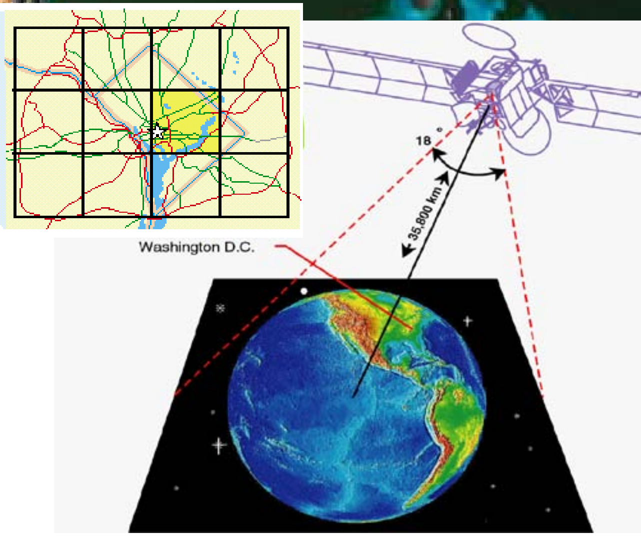
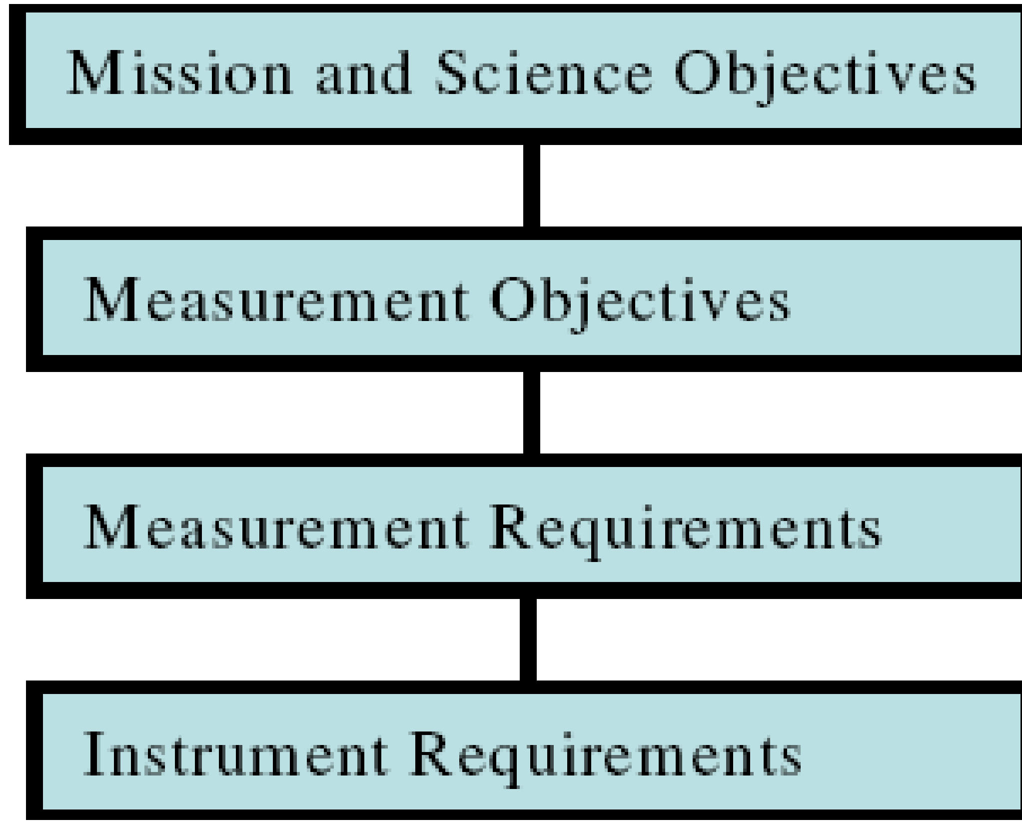


GEO-CAPE Science Goals and Requirements - Atmosphere

Daniel J. Jacob
Co-Lead, GEO-CAPE Atmosphere Science Working Group

Building the Science Traceability Matrix for GEO-CAPE

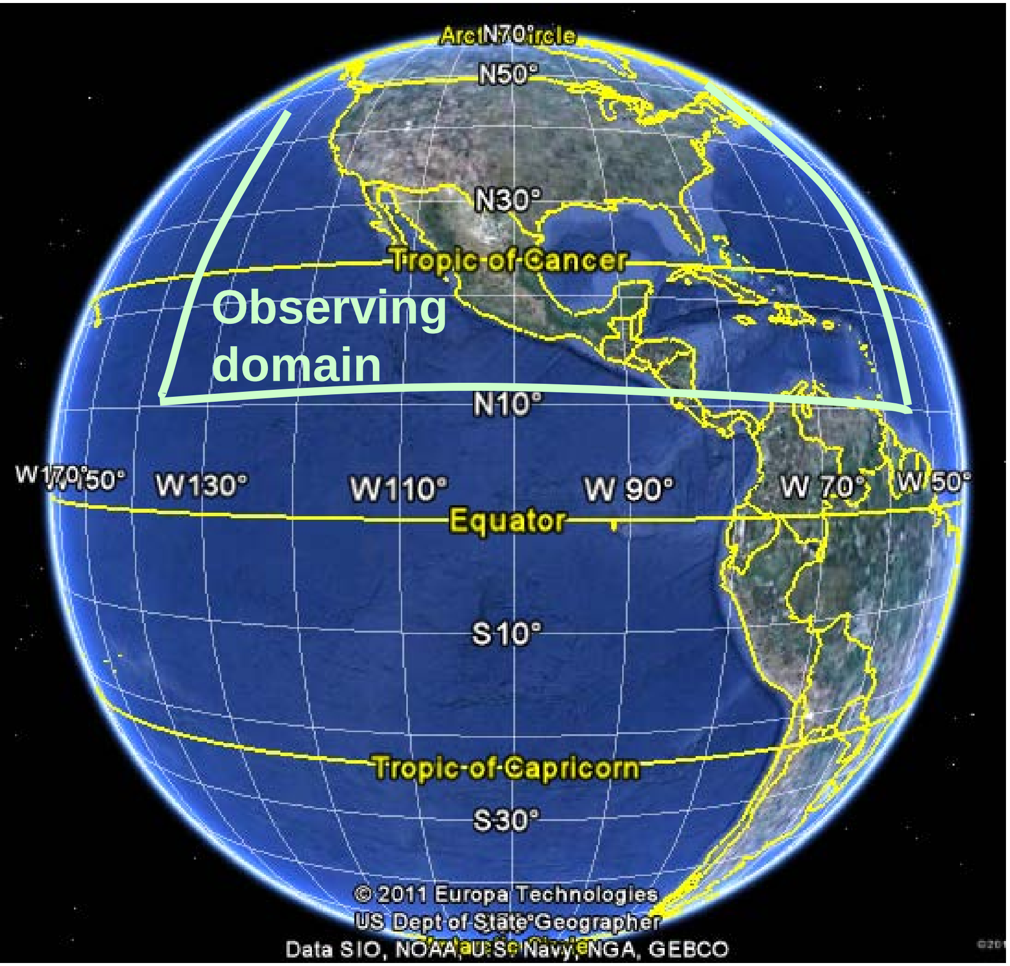
Flow from science objectives to requirements



