Application of DAI-based smoke/dust detection algorithm to VIIRS observations

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JPSS Risk Reduction Algorithm for VIIRS Dust and Smoke Detection

• Adapt GOES-R Advanced Baseline Imager (ABI) aerosol (dust and smoke) detection algorithm
  – For dust, take advantage of deep-blue channels on VIIRS and adapt MODIS dust detection algorithm developed by STAR*

• Simple, fast, and easy to be implemented operationally

• Detects most plumes with good accuracy

*Dust Aerosol Index (DAI) Algorithm for MODIS
Pubu Ciren and Shobha Kondragunta
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• Spectral dependence of three processes allows the dust detection
  ➢ Surface reflectance
  ➢ Rayleigh scattering
  ➢ Dust absorption
6S Radiative Transfer Simulations

6S Simulations:
1. MODIS C5 dust aerosol model used
2. Desert, vegetation, ocean BRDF with easterly wind speed of 6 m/s are used to represent surfaces in 6S

DUST reduces the contrast between 412nm and 440 nm as a result of increasing absorption by dust with decreasing wavelength
MODIS Observations: Dust vs. Clear Sky
Smoke:
- Has the same effect as dust in terms of reduction of the contrast between 412nm to 440nm
- Difference in particle size enables us to pick-out the smoke by introducing short-wave IR channel (2.13 µm)
**Dust Aerosol Index**

\[
DAI = 100 \times [\log_{10}(R'_{412\text{nm}}/R'_{445\text{nm}}) - \log_{10}(R'_{412\text{nm}}/R'_{2.25\mu\text{m}})]
\]

\[
\text{NDAI} = -10 \times [\log_{10}(R_{412\text{nm}}/R_{2.25\mu\text{m}})]
\]

\(R'\) -- reflectance from Rayleigh scattering

- Clouds are first screened by using \(R_{0.42\mu\text{m}}\).
- Residual Clouds over water are screened using 0.86 \(\mu\text{m}\) spatial variability test. Over land, residual clouds are screened by 412 nm spatial variability test. Cirrus clouds are screened using 1.38 \(\mu\text{m}\) test.
- Bright desert surfaces are screened for by bright pixel index (normalized difference of 1.24 \(\mu\text{m}\) and 2.25 \(\mu\text{m}\)).
- Turbid water test based on Shi and Wang, 2007 uses 0.746 \(\mu\text{m}\) and 1.24 \(\mu\text{m}\) measurements.
- Sunglint, snow/ice, fire hot spots are also screened based on different tests (geometry, spectral etc.).
- DAI and NDAI are computed for pixels that pass these tests:
  - Water: \(\text{DAI} \geq 4\) and \(\text{NDAI} \geq -10\)
  - Land: \(\text{DAI} \geq 11.5\) and \(\text{NDAI} \geq 0\)
JPSS RR dust/Smoke Detection

DAI after cloud screening

NDAI after cloud screening

Dust flag

Sunglint flag

Final dust flag
VIIRS Smoke Detection

- The NDAI in the dust algorithm can also indicate the presence of smoke and/or haze mixed in with smoke

<table>
<thead>
<tr>
<th>Surface</th>
<th>Condition</th>
<th>Smoke Detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>DAI ≥ 5.0 and NDAI ≤ -2.0</td>
<td>Thin Smoke</td>
</tr>
<tr>
<td></td>
<td>DAI ≥ 9.0 and NDAI ≤ -2.0</td>
<td>Thick Smoke</td>
</tr>
<tr>
<td>Water</td>
<td>DAI ≥ 4.0 and NDAI ≤ -10.0</td>
<td>Thin Smoke</td>
</tr>
<tr>
<td></td>
<td>$R_{410} &lt; 0.1$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DAI ≥ 9.0 and NDAI ≤ -4.0</td>
<td>Thick Smoke</td>
</tr>
</tbody>
</table>
• Spectral (wavelength dependent) thresholds can separate thick smoke, light smoke, and clear sky conditions.
JPSS RR Dust and Smoke Detection Examples

Smoke over West Coast of United States on September 22, 2012
JPSS RR Dust and Smoke Detection Examples

VIIRS fire hot spots and visible smoke in the RGB image on July 8, 2012

JPSS RR smoke detection algorithm identifies the smoke plumes including the one removed from fire hot spots
VIIRS true color image of blowing dust from different sources in Alaska on April 28, 2013
Validation

• JPSS RR dust detection algorithm run on VIIRS observation for the entire year of 2013.
  – VIIRS smoke/dust frequency vs. CALIPSO and MISR
  – VIIRS smoke and dust detection matchups with CALIPSO and AERONET

• Derive performance metrics
  – Accuracy
  – Probability of Correct Detection (POCD)
  – Probability of False Detection (POFD)

