MODIS Compositing and Forest Change Detection

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Landsat Science Team Meeting
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Boise, Idaho
Background

• Need information to prioritize sketch mapping aerial detection survey flights
  – 2-4 week response time
  – Guidance on where to go vs. where not to go (omission and commission error important)

• Standardized and repeatable method for producing spatial summaries of forest disturbance
Insect damage characteristics

Mountain pine beetle

Gypsy moth defoliation

Balsam bark beetle

Larch casebearer
Basic change detection steps

1) Create vegetation baseline (5 years of MODIS data)
2) Process current-year data (to match baseline)
3) Derive analysis classes (both static and dynamic)
   - control for effects of forest cover differences and BRDF
     - FIA forest group classes (static)
     - scattering angle classes (dynamic)
4) Class-wise statistical analysis (resistant z-scores; RZ)
5) Calculate anomaly scores ($\Delta RZ$) between current-year and baseline data
6) Derive vegetation indices based on anomaly scores
Basic change detection steps

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Why MODIS?

• High Temporal Grain (daily)
  - permits frequent observations to capture disturbances with very finite temporal windows
• High Spectral Grain (blue, green, red, NIR, and MIR wavelengths)
  - disturbances in forest health discernable using spectral indices (NDVI, NDMI, NDFI)
• RSAC’s MODIS ground station makes for easy access to MODIS data.
• Coarse resolution makes the MODIS data more manageable and more area is covered with a single path.
Current MODIS Data – 16-day Composites

Compositing periods overlap - Data delivered every 8 days
Compositing Process

- Imports MODIS AQUA and TERRA L2 data from HDF to IMG format.
- Reprojects to CONUS Albers NAD 83.
- Throws out pixels with viewing angles $\geq 50$ degrees.
- Computes NDVI.
- Compares NDVI values for a pixel over the time period.
- Selects the pixel with the highest NDVI value.
**Example**

If an 8-day composite was being created

**NDVI Values**

<table>
<thead>
<tr>
<th></th>
<th>0.539</th>
<th>0.574</th>
<th>0.540</th>
<th>0.480</th>
<th>0.552</th>
<th>0.102</th>
<th>0.034</th>
<th>0.559</th>
</tr>
</thead>
</table>

Low NDVI values indicates clouds.

Use this day’s data for the composite.
Compositing Process

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- Throws out pixels with viewing angles $\geq 50$ degrees.
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However . . . .
Problem: Different Resolutions

MODIS Bands 1 & 2, which are used to calculate NDVI, are 250 m resolution. Bands 3 – 7, which are included in the composites are 500 m resolution.

Good pixel in Bands 1 & 2, but cloud pixel in the other bands resulting in halo effects around clouded areas in the composites.
Solution

- Calculated mean standard deviations on bands 1, 2, 3, 4, 7. Bands 5 & 6 were excluded due to Terra and Aqua banding.

- High standard deviations in 5x5 window of 250 m pixel = potential border pixel with cloud.
Problem: Shadows

• Tried a lot of different things such as
  – Thresholding
  – Using tassel cap brightness as a shadow indicator
  – Various unsupervised classification techniques
Solution:

- Sum bands 1, 2, and 4 and rank the sums
- The higher the ranking, the greater the likelihood of no shadows.

<table>
<thead>
<tr>
<th>Band</th>
<th>Bandwidth $^1$</th>
<th>Spectral Radiance $^2$</th>
<th>Required SNR $^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>620 - 670</td>
<td>21.8</td>
<td>128</td>
</tr>
<tr>
<td>2</td>
<td>841 - 876</td>
<td>24.7</td>
<td>201</td>
</tr>
<tr>
<td>3</td>
<td>459 - 479</td>
<td>35.3</td>
<td>243</td>
</tr>
<tr>
<td>4</td>
<td>545 - 565</td>
<td>29.0</td>
<td>228</td>
</tr>
<tr>
<td>5</td>
<td>1230 - 1250</td>
<td>5.4</td>
<td>74</td>
</tr>
<tr>
<td>6</td>
<td>1628 - 1652</td>
<td>7.3</td>
<td>275</td>
</tr>
<tr>
<td>7</td>
<td>2105 - 2155</td>
<td>1.0</td>
<td>110</td>
</tr>
</tbody>
</table>

Bandwidth units = nm  
Spectral Radiance = W/m$^2$·μm·sr  
SNR = Signal-to-noise ratio
Selecting The Pixel To Composite

If an 8-day composite was being created

NDVI Values

0.539  0.574  0.540  0.412  0.552  0.102  0.032  0.559

NDVI values are within ± .10. Any of these days could be used for the composite.
Selecting The Pixel To Composite

If an 8-day composite was being created

**NDVI Values**

| 0.539 | 0.574 | 0.540 | 0.412 | 0.552 | 0.102 | 0.032 | 0.559 |

**Mean Focal (5x5) Standard Deviation Values**

| 324 | 471 | **214** | 220 | 302 | 1300 | 130 | 396 |

Of the five pixels with high NDVI values, this pixel has the lowest standard deviation.
Selecting The Pixel To Composite