Trace requirements to their objectives; define "trade space"

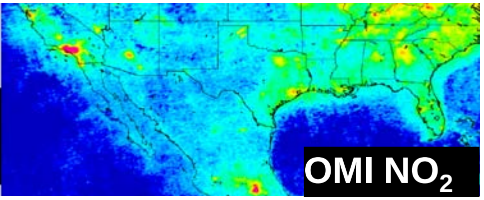
Weiss et al., IEEAC 2004

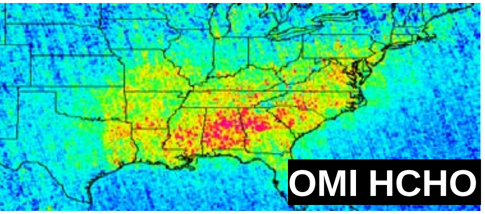
Atmospheric Mission Objective: To Observe, Understand, and Predict Air Quality and Climate Forcing in North America

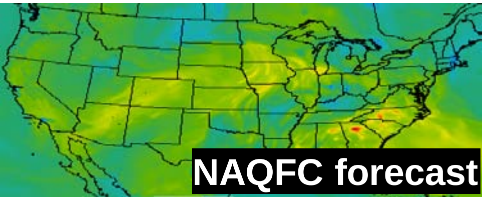


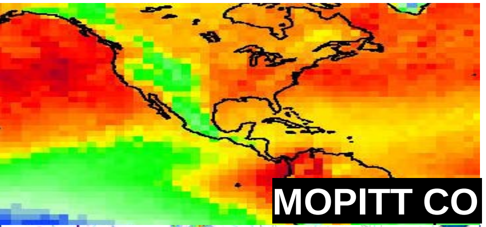
- Orbit centered at 100° W
- Observe North America and adjacent oceans with hourly repeat time
- Pixel resolution: 1x1 km^2 (aerosols), 4x4 km^2 (gases) at 40° N

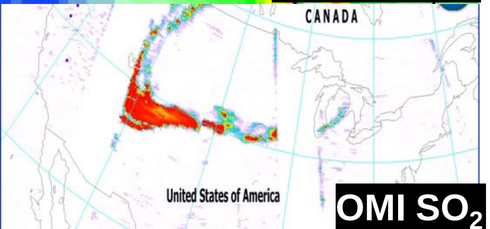
Science Questions for GEO-CAPE - Atmosphere











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?**

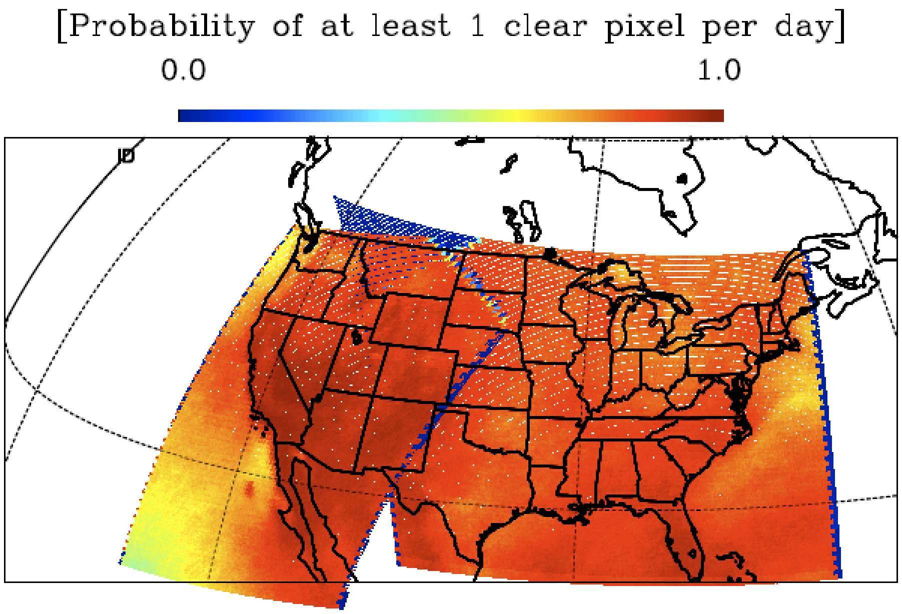
4. **How do we improve air quality forecasts and assessments for societal benefit?**

5. **How does intercontinental transport affect air quality?**

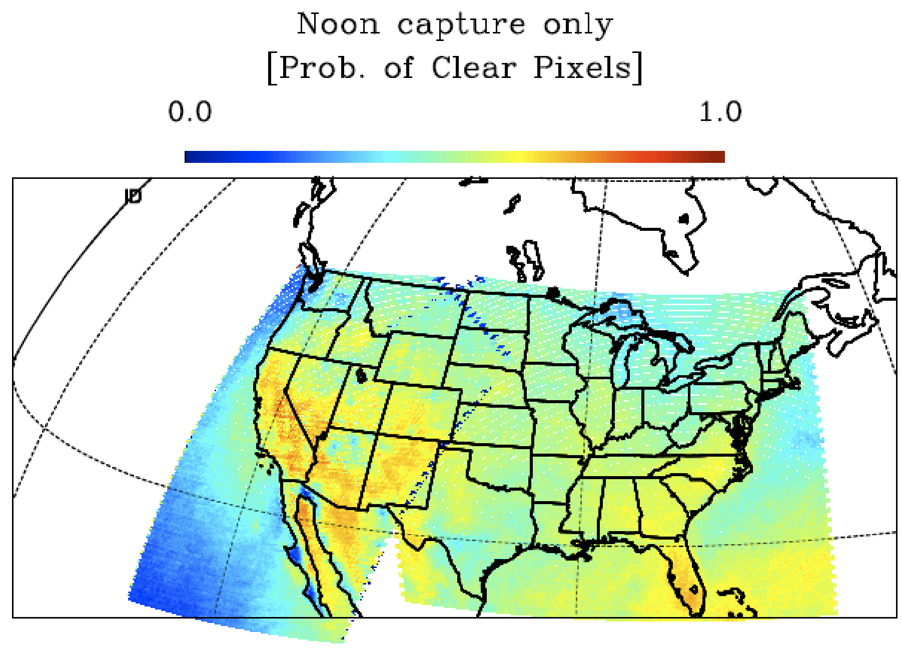
6. **How do episodic events such as wild fires, dust outbreaks, and volcanic eruptions affect atmospheric composition and air quality?**