TRUTH DATA

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
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<tbody>
<tr>
<td>VIIRS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>No</td>
<td>C</td>
<td>D</td>
</tr>
</tbody>
</table>

POCD = A/(A+C)
POFD = B/(A+B)
Accuracy* = (A+D)/(A+B+C+D)
VIIRS vs. CALIPSO

January 31, 2013

Accuracy 83%
POCD 85%
DUST

July

2013.07 VIIRS "Dust" Type Frequency

September

2013.09 VIIRS "Dust" Type Frequency

2013.07 CALIPSO VFM "Dust" Type Frequency (High Quality)

2013.09 CALIPSO VFM "Dust" Type Frequency (High Quality)
### JPSS RR Dust Detection Over Land: VIIRS vs. CALIPSO

<table>
<thead>
<tr>
<th>Month (2013)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11*</th>
<th>12</th>
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</thead>
<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td>100.0</td>
<td>99.4</td>
<td>99.9</td>
<td>99.9</td>
<td>98.4</td>
<td>99.4</td>
<td>99.6</td>
<td>98.7</td>
<td>100.0</td>
<td>100.0</td>
<td>-</td>
<td>100.0</td>
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<tr>
<td><strong>POCD</strong></td>
<td>N/A</td>
<td>71.4</td>
<td>77.8</td>
<td>80.0</td>
<td>75.3</td>
<td>73.4</td>
<td>97.9</td>
<td>76.5</td>
<td>N/A</td>
<td>N/A</td>
<td>-</td>
<td>N/A</td>
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<tr>
<td><strong>POFD</strong></td>
<td>N/A</td>
<td>50.0</td>
<td>8.7</td>
<td>42.8</td>
<td>13.5</td>
<td>53.4</td>
<td>39.4</td>
<td>35.3</td>
<td>N/A</td>
<td>N/A</td>
<td>-</td>
<td>N/A</td>
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* CALIPSO data not available
## JPSS RR Dust Detection Over Water: VIIRS vs. CALIPSO

### Month (2013)

<table>
<thead>
<tr>
<th></th>
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<th>4</th>
<th>5</th>
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<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
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</thead>
<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td>99.8</td>
<td>99.8</td>
<td>99.9</td>
<td>99.9</td>
<td>99.6</td>
<td>99.7</td>
<td>99.8</td>
<td>100.0</td>
<td>100.0</td>
<td>-</td>
<td>100.0</td>
<td></td>
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<tr>
<td><strong>POCD</strong></td>
<td>54.2</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>80.0</td>
<td>94.8</td>
<td>91.8</td>
<td>N/A</td>
<td>N/A</td>
<td>-</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td><strong>POFD</strong></td>
<td>56.6</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>46.1</td>
<td>49.5</td>
<td>47.6</td>
<td>N/A</td>
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<td>-</td>
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* CALIPSO data not available
# JPSS RR Dust Detection: VIIRS vs. AERONET

<table>
<thead>
<tr>
<th>Stations</th>
<th>True positive</th>
<th>False positive</th>
<th>True negative</th>
<th>False negative</th>
<th>Accuracy</th>
<th>POCD</th>
<th>POFD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banizoumbou</td>
<td>10</td>
<td>1</td>
<td>65</td>
<td>12</td>
<td>85.2</td>
<td>45.4</td>
<td>9.0</td>
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<tr>
<td>Darkar</td>
<td>1</td>
<td>0</td>
<td>25</td>
<td>1</td>
<td>96.3</td>
<td>50.0</td>
<td>0.0</td>
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<tr>
<td>IER_Cinzana</td>
<td>2</td>
<td>0</td>
<td>23</td>
<td>1</td>
<td>96.2</td>
<td>66.6</td>
<td>0.0</td>
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<tr>
<td>Solar_Village</td>
<td>6</td>
<td>5</td>
<td>29</td>
<td>4</td>
<td>79.5</td>
<td>60.0</td>
<td>45.4</td>
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<tr>
<td>Capo_Verde</td>
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<td>1</td>
<td>9</td>
<td>0</td>
<td>91.6</td>
<td>100.0</td>
<td>33.3</td>
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<tr>
<td>Cape_San_Juan</td>
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<td>2</td>
<td>18</td>
<td>0</td>
<td>90.4</td>
<td>100.0</td>
<td>66.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Over 401 AERONET stations</th>
<th>Accuracy</th>
<th>POCD</th>
<th>POFD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of 2013</td>
<td>99.8</td>
<td>86.9</td>
<td>39.3</td>
</tr>
</tbody>
</table>
Summary

• An algorithm based on observations from deep-blue and shortwave-IR developed for MODIS has been adapted for VIIRS.
  – Algorithm is simple, fast, and easy to be implemented operationally.
• Dust and smoke detections meet L1RD requirements
• Additional validation on smoke detection is needed
• Additional investigation of data artifacts (false detections) is required to enhance product accuracy