If an 8-day composite was being created

<table>
<thead>
<tr>
<th>NDVI Values</th>
<th>Mean Focal (5x5) Standard Deviation Values</th>
<th>Ranking of sum of bands 1, 2, 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.539</td>
<td>324</td>
<td>70</td>
</tr>
<tr>
<td>0.574</td>
<td>471</td>
<td>80</td>
</tr>
<tr>
<td>0.540</td>
<td>214</td>
<td>60</td>
</tr>
<tr>
<td>0.412</td>
<td>220</td>
<td>70</td>
</tr>
<tr>
<td>0.552</td>
<td>302</td>
<td>60</td>
</tr>
<tr>
<td>0.102</td>
<td>1300</td>
<td>100</td>
</tr>
<tr>
<td>0.032</td>
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</tr>
<tr>
<td>0.559</td>
<td>396</td>
<td>80</td>
</tr>
</tbody>
</table>

Of the five pixels with high NDVI values, these pixels have the highest ranking.
Selecting The Pixel To Composite

If an 8-day composite was being created

**NDVI Values**

| 0.539 | 0.574 | 0.540 | 0.412 | 0.552 | 0.102 | 0.032 | 0.559 |

**Mean Focal (5x5) Standard Deviation Values**

| 324   | 471   | 214   | 220   | 302   | 1300  | 130   | 396   |

**Ranking of sum of bands 1, 2, 4**

| 70   | 80   | 60   | 70   | 60   | 100   | 100   | 80   |
Selecting The Pixel To Composite
If an 8-day composite was being created

The date for these pixels would be used for the composite because:
- High NDVI
- Standard deviation is reasonable.
- High ranking for the sum of bands 1,2,4.
AQUA MODIS Composite 17 May – 1 Jun 2010
Surface Reflectance (bands 2,1,4)
AQUA MODIS Composite 17 May – 1 Jun 2010

Dates
2010 Hotspots

Louisiana Forest Tent Catepillar and Baldcypress Leafroller
2010 Hotspots

Pennsylvania Forest Tent Catepillar

Louisiana Forest Tent Catepillar and Baldcypress Leafroller
2010 Hotspots

- Michigan Forest Tent Catepillar
- Pennsylvania Forest Tent Catepillar
- Louisiana Forest Tent Catepillar and Baldcypress Leafroller
2010 Hotspots

- Michigan Forest Tent Catepillar
- Pennsylvania Forest Tent Catepillar
- Mississippi tornado
- Louisiana Forest Tent Catepillar and Baldcypress Leafroller
Louisiana Forest Tent Caterpillar and Baldcypress Leafroller

MODIS Aqua Composite March 22 - April 6, 2010
Forest Tent Caterpillar Defoliation?
MODIS Composite Date: March 22 – April 6

Polygons are aerial survey results from April 24, 2010
MODIS Composite Date: March 30 – April 14
MODIS Composite Date: April 7 – 22
Pennsylvania Forest Tent Caterpillar
MODIS Composite Date: Apr 15 – Apr 30
Pennsylvania Forest Tent Catepillar
MODIS Composite Date: Apr 23 – May 8
Michigan Forest Tent Catepillar
MODIS Composite Date: 15 Apr – 30 Apr
Michigan Forest Tent Caterpillar
MODIS Composite Date: 23 Apr – 8 May
Michigan Forest Tent Caterpillar
MODIS Composite Date: 1 May – 16 May
Northern CA – developing disturbances?
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Detecting 2010 storm damage

• Tracking tornado and wind reports on NWS Storm Prediction Center Website:
  http://www.spc.noaa.gov/climo/reports/
  – 6 big storm activity days (in forested regions) so far in 2010:
    4/24/10
    4/30/10
    5/1/10
    5/10/10
    5/12/10
    5/19/10
  – 197 tornado reports
  – 428 wind reports
Detecting 2010 storm damage

<table>
<thead>
<tr>
<th>Date</th>
<th>Tornado</th>
<th>Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 24</td>
<td>▲</td>
<td>●</td>
</tr>
<tr>
<td>April 30</td>
<td>△</td>
<td>●</td>
</tr>
<tr>
<td>May 1</td>
<td>▲</td>
<td>●</td>
</tr>
<tr>
<td>May 10</td>
<td>△</td>
<td>●</td>
</tr>
<tr>
<td>May 12</td>
<td>▲</td>
<td>●</td>
</tr>
<tr>
<td>May 19</td>
<td>▲</td>
<td>●</td>
</tr>
</tbody>
</table>
Mississippi tornado (April 24, 2010)
MODIS Composite Date: 23 Apr – 8 May
Mississippi tornado (April 24, 2010)
MODIS Composite Date: 1 May – 16 May
The End

Comments/Questions?

USDA Forest Service, Remote Sensing Applications Center,
FSWeb: http://fsweb.rsac.fs.fed.us
WWW: http://www.fs.fed.us/eng/rsac/