

Credit: TROPOMI, ESA, Copernicus, KNMI

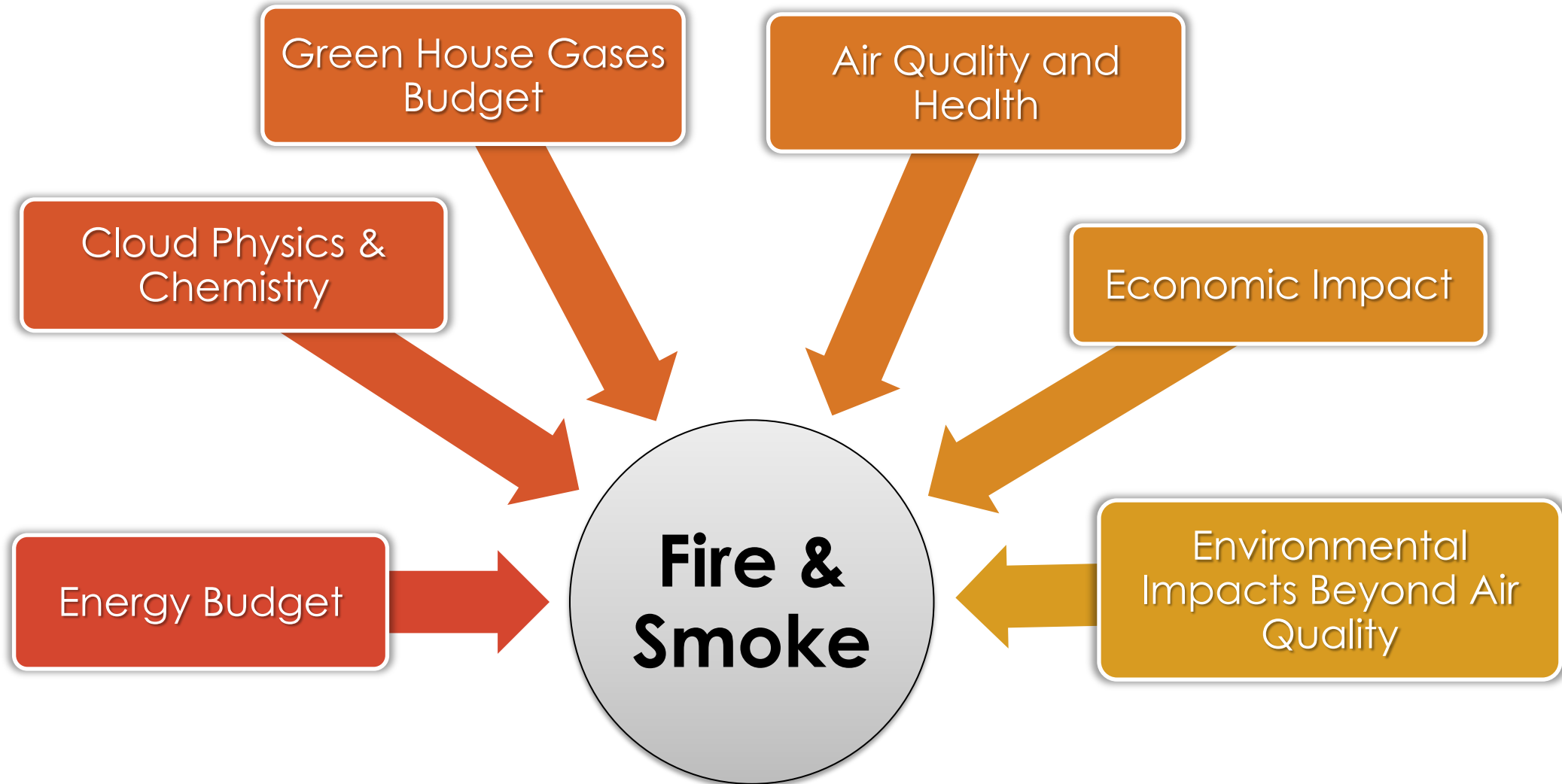


Satellite Detection of Fires and Smoke Transport

Melanie Follette-Cook and Pawan Gupta