Geostationary observation greatly improves probability of observing clear-sky scenes

Geostationary (hourly observation)

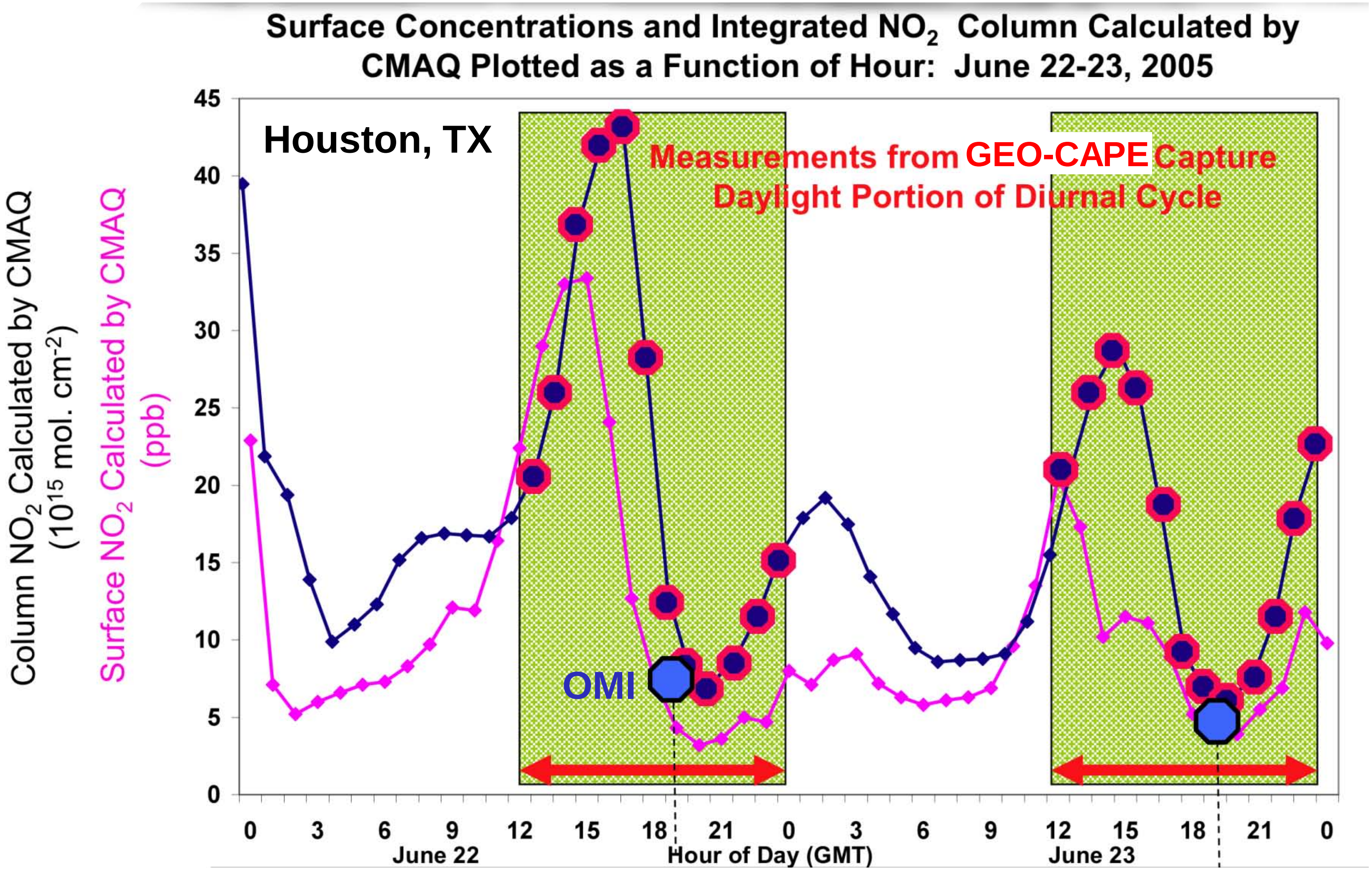


Low-elevation orbit (daily observation)



J. Moisan, NASA/GSFC

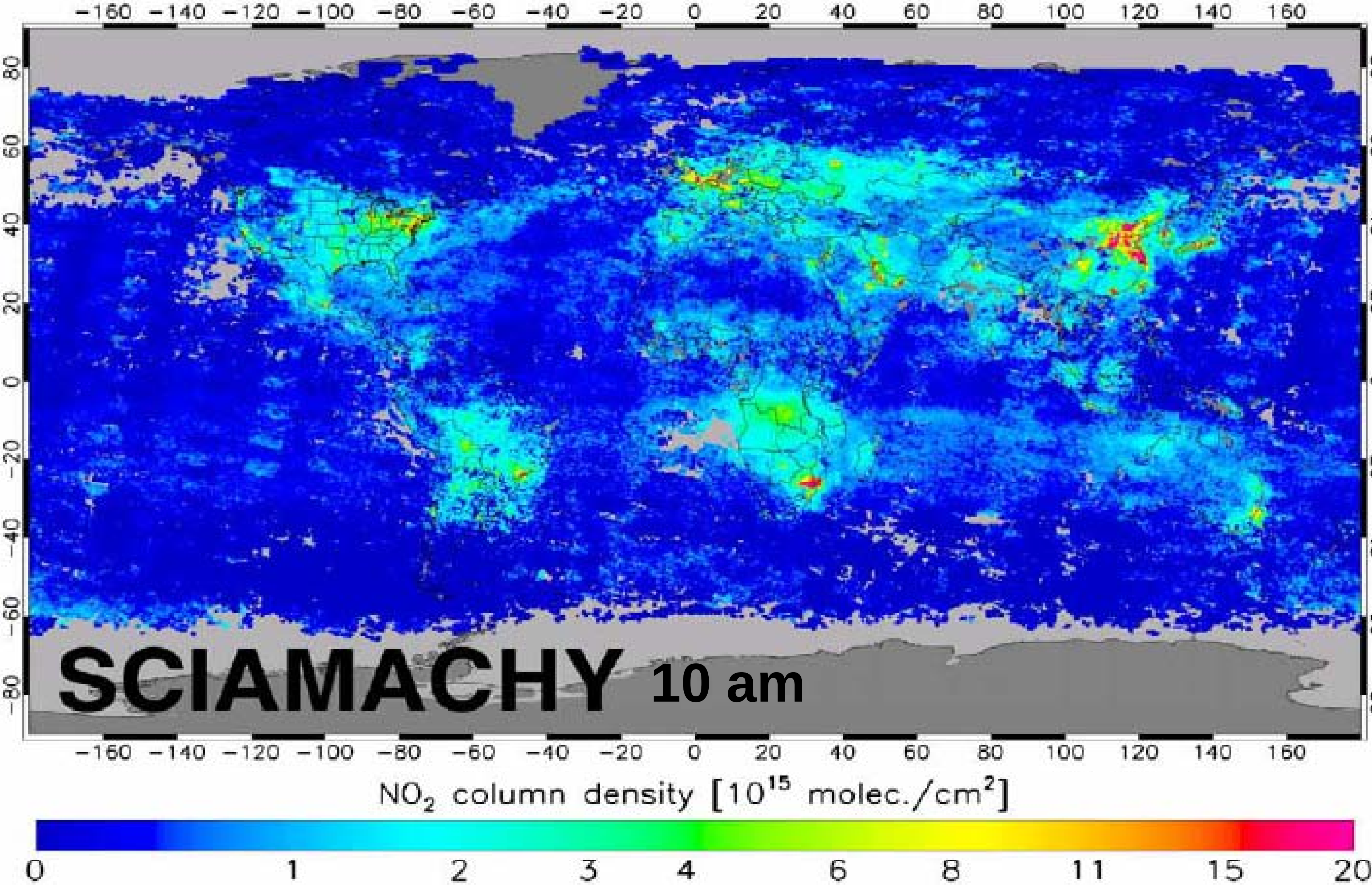
Geostationary view captures diurnal cycle of emissions and chemistry



