Potential Solution to Resolving Data Artifacts in VIIRS Aerosol Detection Product over Land

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Outline

• VIIRS Aerosol Detection Product (ADP)
• Demonstration and analysis of the data artifacts in ADP dust detection
• Dust RGB images using IR bands
• Dust detection using IR bands based on dust RGB method
VIIRS Aerosol Detection Product (ADP)

• Detect smoke and dust using two aerosol indices:
  • Absorbing Aerosol Index (AAI)
    \[
    AAI = -100 \left[ \log_{10} \left( \frac{R_{412}}{R_{440}} \right) - \log_{10} \left( \frac{R'_{412}}{R'_{440}} \right) \right]
    \]
    • \( R_{412} \) and \( R_{440} \) : TOA reflectance at 412nm and 440nm bands
    • \( R'_{412} \) and \( R'_{440} \) : Rayleigh reflectance at 412nm and 440nm bands
  • Dust Smoke Discrimination Index (DSDI)
    • \( DSDI = -10 \log_{10} \left( \frac{R_{412}}{R_{2130}} \right) \)
    • \( R_{412} \) and \( R_{2130} \) : TOA reflectance at 412nm and 2130nm bands
VIIRS Aerosol Detection Product (ADP)

• The detection is based on thresholds of AAI and DSDI, which are different over land and ocean

<table>
<thead>
<tr>
<th>Surface type</th>
<th>Aerosol type</th>
<th>AAI thresholds</th>
<th>DSDI thresholds</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>Dust</td>
<td>&gt; 10</td>
<td>≥ 0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Smoke</td>
<td>≥ 5.0 thin</td>
<td>≤ -3.0 thin</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 9.0 thick</td>
<td>≤ -2.0 thick</td>
<td>0.2&lt;R_{412} &lt;0.4 thick</td>
</tr>
<tr>
<td>Ocean</td>
<td>Dust</td>
<td>&gt; 4.0</td>
<td>≥ -10.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Smoke</td>
<td>≥ 4.5 thin</td>
<td>≤ -10.0 thin</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 10.0 thick</td>
<td>≤ -4.0 thick</td>
<td>R_{2130} &lt; 0.1 thin</td>
</tr>
</tbody>
</table>

Surface type: Land, Ocean
Aerosol type: Dust, Smoke
AAI thresholds: > 10, ≥ 5.0 thin, ≥ 9.0 thick
DSDI thresholds: ≥ 0.0, ≤ -3.0 thin, ≤ -2.0 thick, ≤ -10.0 thin, ≤ -4.0 thick
Other: 0.2<R_{412} <0.4 thick, R_{2130} < 0.1 thin
An example of smoke mask shown on eIDEA (https://www.star.nesdis.noaa.gov/smcd/spb/aq/eidea/)

The dust mask is not shown on eIDEA because of the problems in the following slides.
Problems in dust detection over land

• False detection
• Undetected dust
• Geometry dependent
• Demonstrated in the following cases
Dust storm near Texas/Mexico boundary
Two overpasses
Dust storm near Texas/Mexico boundary

Two overpasses
Since the sun is to the west of the nadir, the overpass at 1902 is in forward reflection geometry and the overpass at 2043 is in backward reflection geometry.
AAI is lower in the backward reflection geometry than that in the forward reflection geometry
An example with the area close to the center of the granule (20170331)

The false detection is more serious in the areas close to the nadir.
Simulation study of AAI vs aerosol load in the three geometries

- Obtain the geometries in the boxes (same area in the three cases)
- Obtain the surface reflectance from surface reflectance database (built from multi-year VIIRS data)
# Parameters for the three cases

<table>
<thead>
<tr>
<th>Case number</th>
<th>description</th>
<th>Lat,lon bound</th>
<th>geometry (sza, vza,azi)</th>
<th>Surface reflectance M1, M2, M3, M5, M11</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20161217 overpass 1</td>
<td>Lat 29.8N-31.8N</td>
<td>forward (54.27, 65.26, 110.86)</td>
<td>0.05, 0.056, 0.067, 0.126, 0.196</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lon 105W-103W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>20161217 overpass 2</td>
<td></td>
<td>backward (60.37, 57.52, 55.80)</td>
<td>0.070, 0.081, 0.098, 0.185, 0.275</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>20170331</td>
<td></td>
<td>nadir (29.11, 13.29, 128.71)</td>
<td>0.076, 0.087, 0.103, 0.182, 0.269</td>
</tr>
</tbody>
</table>
Simulated AAI vs AOD (using LUT in Enterprise AOD algorithm)

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

• Good sensitivity in forward direction, some sensitivity in backward direction, no sensitivity near nadir
• Dust and smoke are similar in AAI
Dust RGB

• Used by EUMETSAT (European Organization for Meteorological Satellites) on MSG (Meteosat Second Generation) (https://www.eumetsat.int/website/home/Data/Training/TrainingLibrary/DAT_2042669.html?lang=EN)

• Three IR bands are used: IR8.7, IR10.8 and IR12.0
  • Brightness temperature at IR10.8 is less than that at IR12.0
    • Surface emissivity in 10.8 µm is similar to that in 12 µm
    • More absorption for dust in 10.8 µm than in 12 µm
  • Brightness temperature is close in IR10.8 and in IR8.7
    • Surface emissivity in 10.8 µm is higher than that in 8.7 µm
    • More absorption for dust in 8.7 µm than in 10.8 µm
Dust RGB

- R: bt12 – bt10.8 (bt– brightness temperature)
- G: bt10.8-bt8.7
- B: bt10.8

- Using this method, dust shows as magenta color over desert

https://www.eumetsat.int/website/home/Data/Training/TrainingLibrary/DAT_2042669.html?lang=EN
The three cases plotted in dust RGB image
Use thresholds to detect dust in IR bands

Determine thresholds through visual inspection of the dust cases

<table>
<thead>
<tr>
<th></th>
<th>thresholds</th>
</tr>
</thead>
<tbody>
<tr>
<td>R: bt12 – bt10.8</td>
<td>&gt; 0</td>
</tr>
<tr>
<td>G: bt10.8-bt8.7</td>
<td>&lt; 0.5 in North America&lt;br&gt; &lt; 4 in North Africa and Arabian Peninsula</td>
</tr>
<tr>
<td>B: bt10.8</td>
<td>&gt; 273</td>
</tr>
</tbody>
</table>
Dust mask (brown color regions) using IR bands for the three cases.
Another case with no dust
20150909 North Africa and Arabian Peninsula

RGB

Dust RGB

AOD

IRDM

ADP
20150909 North Africa and Arabian Peninsula

RGB Dust RGB AOD

False detection in ADP

IRDM ADP
Another case in North Africa 20130823

RGB

Dust RGB

AOD

IRDM

ADP
Summary

• Current ADP dust detection over land using deep blue bands has many areas of false detections
  • Less or no sensitivity of AAI to the aerosol load in some geometries and surface conditions

• An alternative dust detection method based on IR bands is proposed

• Case studies show that using IR bands for dust detection can greatly reduce false detections