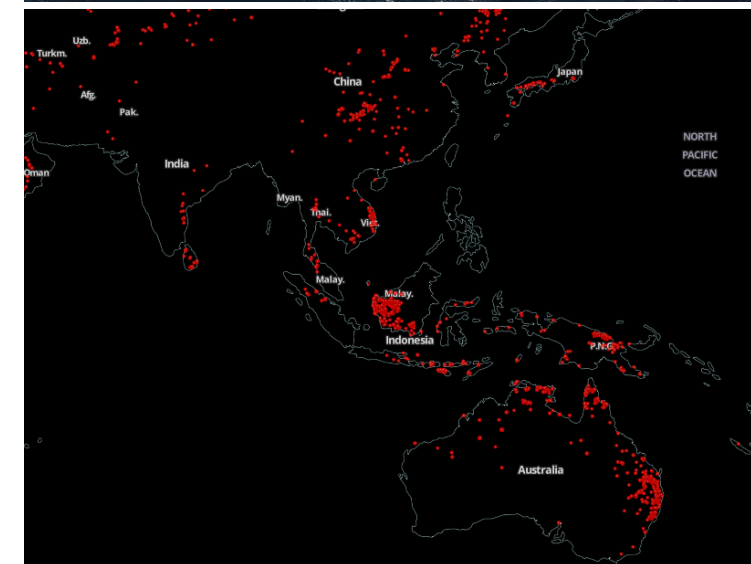
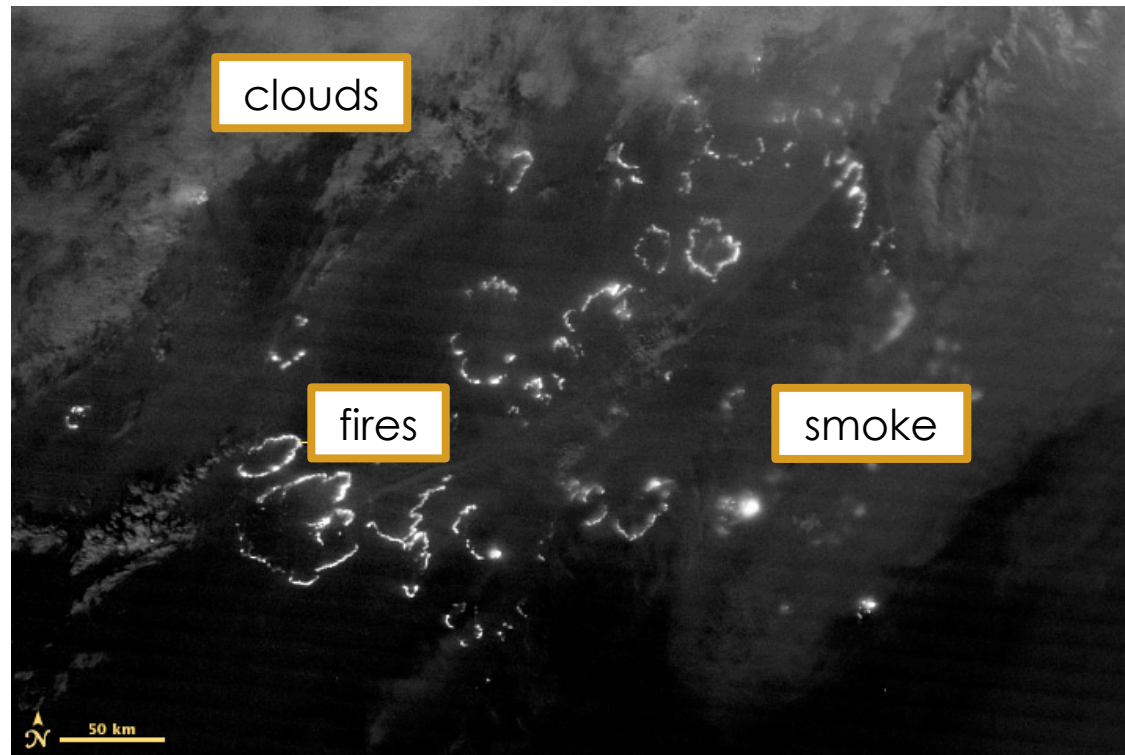
Application of Satellite Observations for Air Quality and Health Exposure, Oct 9 and 11, 2019