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)

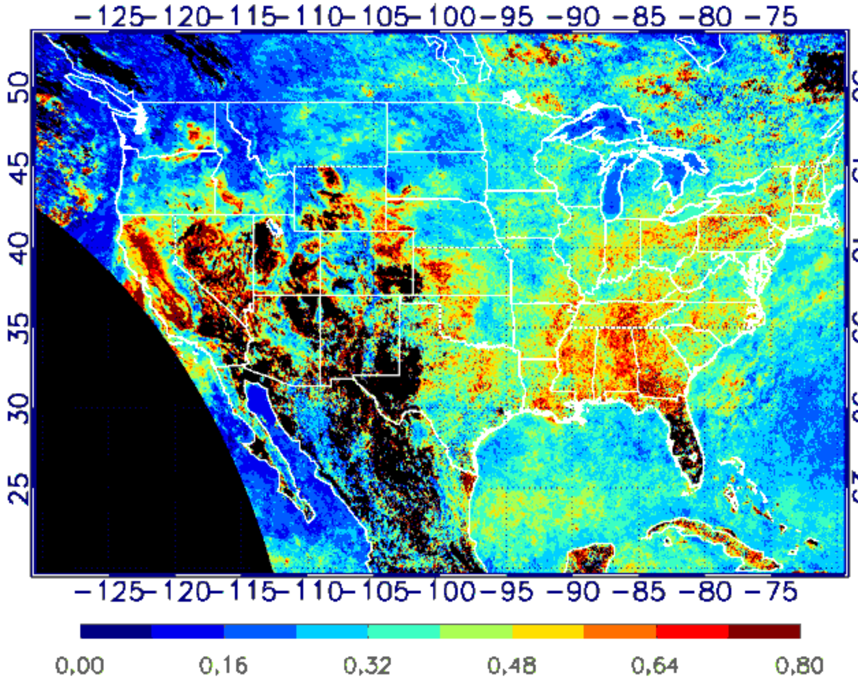


Boersma et al. [2008]

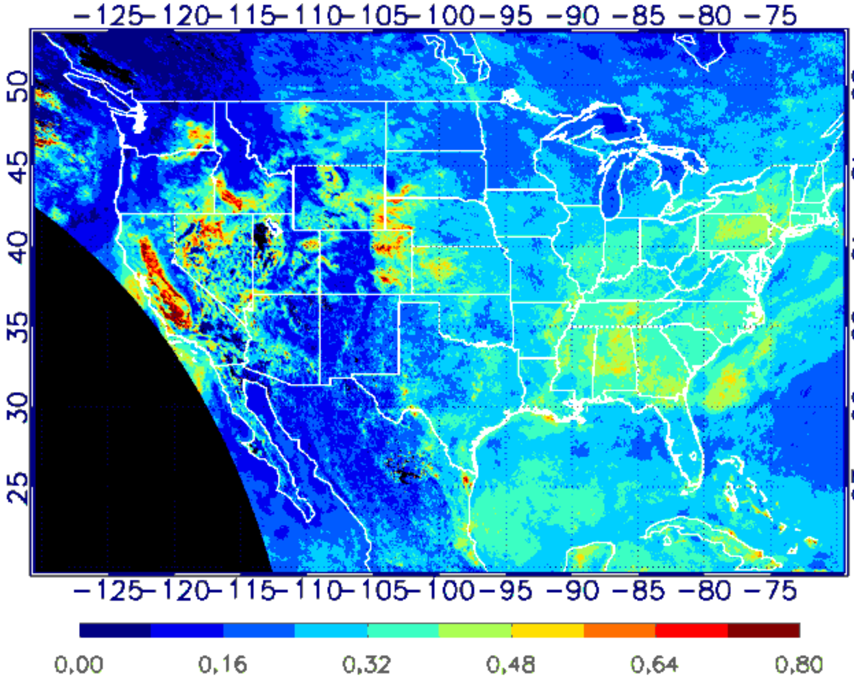
Geostationary measurements decrease diurnal bias in satellite aerosol optical depth (AOD) data

