TEMPO & GOES-R synergy update and GEO-TASO aerosol retrieval

Jun Wang
Xiaoguang Xu, Shouguo Ding, Weizhen Hou
University of Nebraska-Lincoln

Robert Spurr
RT solutions

Xiong Liu, Kelly Chance
Harvard-Smithsonian Center for Astrophysics
GOES-R to be launched in Oct. 2015

ABI: Advanced Baseline Imager

<table>
<thead>
<tr>
<th>Future GOES imager (ABI) band</th>
<th>Wavelength range (μm)</th>
<th>Central wavelength (μm)</th>
<th>Nominal subsatellite IGFOV (km)</th>
<th>Sample use</th>
<th>Heritage instrument(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.45–0.49</td>
<td>0.47</td>
<td>1</td>
<td>Daytime aerosol over land, coastal water mapping</td>
<td>MODIS</td>
</tr>
<tr>
<td>2</td>
<td>0.59–0.69</td>
<td>0.64</td>
<td>0.5</td>
<td>Daytime clouds fog, insolation, winds</td>
<td>Current GOES imager/ sounder</td>
</tr>
<tr>
<td>3</td>
<td>0.846–0.885</td>
<td>0.865</td>
<td>1</td>
<td>Daytime vegetation/burn scar and aerosol over water, winds</td>
<td>VIIRS, spectrally modified AVHRR</td>
</tr>
<tr>
<td>4</td>
<td>1.371–1.386</td>
<td>1.378</td>
<td>2</td>
<td>Daytime cirrus cloud</td>
<td>VIIRS, MODIS</td>
</tr>
<tr>
<td>5</td>
<td>1.58–1.64</td>
<td>1.61</td>
<td>1</td>
<td>Daytime cloud-top phase and particle size, snow</td>
<td>VIIRS, spectrally modified AVHRR</td>
</tr>
<tr>
<td>6</td>
<td>2.225–2.275</td>
<td>2.25</td>
<td>2</td>
<td>Daytime land/cloud properties, particle size, vegetation, snow</td>
<td>VIIRS, similar to MODIS</td>
</tr>
<tr>
<td>7</td>
<td>3.80–4.00</td>
<td>3.90</td>
<td>2</td>
<td>Surface and cloud, fog at night, fire, winds</td>
<td>Current GOES imager</td>
</tr>
</tbody>
</table>

from Schmit et al., 2005.
# ABI Capability

<table>
<thead>
<tr>
<th>ABI</th>
<th>Current GOES Imager</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral Coverage</td>
<td>16 bands</td>
</tr>
</tbody>
</table>

**Spatial Resolution**

<table>
<thead>
<tr>
<th></th>
<th>ABI</th>
<th>Current GOES Imager</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.64 μm Visible</td>
<td>0.5 km</td>
<td>~ 1 km</td>
</tr>
<tr>
<td>Other visible/near-IR</td>
<td>1.0 km</td>
<td>n/a</td>
</tr>
<tr>
<td>Bands (&gt;2 μm)</td>
<td>2 km</td>
<td>~ 4 km</td>
</tr>
</tbody>
</table>

**Spatial Coverage**

<table>
<thead>
<tr>
<th></th>
<th>ABI</th>
<th>Current GOES Imager</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Disk</td>
<td>4 per hour</td>
<td>Scheduled (3 hrly)</td>
</tr>
<tr>
<td>CONUS</td>
<td>12 per hour</td>
<td>~4 per hour</td>
</tr>
<tr>
<td>Mesoscale</td>
<td>Every 30 sec</td>
<td>n/a</td>
</tr>
</tbody>
</table>

**Visible (reflective bands)**

<table>
<thead>
<tr>
<th></th>
<th>ABI</th>
<th>Current GOES Imager</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-orbit calibration</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

[http://www.goes-r.gov/](http://www.goes-r.gov/)
Strategy for Retrieval Algorithm

• Algorithm development strategy
  – **Forward thinking**: the GOES+TEMPO synergy algorithm is for aerosol science 5-8 years from now.
  – **Holistic thinking**: aerosol will affect O3 and other gas retrieval in UV + Vis gas retrieval algorithm; likewise, gas affects aerosol retrieval.
  – **Think about users**: satellite data provides a constraint, but can not provide all information users needed. Getting the data is not a key question; the key is the uncertainty associated with each retrieval and how does that help what users already have, in places where obs. data is not available. Recall clouds are there 70% of the time. A big community to use these data will modelers and data assimilation folks.
  – **Think about validation**: link retrieval to what can be measured.
  – **Think about STM**: climate or air pollution?
Progress for Retrieval Algorithm

• What we have been developed so far:
  – A inversion/optimization framework that is consistent with what is used for TEMPO O3 retrievals.
  – Seek to provide uncertainty for each individual retrievals.
  – State-of-the-art treatment of gas absorption
  – Tested with AERONET sky radiance so far; Put physically-based constraints to ensure retrieval smoothness and reduce unphysical outliers.
  – Used with GEOS-Chem to provide satellite simulator for answering OSSE-type questions (e.g., from AOD \( \rightarrow \) emission).

