Satellite Imagery Access, Interpretation, and Tools for Dust, Smoke, and Pollution Monitoring

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Satellite Remote Sensing of Air Quality, 18-19 November 2018
Learning Objectives

By the end of this presentation, you will be able to:

• Recognize satellite imagery, label features, and recite applications of satellite imagery

• Access and perform basic analysis of satellite imagery
Visible Image Science

• Visible satellite images are essentially photographs
• All the energy collected by the visible sensors (cameras) onboard the satellite is light energy from the sun, reflected by the Earth
• The reflectance is a measure of albedo, which is the percentage of light energy reflected by the Earth
• The higher the albedo, the more light reflected back into space (i.e. clouds appear bright)
• The lower the albedo, the more light energy is absorbed (i.e. water appears dark)
Wavelength Selection

Earth observing satellite remote sensing instruments typically make observations at many discrete wavelengths, or **wavelength bands**.
RGB Imagery

• Create an image using any 3 bands
• Load red, green, and blue satellite bands into corresponding display channels
• Simulates what the human eye sees
True Color Image (or RGB)

A MODIS “true color image” will use MODIS visible wavelength bands 1, 4, 3

R = 0.66 µm
G = 0.55 µm
B = 0.47 µm
Moderate Resolution Imaging Spectroradiometer (MODIS)

- Spatial Resolution
  - 250 m, 500 m, 1 km
- Platform
  - Terra & Aqua
- Temporal Resolution
  - 2000 – present
    - Daily, 8-day, 16-day, monthly, quarterly, yearly
- Data Format
  - Hierarchical Data Format – Earth Observing System (HDF-EOS)

- Spectral Coverage
  - 36 bands (major bands include red, blue, IR, NIR, MIR)
    - Bands 1-2: 250 m
    - Bands 3-7: 500 m
    - Bands 8-36: 1,000 m
## MODIS Reflected Solar Bands

<table>
<thead>
<tr>
<th>Primary Use</th>
<th>Band No</th>
<th>Bandwidth (nm)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land/Cloud</td>
<td>1**</td>
<td>620-670</td>
<td>500m Spatial Resolution</td>
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<tr>
<td>Boundaries</td>
<td>2**</td>
<td>841-876</td>
<td>250m Spatial Resolution</td>
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<tr>
<td>Land/Cloud</td>
<td>3*</td>
<td>459-479</td>
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<tr>
<td>Properties</td>
<td>4*</td>
<td>545-565</td>
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<td>5*</td>
<td>1230-1250</td>
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<td>6*</td>
<td>1628-1652</td>
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<td></td>
<td>7*</td>
<td>2105-2155</td>
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<tr>
<td>Ocean Color/</td>
<td>8</td>
<td>405-420</td>
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<tr>
<td>Phytoplankton/</td>
<td>9</td>
<td>438-448</td>
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<tr>
<td>Biogeochemistry</td>
<td>10</td>
<td>483-493</td>
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<td>11</td>
<td>526-536</td>
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<td>12</td>
<td>546-556</td>
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<td>13</td>
<td>662-672</td>
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<td>14</td>
<td>673-683</td>
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<td>15</td>
<td>743-753</td>
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<td></td>
<td>16</td>
<td>862-877</td>
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<tr>
<td>Atmospheric</td>
<td>17</td>
<td>890-920</td>
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<tr>
<td>Water Vapor</td>
<td>18</td>
<td>931-941</td>
<td></td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>915-965</td>
<td></td>
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</tbody>
</table>
VIIRS Image
Doing More with Satellite Imagery

If we understand the physics of how particular wavelengths interact with objects we can create images to emphasize what we want to see

Visible imagery water is dark because it absorbs most of the energy

Clouds are white because they reflect most incoming energy

Pollution is hazy depending on its absorption properties
What can we learn from true color imagery?

(Possible) identification of land, ocean, and atmosphere features
What can we learn from true color imagery?

(Possible) identification of land, ocean, and atmosphere features.
Features in True Color (Atmosphere)
Glint
Feature Identification
More reliable with clear source in image

- Australian Dust
- Sangeang Api, Indonesia
- Urban-industrial/smoke pollution?
- Urban-industrial/smoke pollution?
Feature Identification

More reliable when a clear source is in the image

Saharan dust

Wildfire Smoke

Oil Fires in Iraq

Smoke from Alaskan wildfires (2004)
Using Time Series Imagery

Dust Transport

April 6, 2013; Images from NASA Worldview

Terra: ~10:30 a.m.

Aqua: ~1:30 p.m.
Terra: ~10:30 a.m.

Aqua: ~1:30 p.m.

April 8, 2013; Images from NASA Worldview
Geostationary Observations – GOES-16 (East)

Source: [http://rammb-slider.cira.colostate.edu](http://rammb-slider.cira.colostate.edu)
GOES-16 Loop: Dust

Watch for blowing dust sources at these locations

Image: NOAA CoRP. STAR: http://rammb.cira.colostate.edu/ramsdis/online/loop.asp?data_folder=loop_of_the_day/goes-16/20170330000000&number_of_images_to_display=100&loop_speed_ms=100
HIMAWARI-8 Loop: Fog and Smoke over Australia

Image: NOAA CoRP, STAR: http://rammb.cira.colostate.edu/ramsdis/online/loop.asp?data_folder=loop_of_the_day/himawari/20160107000000&number_of_images_to_display=100&loop_speed_ms=100
GOES-16 Loop: Smoke Over the Southeast U.S.

Image: NOAA CoRP. STAR: http://rammb.cira.colostate.edu/ramsdis/online/loop.asp?data_folder=loop_of_the_day/goes-16/20170306000000&number_of_images_to_display=100&loop_speed_ms=100
False Color Images

- Load bands into the red, green, and blue display channels
- Do not correspond to the visible red, green, and blue wavelengths

\[
\begin{align*}
R &= 1.6 \, \mu m \\
G &= 1.2 \, \mu m \\
B &= 2.1 \, \mu m
\end{align*}
\]
True vs. False Color Images

R = 0.66 µm  
G = 0.55 µm  
B = 0.47 µm

R = 1.6 µm  
G = 1.2 µm  
B = 2.1 µm
Change in Vegetation Color from Space
Earth Observatory Story

An article on feature detection in an image:

http://earthobservatory.nasa.gov/Features/ColorImage/page2.php
Image Archive and Gallery Links

- ARSET Satellite Imagery Overview and links
- MODIS Rapid Response Site
- NASA’s Visible Earth
  - [http://visibleearth.nasa.gov](http://visibleearth.nasa.gov)
- NASA’s Earth Observatory
  - [http://earthobservatory.nasa.gov](http://earthobservatory.nasa.gov)
- NASA’s Earth Observations (NEO)
  - [http://neo.sci.gsfc.nasa.gov](http://neo.sci.gsfc.nasa.gov)
- MODIS-Atmos (MODIS Atmosphere Product Reference Site)
- GLIDER Tool
  - [http://www.ssec.wisc.edu/hydra](http://www.ssec.wisc.edu/hydra)
Tour of Some Useful Image Archives

• Earth Observatory: Events & More
  – http://earthobservatory.nasa.gov

• Worldview: Near Real-Time
  – http://earthdata.nasa.gov/labs/worldview
Questions & Discussion Prompts

• What are the differences between true color and false color images?

• What are three applications of true color images for air quality monitoring?

• Does access of near real-time, true color imagery provide any useful information to air quality forecasters?
Questions?