Monthly mean AOD observations, July 2008

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



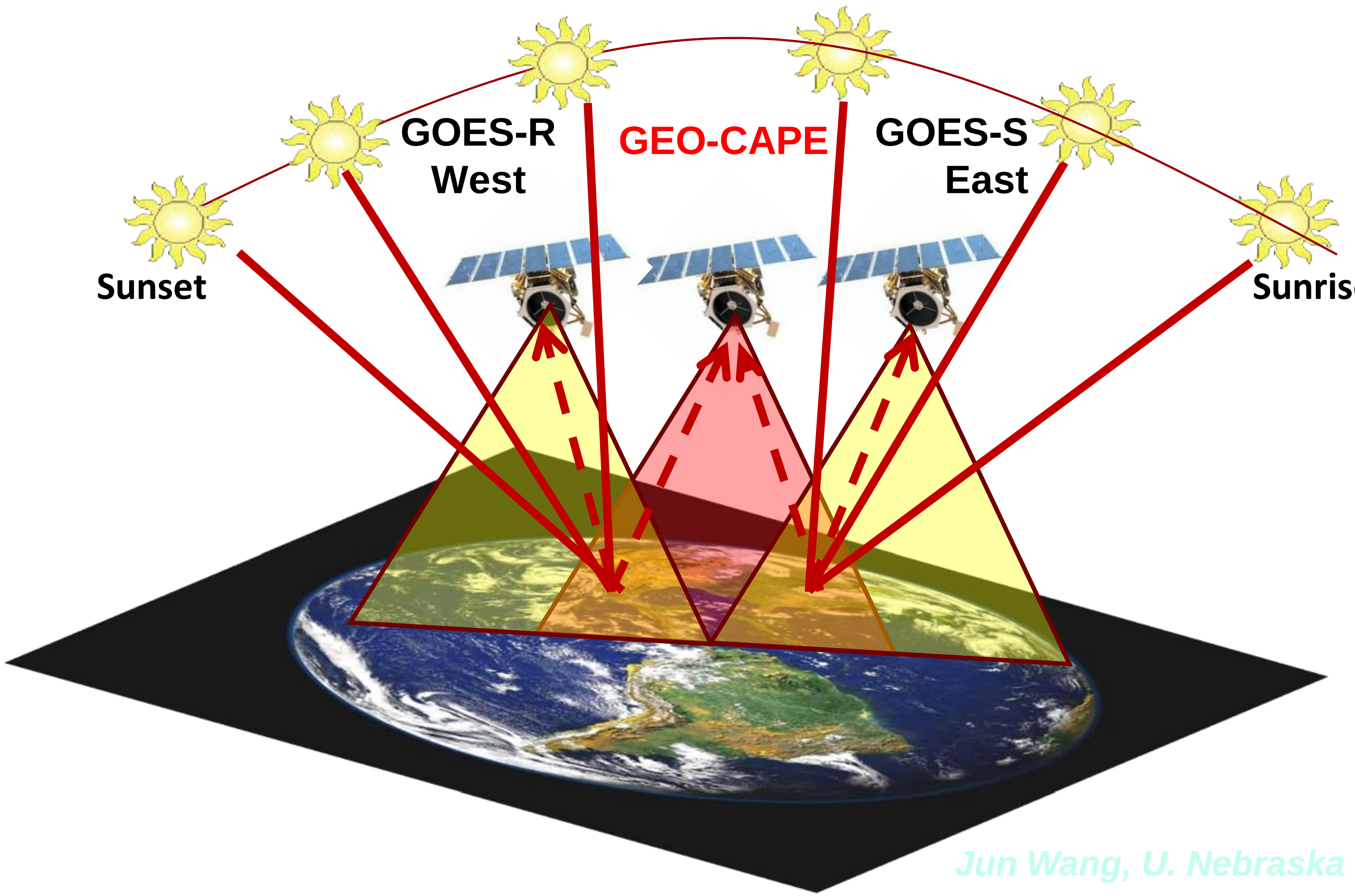
from GOES every 30 min in daytime



Shobha Kondragunta, NOAA NESDIS

GEO-CAPE and GOES-R/S synergy

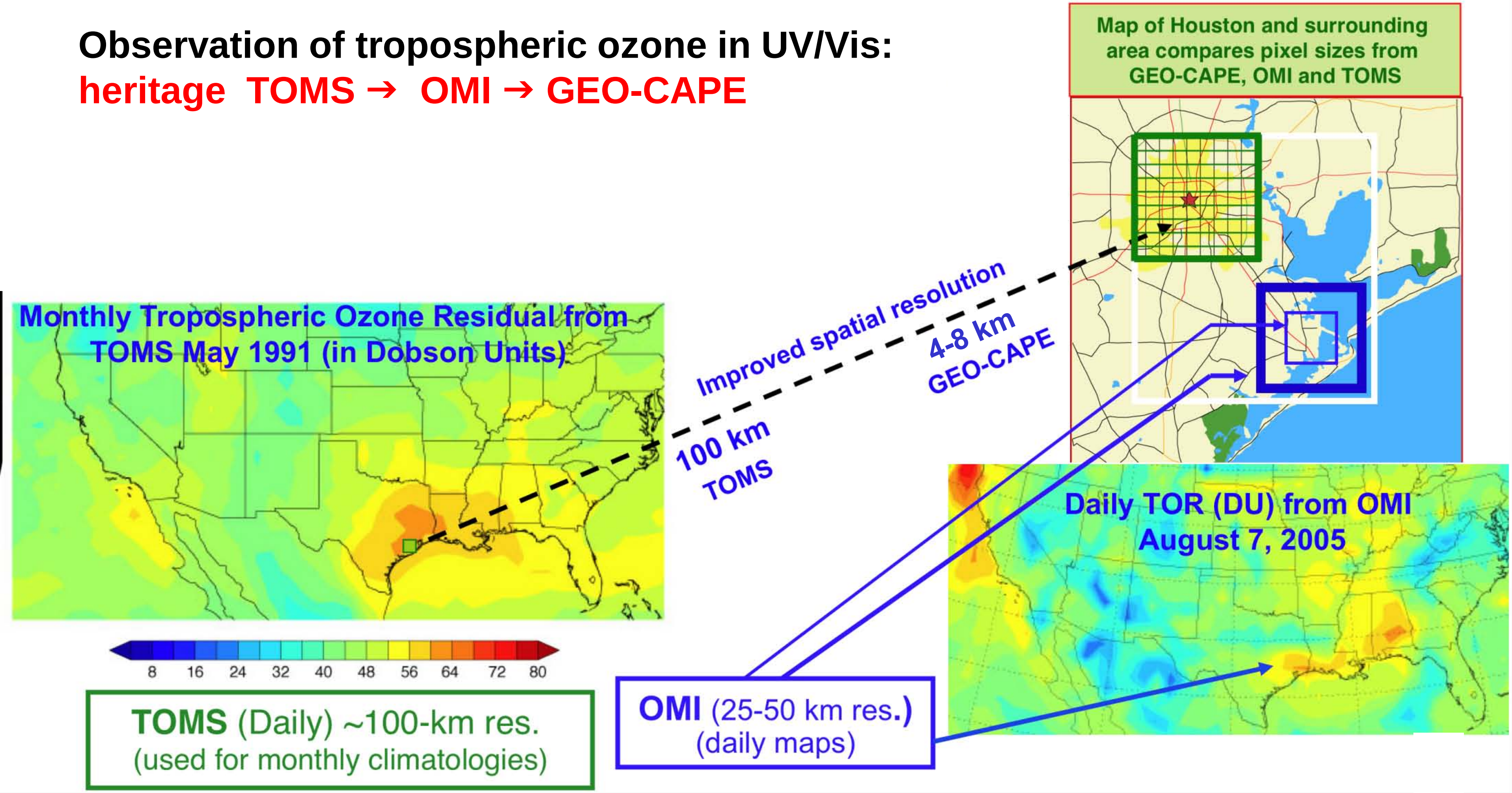
Joint retrieval of geostationary observations collected from multiple scattering angles can better characterize aerosol altitude, size distribution, and composition