• Decision has not been made; some can not be answered without further studies:
  – Treatment of surface (there were multi-ways to do it, discussed later)
  – The role of priori knowledge for the retrieval: e.g., aerosol climatology from models, ground-based network, and existing satellite products.
  – What to retrieve and what not? Trying to pushing the limits, while still maintaining good accuracy. Fine-mode AOD, surface reflectance?
A numerical testbed for remote sensing of aerosols, and its demonstration for evaluating retrieval synergy from a geostationary satellite constellation of GEO-CAPE and GOES-R

Jun Wang\textsuperscript{a,\ast}, Xiaoguang Xu\textsuperscript{a}, Shouguo Ding\textsuperscript{a}, Jing Zeng\textsuperscript{a}, Robert Spurr\textsuperscript{b}, Xiong Liu\textsuperscript{c}, Kelly Chance\textsuperscript{c}, Michael Mishchenko\textsuperscript{d}
Highlights

• A numerical testbed for remote sensing of aerosols for any satellite/algorithm design.

• Linearly and coupled scattering and radiative transfer codes, optimization code included.

• Hyperspectral study of gas absorption effect on retrievals of aerosol height.

• Strong synergy between geo-satellites (GOES and TEMPO/GEO-CAPE) for aerosol retrieval.

• Polarization in O2 A band is sensitive to aerosol height over visibly bright surface.
Joint retrieval reduces AOD and fine-mode AOD uncertainties respectively from 30% to 10% and from 40% to 20%.

The improvement of AOD is especially evident for cases when either TEMPO or GOES-R (but not both) are located close to the direction of the Sun (solar azimuth).
BRDF at deep-blue and UV wavelengths, and its relationship with counterparts in NIR

- To apply MODIS-type algorithm, we need to link GOES-R NIR reflectance in one geometry with the TEMPO surface UV and blue reflectance in another geometry.
- Here we use CAI as a proxy for TEMPO and MODIS/VIIRS as a proxy for GOES-R.

Cloud-Aerosol-Imager characteristics:

<table>
<thead>
<tr>
<th>BAND</th>
<th>RESOLUTION</th>
<th>SWATH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 1 (0.38μm)</td>
<td>0.5 km</td>
<td>1000 km</td>
</tr>
<tr>
<td>Band 2 (0.67μm)</td>
<td>0.5 km</td>
<td>1000 km</td>
</tr>
<tr>
<td>Band 3 (0.87μm)</td>
<td>0.5 km</td>
<td>1000 km</td>
</tr>
<tr>
<td>Band 4 (1.6μm)</td>
<td>1.5 km</td>
<td>750 km</td>
</tr>
</tbody>
</table>
OMI LER resolution is too coarse (0.5° X 0.5°) to be used for AOD retrieval from CAI (0.5 m X 0.5 m).

patches due to surface reflectance database.
Can we extrapolate the UV reflectance from MODIS channels?

For MODIS, wavelength (nm) of reflectance is

645  555  469  555  1240  1640  2130
For MODIS, wavelength(nm) of reflectance is

645  555  469  555  1240  1640  2130
Extrapolation appears to be good for most surface types except roofing shingles.
First Trial

SZA=30, VZA=0, SR⁻¹

0.67 um

0.47 um

0.38 um
Comparison with OMI

\[ y = 0.65x + 0.02 \]

\[ R = 0.5680 \]

OMI LER Reflectance
Geo-TASO work

with James Leitch and Ball team
Tree & Green Grass

- 580 nm Radiance of Tree (W/m² sr µm)
- 580 nm Radiance of Green Grass (W/m² sr µm)
- Frequency (%)

![Graphs and Maps]
Geo-TASO measurements over grass

Average Radiance of Green Grass at the level of Aircraft

400 nm  550 nm  700 nm
The reflectance in green band highly depends on Chlorophyll.
Summary

• Deriving high-resolution UV surface BRDF and their link to visible spectrum – in progress
• Retrieving AOD with high-resolution UV data – in progress
• Geo-TASO work – in progress
Thank you.