Development of Near Real Time TEMPO Aerosol Index/Aerosol Detection Product

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Objective

- Wildfire smoke and blowing dust are becoming more frequent and dominant factors for air pollution.

- The ability to monitor smoke/dust outbreaks from space with both high temporal and spatial resolution provides unique tools for operational and research applications.

- NOAA’s operational Enterprise Aerosol Detection Product (ADP), also called smoke/dust mask, provides smoke/dust flags at the pixel level from:
  - VIIRS: S-NPP, NOAA-20 and NOAA-21 (11 yrs. record)
  - ABI: GOES-16, -17 and -18 (~6 yrs. record)

- TEMPO’s UV-VIS spectrometer, currently in orbit, has better wavelengths for characterizing absorbing aerosols.

- Hourly smoke/dust mask can be generated by synergistically combining TEMPO with ABI observations & applying NOAA’s Enterprise ADP algorithm.
NOAA Enterprise Aerosol Detection Algorithm

- One algorithm working on observations from multiple sensors including both GEO and LEO platforms.
- Uniform input and output structure.

**Absorbing Aerosol Index**

\[ AAI = -10\left[\log_{10}\left(\frac{R_{412}}{R_{440}}\right) - \log_{10}\left(\frac{R'_{412}}{R'_{440}}\right)\right] \]

**Dust Smoke Discrimination Index**

\[ DSDI = -10\left[\log_{10}\left(\frac{R_{412}}{R_{2250}}\right)\right] \]

**Dust Detection**

- Brightness Temperature Difference (BTD)
  \[ BTD_1 = BT_{11\mu m} - BT_{12\mu m} \]
  \[ BTD_2 = BT_{3.9\mu m} - BT_{11\mu m} \]

**Smoke Detection**

Spectral contrast and Spectral variability

\[ R_1 = \rho_{0.47\mu m} \cdot \rho_{0.64\mu m} \]
\[ R_2 = \rho_{0.86\mu m} \cdot \rho_{0.64\mu m} \]
\[ R_3 = \rho_{0.47\mu m} \cdot \rho_{1.61\mu m} \]
\[ R_4 = \rho_{2.25\mu m} \cdot \rho_{1.61\mu m} \]

**Presence of smoke/dust**

Presence and relative intensity of smoke/dust

12 July 2023
In 2014, China adopted measures to reduce pollution

NOAA TEMPO/ABI Hybrid Aerosol Detection Algorithm

- Hybrid approach taking into account the synergy between an Imager and a spectrometer
  - Temporally coincident
  - Spectrally complementary
  - Spatially overlapping

- Enterprise approach lets the algorithm work on any given imager and spectrometer
  - Imagers: ABI, FCI, AHI, AMI, VIIRS, METImage
  - Spectrometers: TEMPO, Sentinel-4, GEMS, TROPOMI, UVN

<table>
<thead>
<tr>
<th>TEMPO+ABI</th>
<th>ABI</th>
<th>TEMPO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporal Frequency</td>
<td>10 minutes</td>
<td>Hourly</td>
</tr>
<tr>
<td>Spectral Coverage</td>
<td>Vis-IR, 16 bands</td>
<td>UV-VIS 290-490 nm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>540-740 nm</td>
</tr>
<tr>
<td>Spatial Resolution</td>
<td>0.5/1.0/2.0 km</td>
<td>2.0x4.7 km</td>
</tr>
</tbody>
</table>

Trans-Atlantic 'Godzilla' Dust in 2020

SNPP VIIRS (2250 nm)
TROPOMI (412 nm)
TEMPO/ABI Hybrid ADP Algorithm Tested Using GEMS and AHI Data

### Dust Smoke Discrimination Index

$$\text{DSDI} = -10 \log_{10}(R_{412}/R_{2250})$$

### Absorbing Aerosol Index

$$\text{AAI} = -100 \left[ \log_{10}(R_{412}/R_{440}) - \log_{10}(R'_{412}/R'_{440}) \right]$$

Reflectance

03/04/2022
Hybrid ADP Test Case: - Smoke intrusion from Siberia wildfires (July 17, 2023 04:45 UTC)
Absorbing Aerosol Index: Deep-Blue vs. UV Wavelengths

For absorbing aerosols, such as smoke and dust, the absorption is larger at UV wavelengths than at longer wavelengths.

By shifting the wavelengths pair from 412/440 nm to 354/388 nm, the absorbing aerosol index shows a stronger contrast between areas with and without smoke/dust.

The advantage of using UV wavelengths for smoke and dust detection will be explored in NOAA TEMPO/ABI hybrid ADP.
Co-registration Tables for ABI Bands to TEMPO Bands

- The difference in the pixel size and orientation requires a weighted average during re-gridding.
- Using TEMPO proxy L1B data, co-registration tables between ABI and TEMPO bands were created.
- Larger than ~2% difference is seen after applying the weighted average with the co-registration Table.

\[
R = \frac{\sum_{1}^{n} w_i \cdot R_i}{\sum_{1}^{n} w_i}
\]

Where:
- \(R\): remapped reflectance
- \(n\): no. of ABI pixels
- \(w_i\): weight at pixel \(i\)
- \(R_i\): ABI reflectance at pixel \(i\)

Weight=overlapped area/ABI pixel area

0.55 0.731 0.204
Summary

- NOAA has developed a TEMPO/ABI hybrid aerosol detection algorithm that is ready to run in near real time, once TEMPO data become operational.
  - The algorithm will run through both the Deep-Blue and IR-Visible paths.

- The TEMPO/ABI hybrid algorithm was tested with GEMS and AHI data.
  - Initial results indicate the hybrid algorithm is capable of identifying both smoke/smog and dust plumes.

- A new UV algorithm path will be explored to take advantage of TEMPO’s UV wavelengths.
  - Potential for more accurate smoke/dust detection!
  - Smoke and dust over clouds that is currently not possible with visible AAI.