Jun Wang, U. Nebraska - Lincoln

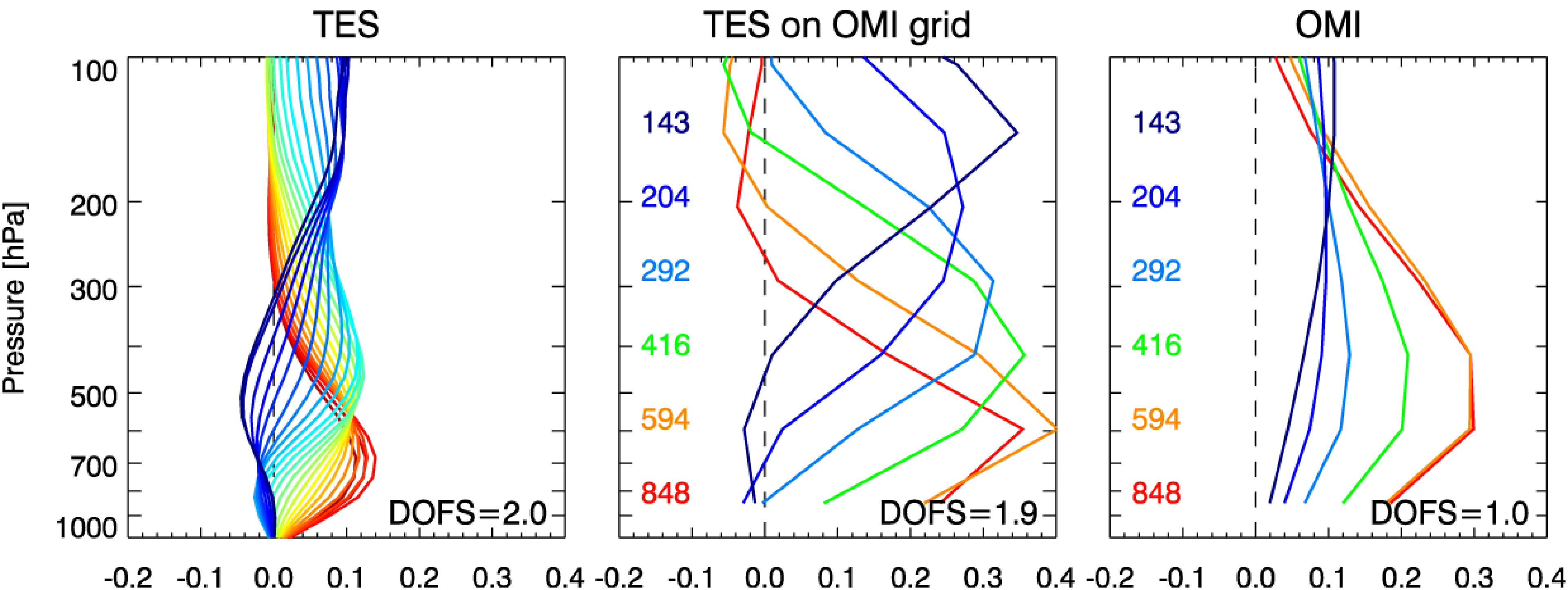
GEO-CAPE resolution of 4-8 km for gases will allow resolution of urban scales

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



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

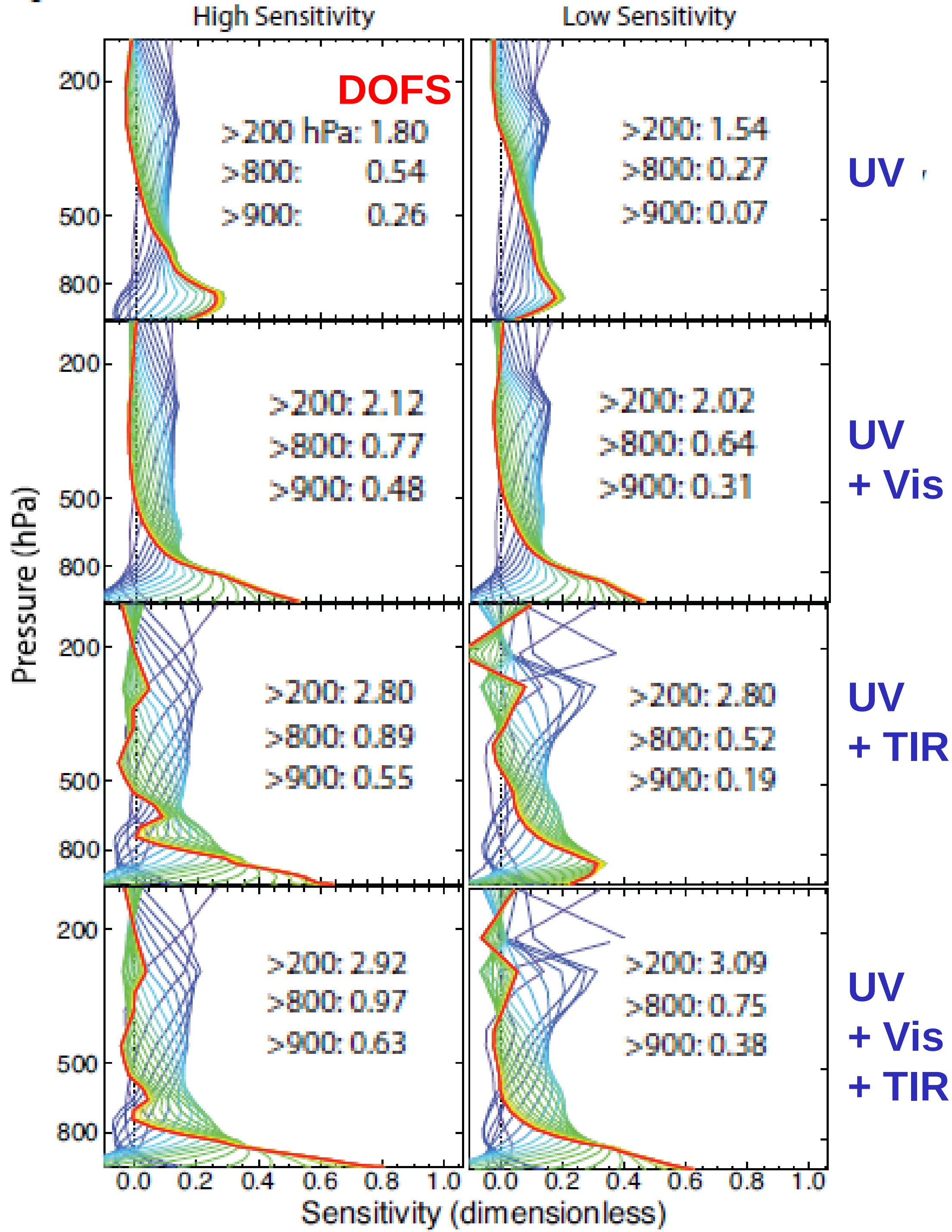
and degrees of freedom for signal (DOFS) in the troposphere



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

Zhang et al. [2010]

