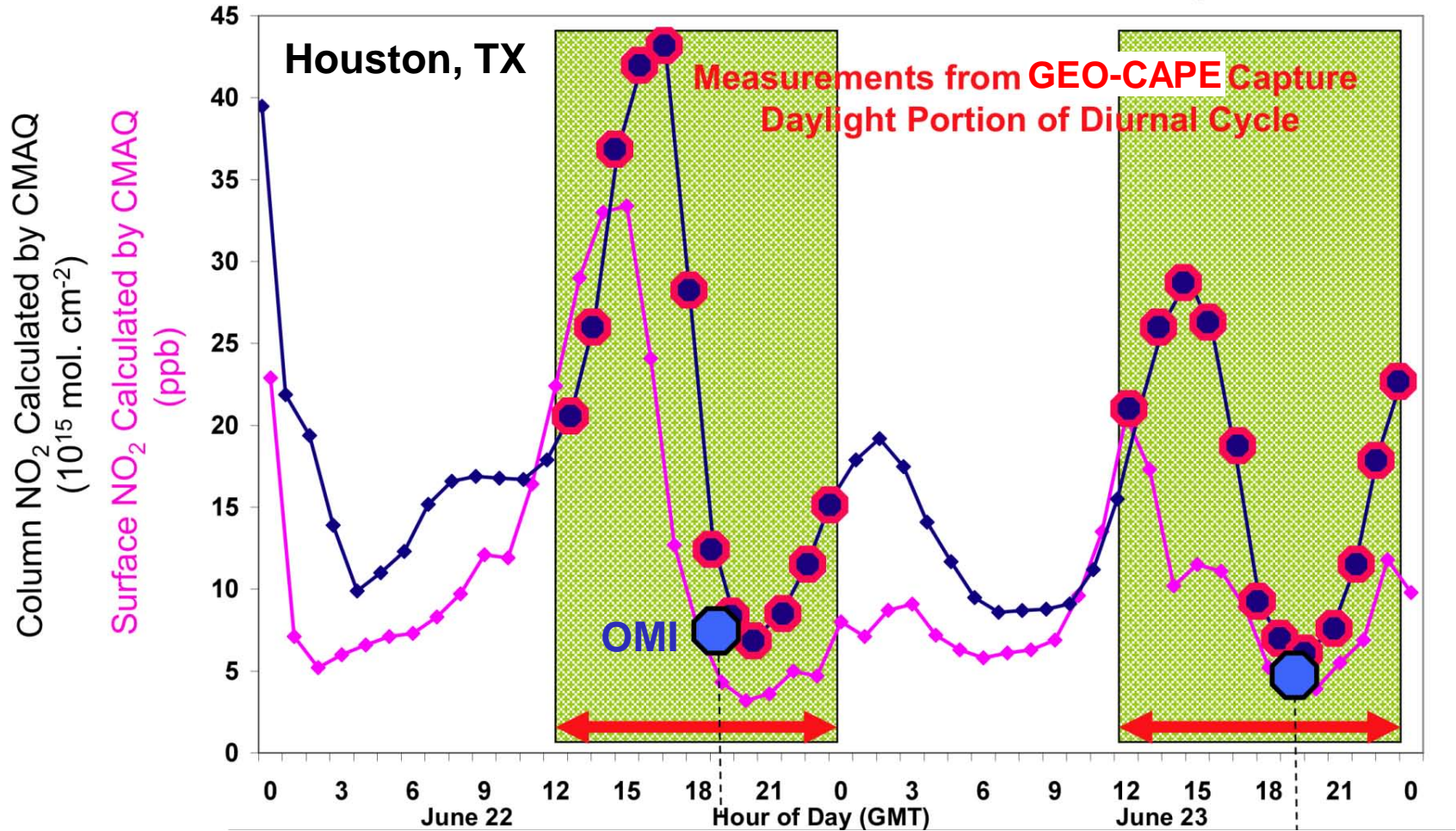
Noon capture only
[Prob. of Clear Pixels]

