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

- Mission and Science Objectives
- Measurement Objectives
- Measurement Requirements
- Instrument 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 km² (aerosols), 4x4 km² (gases) at 40° N
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]

Noon capture only

[Prob. of Clear Pixels]
Geostationary view captures diurnal cycle of emissions and chemistry.

Low-elevation-orbit observations offer no such information.
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
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
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.

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

Zoogman et al. [2011]
<table>
<thead>
<tr>
<th>Species</th>
<th>Precision</th>
<th>Spectral region</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>O₃</td>
<td>Stratosphere: 5% 2 km-tropopause: 15 ppb 0-2 km: 10 ppb</td>
<td>UV, Vis, TIR</td>
<td>Surface AQ, transport, climate forcing</td>
</tr>
<tr>
<td>CO</td>
<td>2 km – tropopause: 20 ppb 0-2 km: 20 ppb</td>
<td>SWIR, MWIR</td>
<td>CO emission, transport</td>
</tr>
<tr>
<td>Aerosol</td>
<td>0.05 (AOD)</td>
<td>Vis</td>
<td>Surface AQ, aerosol sources and transport, climate forcing</td>
</tr>
<tr>
<td>NO₂</td>
<td>1x10¹⁵ cm⁻²</td>
<td>Vis</td>
<td>NOₓ emissions, chem.</td>
</tr>
<tr>
<td>HCHO</td>
<td>1x10¹⁶ cm⁻²</td>
<td>UV</td>
<td>VOC emissions, chem.</td>
</tr>
<tr>
<td>SO₂</td>
<td>1x10¹⁶ cm⁻²</td>
<td>UV</td>
<td>SOₓ emissions, chem.</td>
</tr>
<tr>
<td>CH₄</td>
<td>Troposphere: 20 ppb</td>
<td>SWIR</td>
<td>CH₄ emissions</td>
</tr>
<tr>
<td>NH₃</td>
<td>0-2 km: 2 ppb</td>
<td>TIR</td>
<td>NH₃ emissions</td>
</tr>
<tr>
<td>CHOCHO</td>
<td>4x10¹⁴ cm⁻²</td>
<td>Vis</td>
<td>VOC emissions, chem., aerosol formation</td>
</tr>
<tr>
<td>Absorbing aerosol</td>
<td>0.02 (AAOD)</td>
<td>UV</td>
<td>Climate forcing</td>
</tr>
<tr>
<td>Aerosol index</td>
<td>0.1</td>
<td>UV</td>
<td>Aerosol events</td>
</tr>
<tr>
<td>Aerosol centroid height</td>
<td>1 km</td>
<td>Vis, NIR</td>
<td>Aerosol plume height, large-scale transport, AQ to PM conversion</td>
</tr>
</tbody>
</table>
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
Observation of methane from space

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

<table>
<thead>
<tr>
<th>US anthropogenic methane source, Tg a⁻¹</th>
</tr>
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<tbody>
<tr>
<td>EDGAR v3</td>
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<tr>
<td>EDGAR v4</td>
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<td>EPA [2009]</td>
</tr>
<tr>
<td>Kort et al. [2008] top-down</td>
</tr>
</tbody>
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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.