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



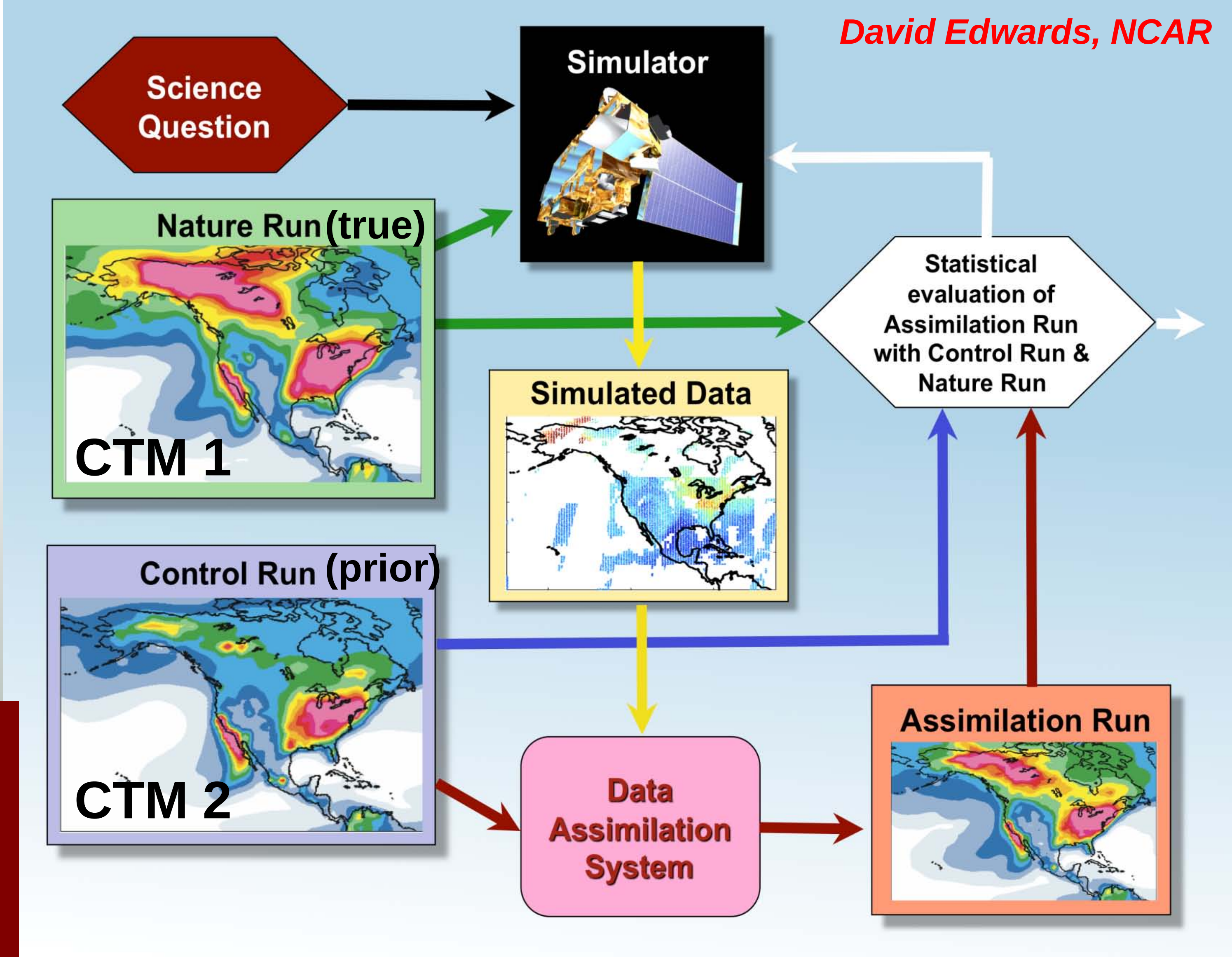
- Numbers show the degrees of freedom for signal (DOFS) for different altitude ranges
- Multiispectral observation enables sensitivity to ozone below 1 km.

Natraj et al. [2011]

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

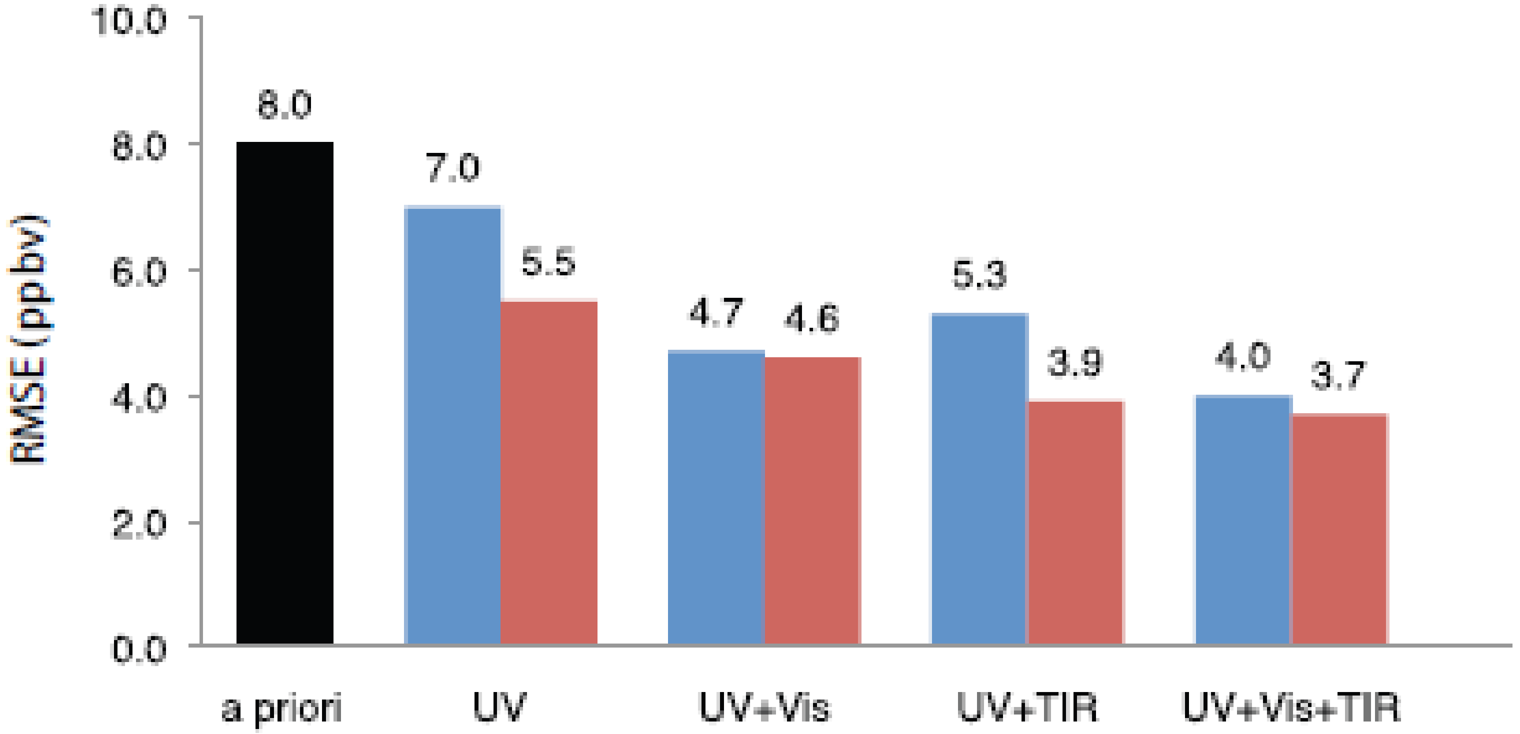
OSSEs provide a practical way of defining a traceability matrix to map: science requirements through measurement requirements onto instrument requirements