0.0 1.0



Geostationary view captures diurnal cycle of emissions and chemistry

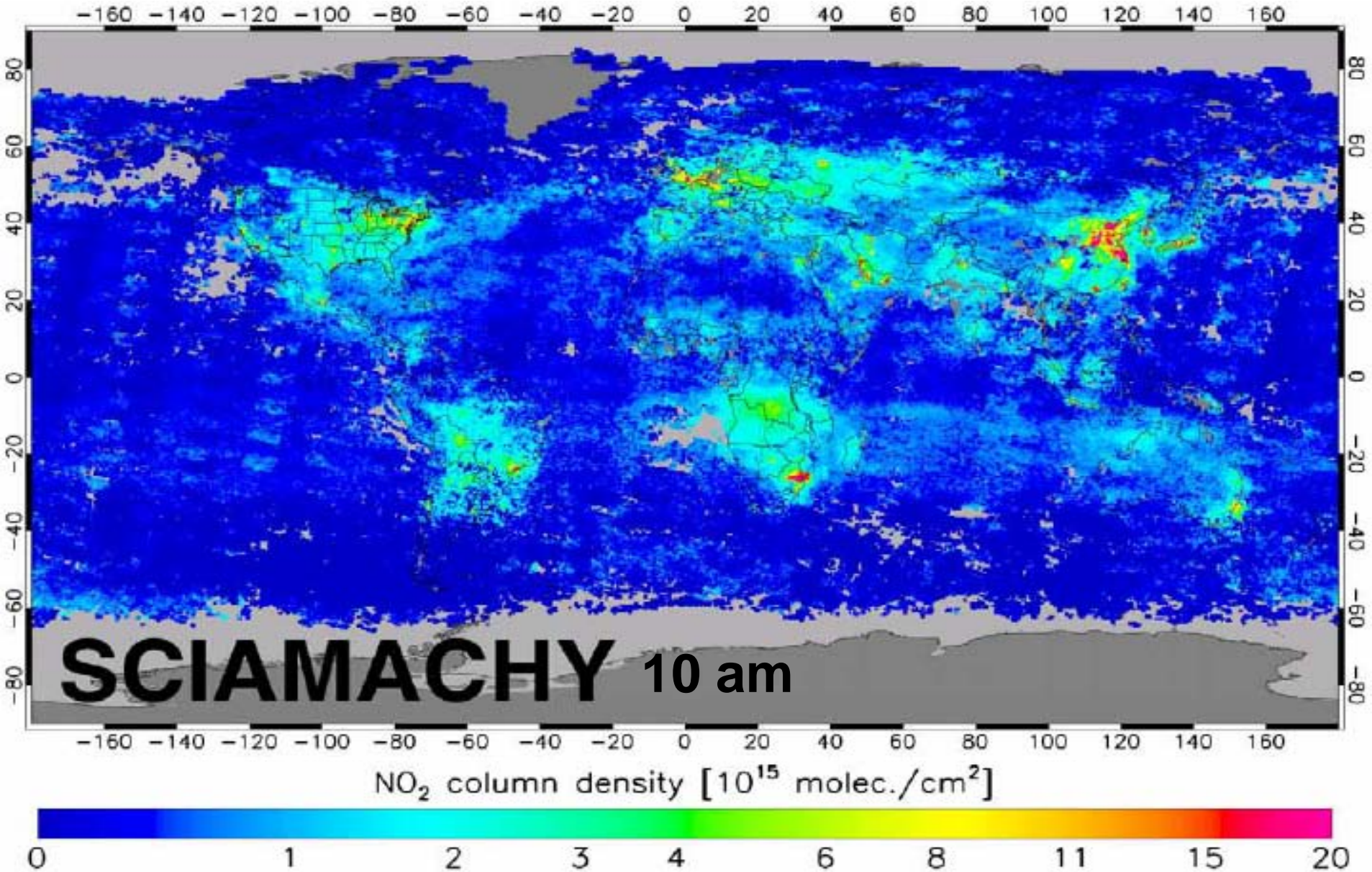
Surface Concentrations and Integrated NO_2 Column Calculated by CMAQ Plotted as a Function of Hour: June 22-23, 2005



Low-elevation-orbit observations offer no such information

DIURNAL VARIATION OF NO_x SEEN FROM SPACE

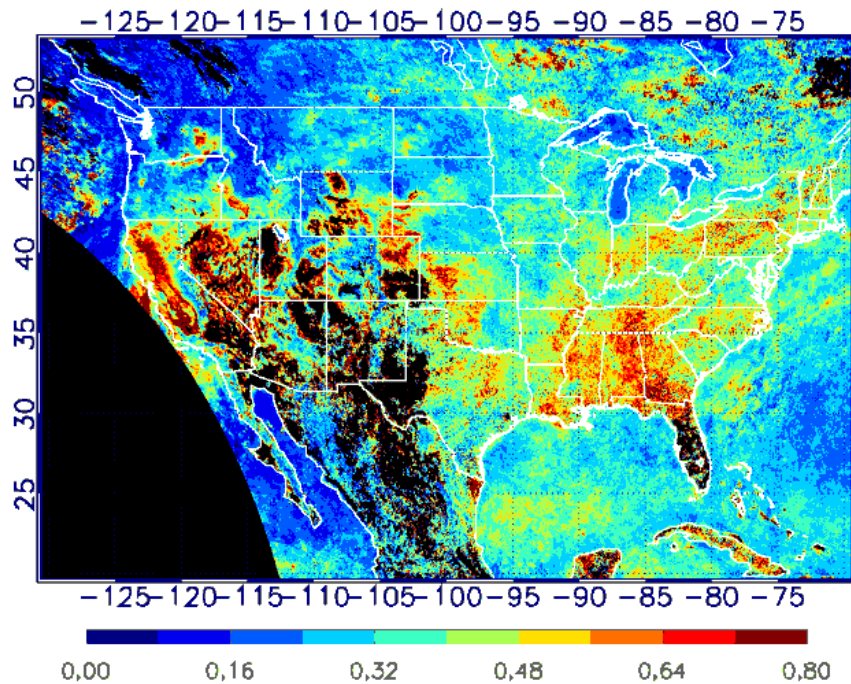
from the OMI and SCIAMACHY satellite instruments (Aug 2006)



