Smoke Monitoring from Space

Melanie Follette-Cook, Pawan Gupta, and Bryan Duncan

Learning Objectives

By the end of this presentation, you will be able to:
• describe existing satellite capabilities for smoke monitoring
• describe available smoke products and their applications
Fires in Pictures – Google Image Search
Forest Fires in Pictures - Google Image Search
Agriculture Fires in Pictures - Google Image Search
Waste Burning in Pictures - Google Image Search
Importance of Smoke and Fire Monitoring
Fire Detection From Satellites

- By detecting smoke
- By detecting temperature anomaly
- By detecting light
Visible Smoke From Fires
Spectral Signatures - Smoke Over Land

Zhao et al., 2010
Spectral Signatures - Smoke Over Ocean

Zhao et al., 2010
Smoke Detection Example (Zhao et al., 2010)
Smoke Monitoring Tools – Worldview

NRT Data & Image Access

- Visible Imagery (MODIS, VIIRS)
- Fire Detection (MODIS, VIIRS)
- Aerosol Optical Depth (MODIS, OMI, MISR)
- Aerosol Index (OMI)
- Day-Night Band (VIIRS)
Smoke Monitoring Tools – MISR Plume Height

https://misr.jpl.nasa.gov/getData/accessData/MisrMinxPlumes2/
HIMAWARI-8

Smoke and smog over India – 11/8/2016

http://rammb.cira.colostate.edu/ramsdis/online/images/loop_of_the_day/himawari/2016110800000/video/2016110800000_india.gif
HIMAWARI-8

Eruption of Sinabung – 2/19/2018

http://rammb.cira.colostate.edu/ramsdis/online/images/loop_of_the_day/himawari/20180219000000/video/20180219000000_sinabung.gif
Other Tools

• NASA’s GEOS-5 Aerosol Forecasts: https://portal.nccs.nasa.gov/cgi-fp/fp_2d_chem.cgi
  – Click on the 7-SEAS region

• NRL Forecasts: https://www.nrlmry.navy.mil/aerosol/#currentaerosolmodeling
Questions?
Satellite Based Fire Products: Methods, Data Access, and Applications

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MODIS

- **Spatial Resolution**
  - 250 m, 500 m, 1 km

- **Temporal Resolution**
  - Daily, 8 day, 16 day, monthly, quarterly, yearly
  - 2000–present

- **Data Format**
  - Hierarchical data format – Earth Observing System Format (HDF–EO8)

- **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: 1000 m
MODIS Active Fire Products (MOD04A1/MYD04A1)

- Near Real-Time (NRT) thermal anomalies and fire locations
- Provides snapshots of active burning fires and burned areas
- The Active Fire product delivers actively burning locations on a daily basis at 1 km resolution (additional 8 day and monthly products)

Global Fire Map (September 17 – 26, 2016)

Colors range from red, where the fire count is low, to yellow where the number of fires is large
MODIS Thermal Anomalies Algorithm

- MODIS Fire Detection:
  - 1 km pixel flagged as containing one or more fires
  - can also detect volcanic signatures

- Significant increase in absolute radiance at 4 µm (band 22) and 11 µm (band 31)
  - cloud masks applied
  - VIIRS active fire detection algorithm is similar

VIIRS fire detections, NASA Worldview
MODIS C6 Fire Detection Algorithm

http://modis-fire.umd.edu/pages/manuals.php

**Table 2: MODIS channels used for active-fire detection and characterization.**

<table>
<thead>
<tr>
<th>Channel</th>
<th>Central wavelength (µm)</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.65</td>
<td>Sun glint and coastal false alarm rejection; cloud masking.</td>
</tr>
<tr>
<td>2</td>
<td>0.86</td>
<td>Bright surface, sun glint, and coastal false alarm rejection; cloud masking.</td>
</tr>
<tr>
<td>7</td>
<td>2.1</td>
<td>Sun glint and coastal false alarm rejection.</td>
</tr>
<tr>
<td>21</td>
<td>3.96</td>
<td>High-range channel for fire detection and characterization.</td>
</tr>
<tr>
<td>22</td>
<td>3.96</td>
<td>Low-range channel for fire detection and characterization.</td>
</tr>
<tr>
<td>31</td>
<td>11.0</td>
<td>Fire detection, cloud masking.</td>
</tr>
<tr>
<td>32</td>
<td>12.0</td>
<td>Cloud masking.</td>
</tr>
</tbody>
</table>

- Potential fire pixel identified
  - 0.86 reflectance < 0.35
  - BT4 > BT4* (where 300 K ≤ BT4* ≤ 330 K)
  - BT4 – BT11 > ΔBT* (where 10 K ≤ ΔBT* ≤ 35 K)
- Otherwise flagged as non-fire pixel
MODIS Thermal Anomalies Algorithm

- Limitations
  - False positives: small forest clearings (bare soil)
  - Large fire omissions due thick smoke
- Collection 6 (most recent) improves upon these errors
  - Global commission error of 1.2%

MODIS fire detections, NASA Worldview
MODIS Land Products: Burned Area (MCD64A1)

• The combined Terra & Aqua MODIS Burned Area Product is a monthly gridded 500m product
• MODIS detects the approximate date of burning at 500m resolution
• Maps include the spatial extent of recent fires
• For more information: http://modis-fire.umd.edu

This image shows the extent of the Long Draw fire that occurred in southeastern Oregon. The colors represent the approximate day of the burning from July 8 (start of fire) to July 12, 2012 (end of fire)
Where to Obtain MODIS Fire Products

**Archived data**


NASA Earthdata: [https://earthdata.nasa.gov/](https://earthdata.nasa.gov/)

**Near Real Time (NRT)**

Worldview: [http://worldview.earthdata.nasa.gov](http://worldview.earthdata.nasa.gov)
(archived data also accessible)

Fire Information for Resource Management System (FIRMS)

- Near real-time (NRT) active fire data within 3 hours of satellite overpass
- Global MODIS and VIIRS fire locations
- Historical data available
- Available in:
  - Email alerts
  - GIS-friendly file format
  - Visualization in Web Fire Mapper or Worldview
VIIRS Active Fire Product

- Released October 22, 2012
- Spatial resolution:
  - 750 m (M-band)
  - 375 m (I-band)
- Data still preliminary and continually undergo evaluation & calibration
- Data available as:
  - ASCII
  - KMZ
  - TIFF
- Exercise on this tool in upcoming session
VIIRS Active Fire Map

http://viirsfire.geog.umd.edu/map/viirsMap.php
Where to Obtain VIIRS Land Products

**Worldview:** [http://worldview.earthdata.nasa.gov](http://worldview.earthdata.nasa.gov)

**VIIRS Active Fire:** [http://viirsfire.geog.umd.edu/pages/about.php](http://viirsfire.geog.umd.edu/pages/about.php)

**NOAA Comprehensive Large Array-Data Stewardship System (CLASS):**
[http://www.class.ngdc.noaa.gov/saa/products/welcome](http://www.class.ngdc.noaa.gov/saa/products/welcome)

**Level-1 and Atmosphere Archive & Distribution System:**
[http://ladsweb.nascom.nasa.gov](http://ladsweb.nascom.nasa.gov)
References

• User guides for the MODIS active fire and burned area products

• VIIRS Active Fire page:
  – http://viirsfire.geog.umd.edu/

• NASA VIIRS Land Products
Questions & Discussion Prompts

• Changes in what retrieved quantity are used to detect fires?

• What is a source of uncertainty for fire detection?