Examine how the new data would improve a data assimilation system



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

Zoogman et al. [2011]

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	1×10^{15} cm^{-2}	Vis	NO_x emissions, chem.
HCHO	1×10^{16} cm^{-2}	UV	VOC emissions, chem.
SO_2	1×10^{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	4×10^{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 100º W, observing domain north of 10º N**

- **Hourly data over land/coastlines with pixel resolution of 1x1 km^2 (aerosols) and 4x4 km^2 (gases), for SZA<70º (some species), <50º (others)**
  - co-add 1x1 km^2 pixel information spectrally (aerosols) and spatially (gases)
  descope option: degrade to 2x2 km^2 (aerosols) and 8x8 km^2 (gases)

- **Daily data over open oceans (O_3, CO, aerosol) with pixel resolution of 16x16 km^2**
  descope option: cancel data over open ocean

- **Ozone and CO: two pieces of information in troposphere including sensitivity below 2 km**

- **NO_2, HCHO, SO_2, CH_4, CHOCHO, NH_3 : columns only**
  descope options: cancel HCHO, SO_2, CH_4, CHOCHO, NH_3

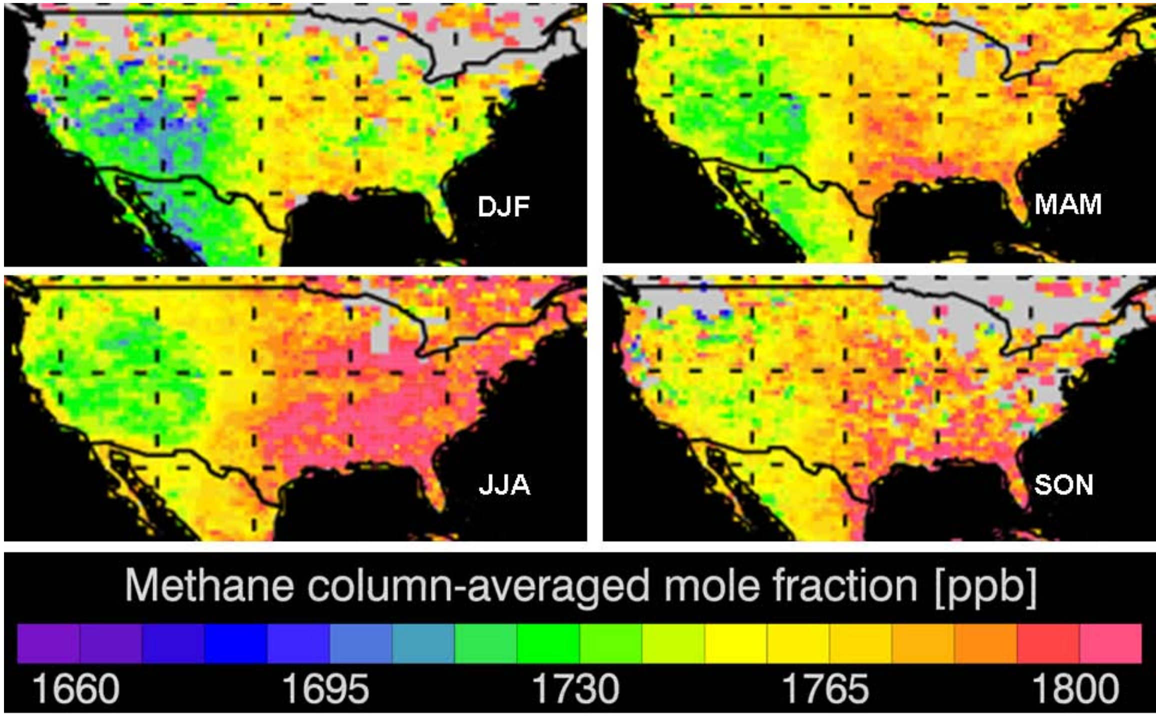
- **Aerosol optical depth (AOD), absorption (AAOD), index (AI), height (AOCH)**
  descope options: cancel AAOD, AI, AOCH

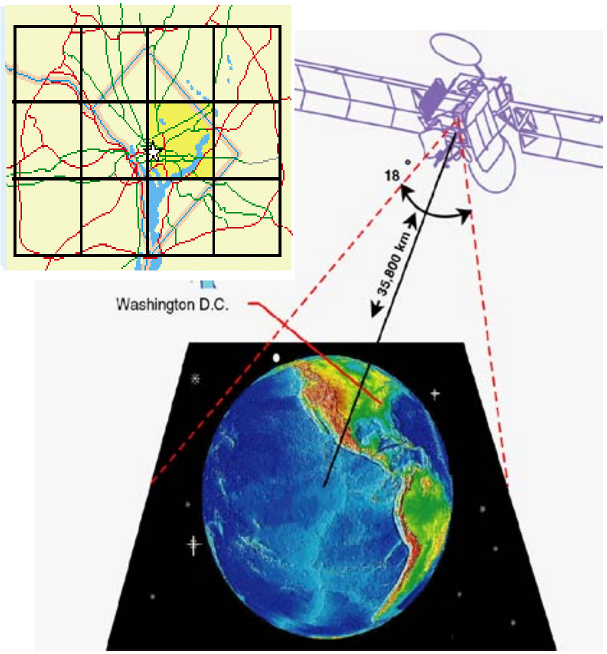
Observation of methane from space

Large uncertainty in US emission estimates;
sources may be episodic (venting) or vary diurnally (landfills)

US anthropogenic methane source, Tg a^{-1}	
EDGAR v3	40.0
EDGAR v4	29.0
EPA [2009]	28.0
Kort et al. [2008] top-down	49.0

SCIAMACHY methane data (2003)





GEO-CAPE will significantly improve observational capability :

1. High-temporal resolution measurements to capture changes in pollutant distributions due to changing photochemistry, emissions and meteorology
2. High-spatial resolution measurements to access the city scale with continuous full-coverage of North America
3. Exploitation of multispectral observations to improve information content in the vertical profile
4. Development of an integrated measurement system for atmospheric composition including ground-based, suborbital, and satellite platforms