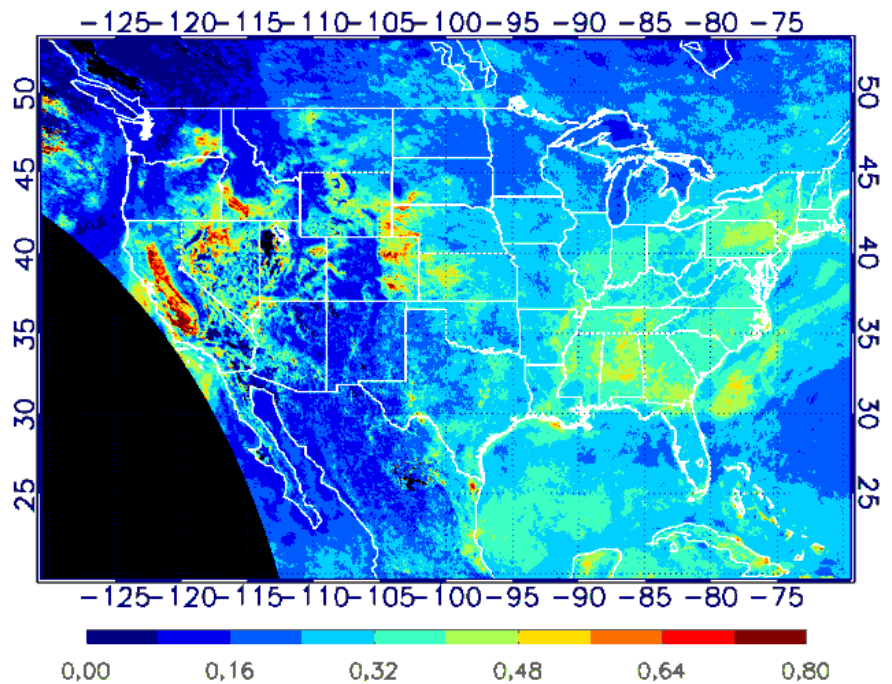
Geostationary measurements decrease diurnal bias in satellite aerosol optical depth (AOD) data

Monthly mean AOD observations, July 2008

from MODIS at 10:30 and 13:30 local
(Terra and Aqua satellites)