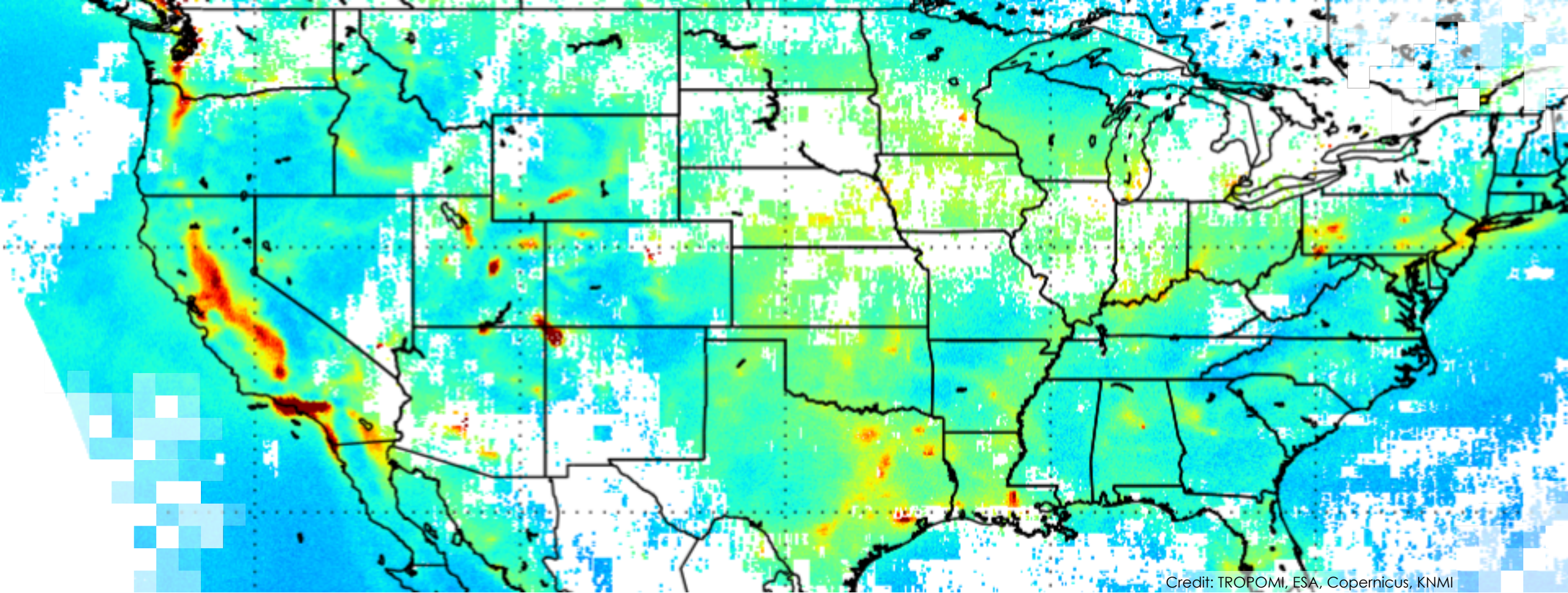
Importance of Smoke and Fire Monitoring



Fire Detection From Satellites

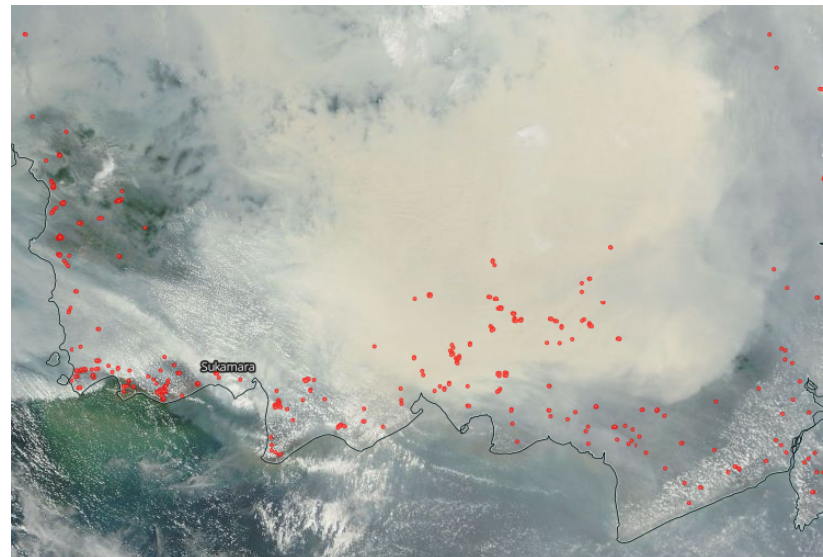
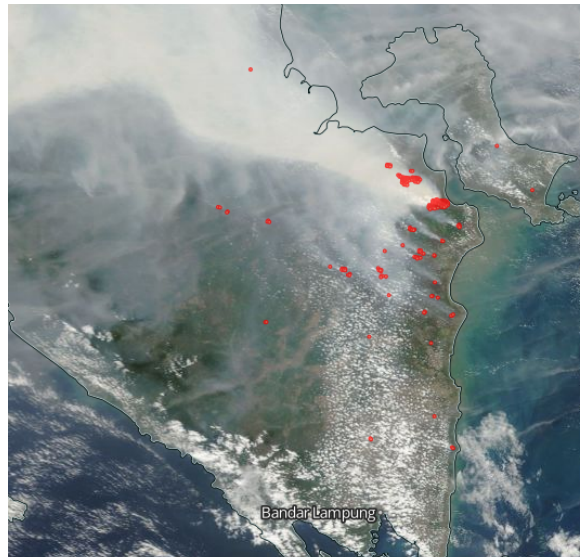