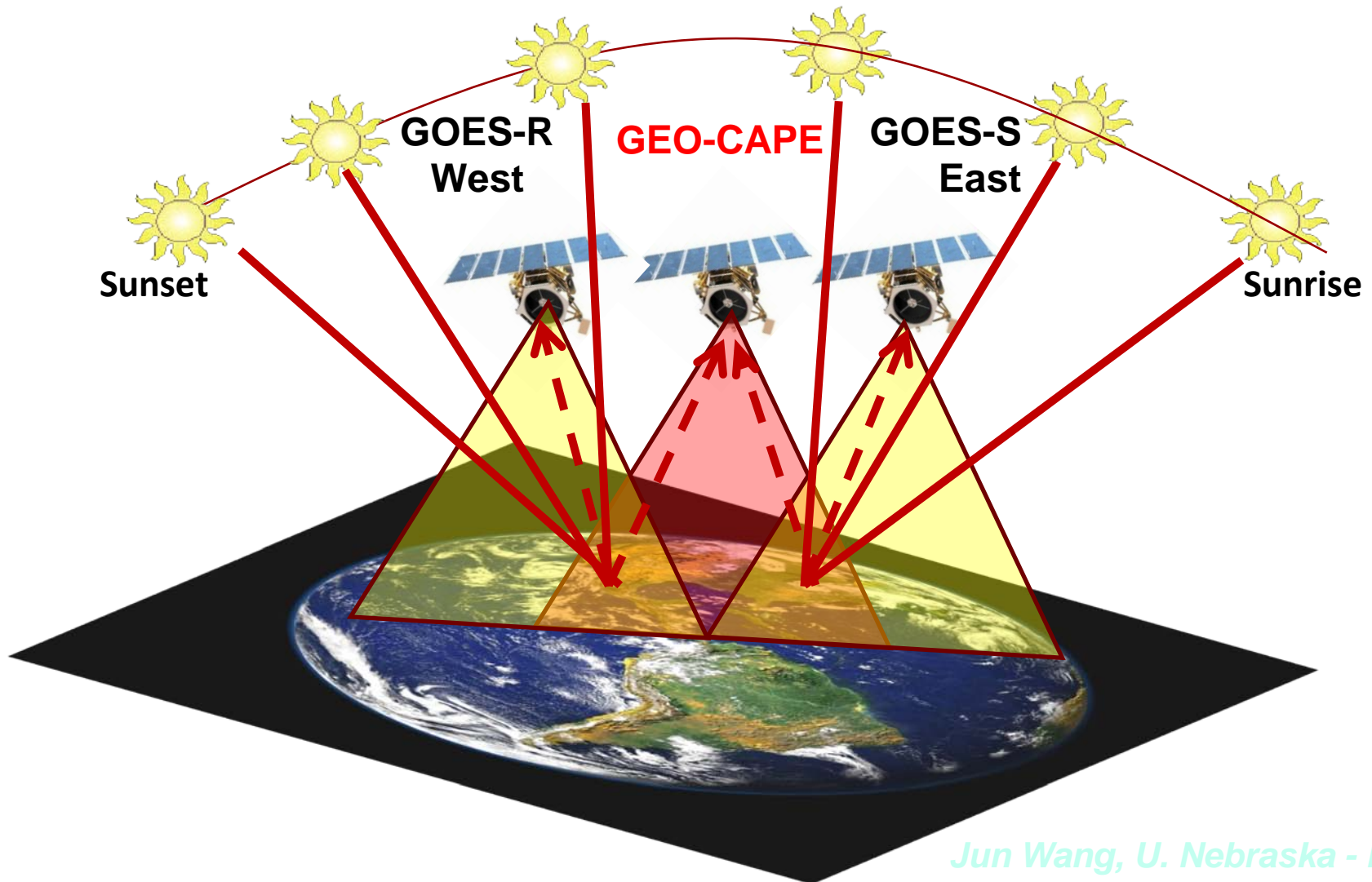


from GOES every 30 min in daytime



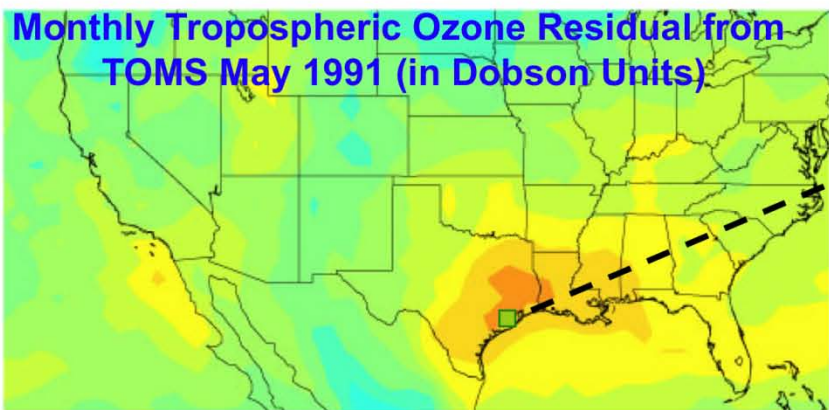
GEO-CAPE and GOES-R/S synergy

Joint retrieval of geostationary observations collected from multiple scattering angles can better characterize aerosol altitude, size distribution, and composition



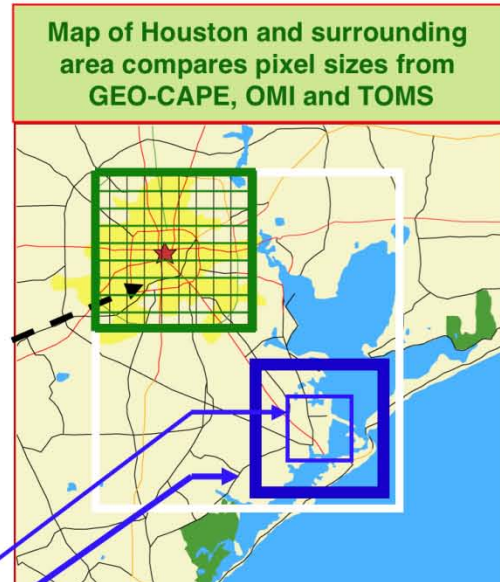
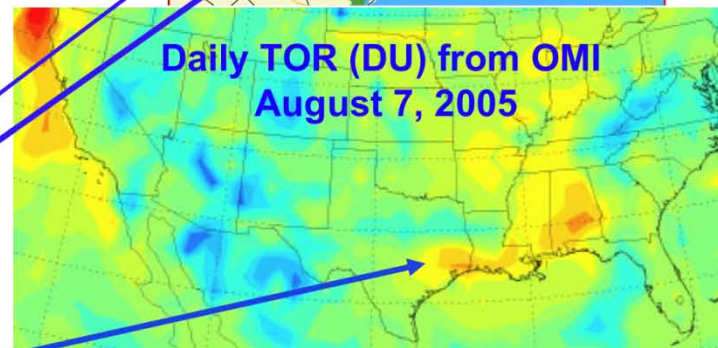
GEO-CAPE resolution of 4-8 km for gases will allow resolution of urban scales

Observation of tropospheric ozone in UV/Vis:
heritage **TOMS** → **OMI** → **GEO-CAPE**



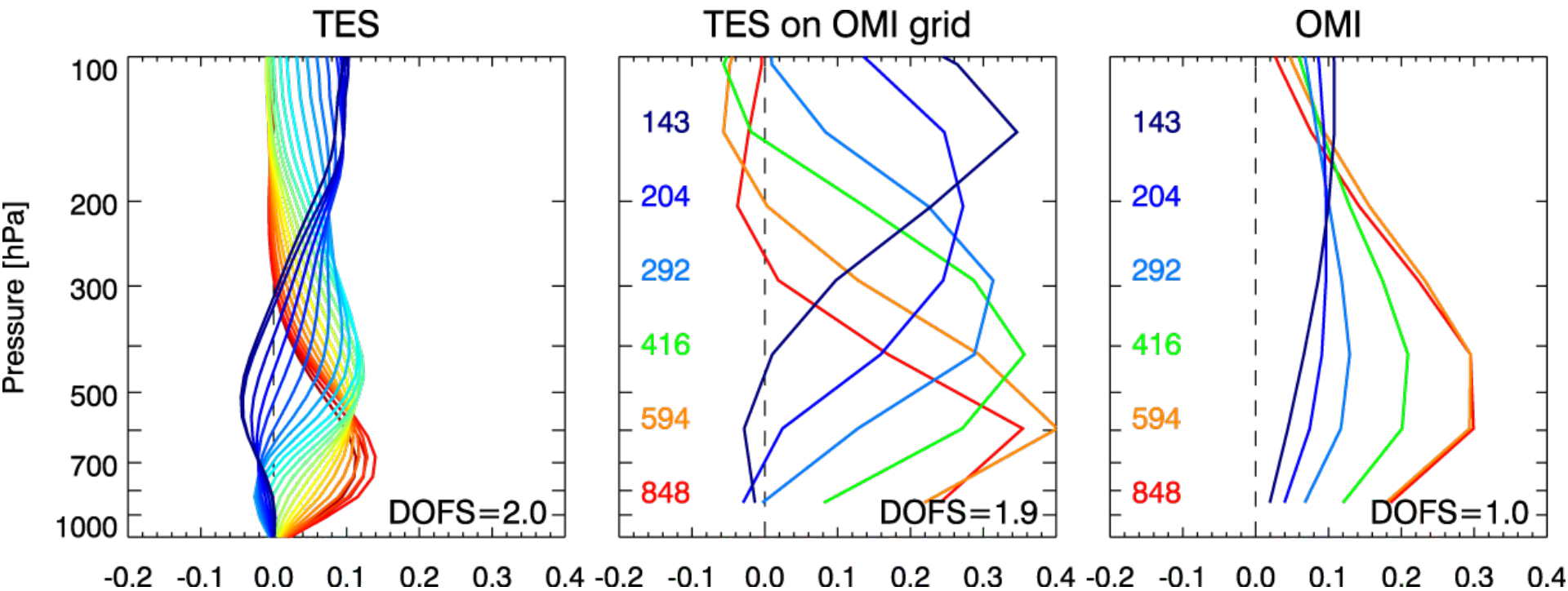
TOMS (Daily) ~100-km res.
(used for monthly climatologies)

OMI (25-50 km res.)
(daily maps)



Typical averaging kernels for ozone retrievals from TES and OMI on Aura

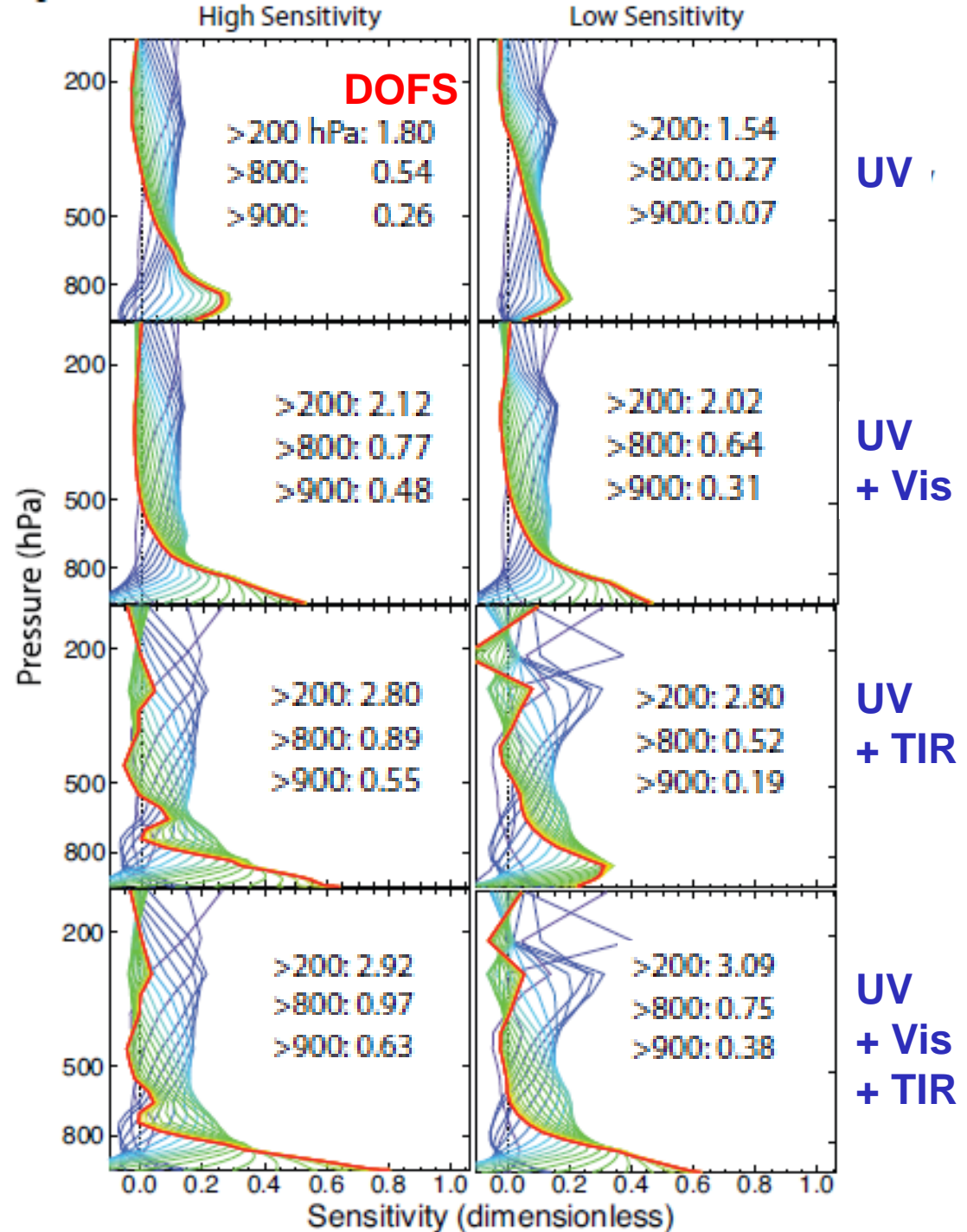
and degrees of freedom for signal (DOFS) in the troposphere



**GEO-CAPE needs to increase the information content in the boundary layer
for better relevance to ozone air quality**

Multispectral observation of ozone in GEO-CAPE: averaging kernels for different UV/Vis/TIR instrument configurations

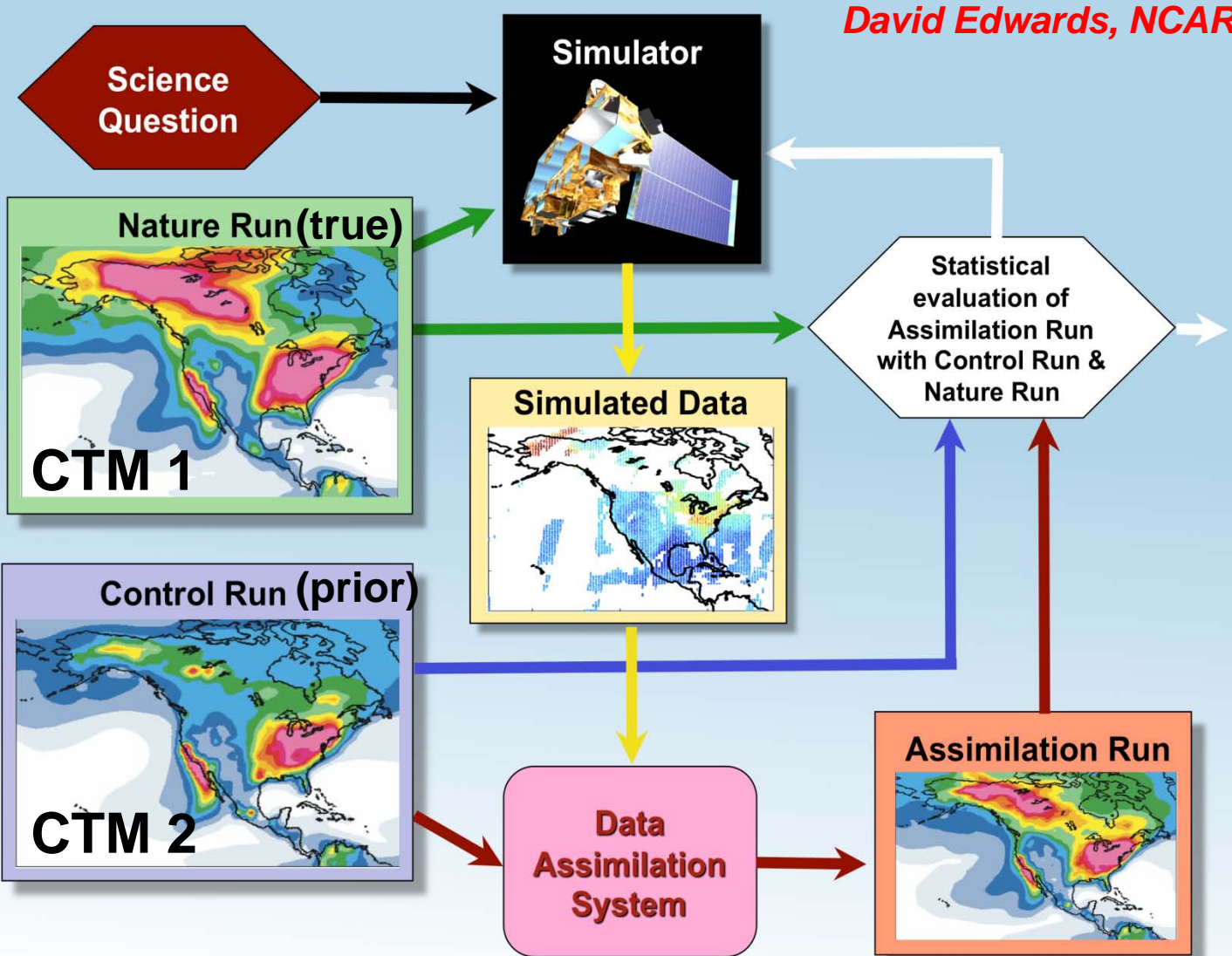
- Numbers show the degrees of freedom for signal (DOFS) for different altitude ranges
- Multiispectral observation enables sensitivity to ozone below 1 km.



Chemical Observation System Simulation Experiment (OSSEs) can help evaluate proposed satellite and instrument configurations in a data assimilation framework

OSSEs provide a practical way of defining a traceability matrix to map: **science requirements** through **measurement requirements** onto **instrument requirements**

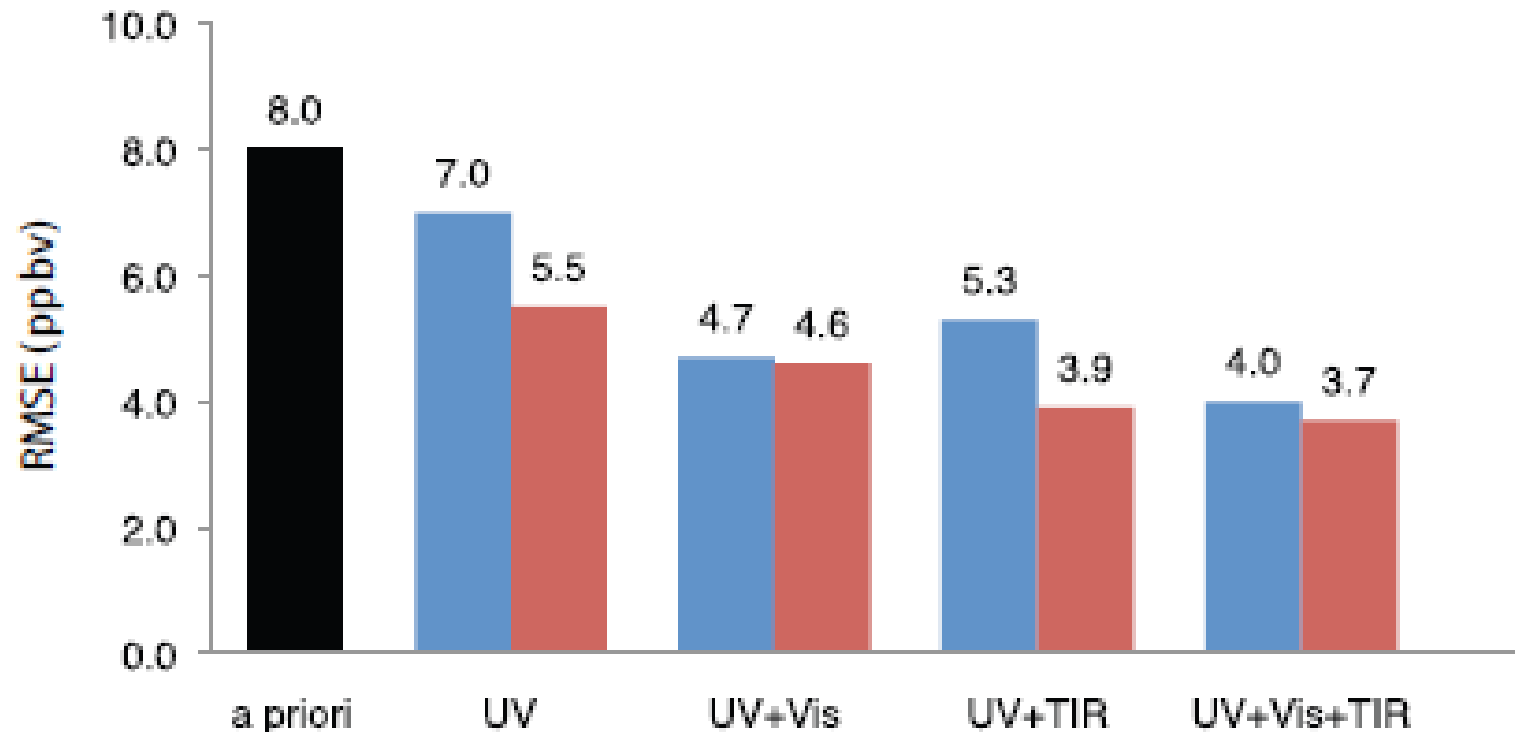
Examine how the new data would improve a data assimilation system



David Edwards, NCAR

OSSE application to data assimilation for surface ozone

Root-mean-square error (RMSE) of data assimilation system for daily maximum 8-h average (MDA8) surface ozone before (a priori) and after assimilation of synthetic GEO-CAPE data



Multi-spectral ozone observation from GEO-CAPE can reduce error by 50%; adjoint model analysis shows that surface ozone is most sensitive to production below 2 km

Species	Precision	Spectral region	Rationale
O ₃	Stratosphere: 5% 2 km-tropopause: 15 ppb 0-2 km: 10 ppb	UV, Vis, TIR	Surface AQ, transport, climate forcing
CO	2 km – tropopause: 20 ppb 0-2 km: 20 ppb	SWIR, MWIR	CO emission, transport
Aerosol	0.05 (AOD)	Vis	Surface AQ, aerosol sources and transport, climate forcing
NO ₂	1x10 ¹⁵ cm ⁻²	Vis	NO _x emissions, chem.
HCHO	1x10 ¹⁶ cm ⁻²	UV	VOC emissions, chem.
SO ₂	1x10 ¹⁶ cm ⁻²	UV	SO _x emissions, chem.
CH ₄	Troposphere: 20 ppb	SWIR	CH ₄ emissions
NH ₃	0-2 km: 2 ppb	TIR	NH ₃ emissions
CHOCHO	4x10 ¹⁴ cm ⁻²	Vis	VOC emissions, chem., aerosol formation
Absorbing aerosol	0.02 (AAOD)	UV	Climate forcing
Aerosol index	0.1	UV	Aerosol events
Aerosol centroid height	1 km	Vis, NIR	Aerosol plume height, large-scale transport, AC to PM conversion

Measurement requirements for GEO-CAPE (baseline) and descope options

- Orbit centered over 100° W, observing domain north of 10° N
- Hourly data over land/coastlines with pixel resolution of 1x1 km² (aerosols) and 4x4 km² (gases), for SZA<70° (some species), <50° (others)
- *co-add 1x1 km² pixel information spectrally (aerosols) and spatially (gases)*
descope option: degrade to 2x2 km² (aerosols) and 8x8 km² (gases)
- Daily data over open oceans (O₃, CO, aerosol) with pixel resolution of 16x16 km²
descope option: cancel data over open ocean
- Ozone and CO: two pieces of information in troposphere including sensitivity below 2 km
- NO₂, HCHO, SO₂, CH₄, CHOCHO, NH₃ : columns only
descope options: cancel HCHO, SO₂, CH₄, CHOCHO, NH₃
- Aerosol optical depth (AOD), absorption (AAOD), index (AI), height (AOCH)
descope options: cancel AAOD, AI, AOCH