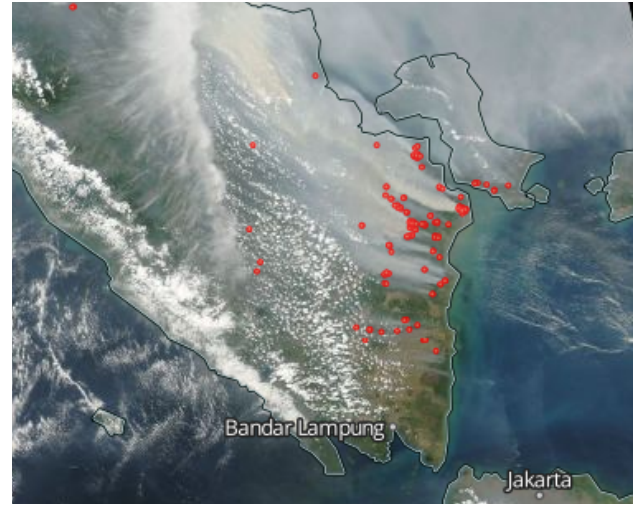
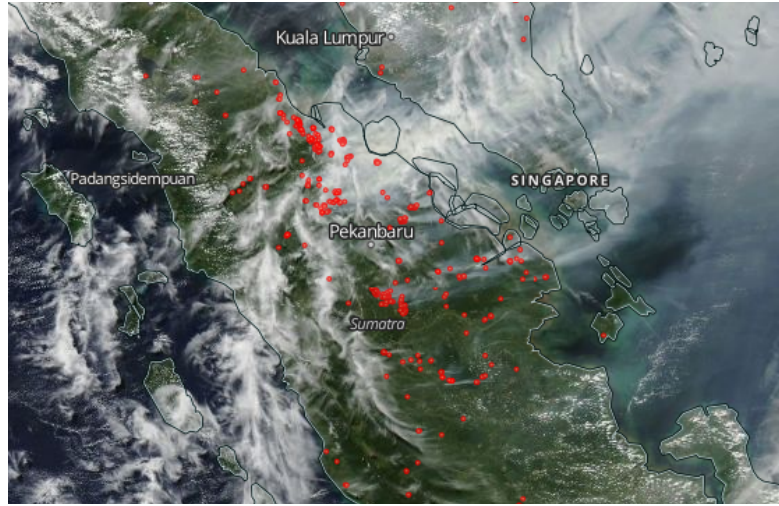
- By detecting smoke
- By detecting temperature anomaly
- By detecting light



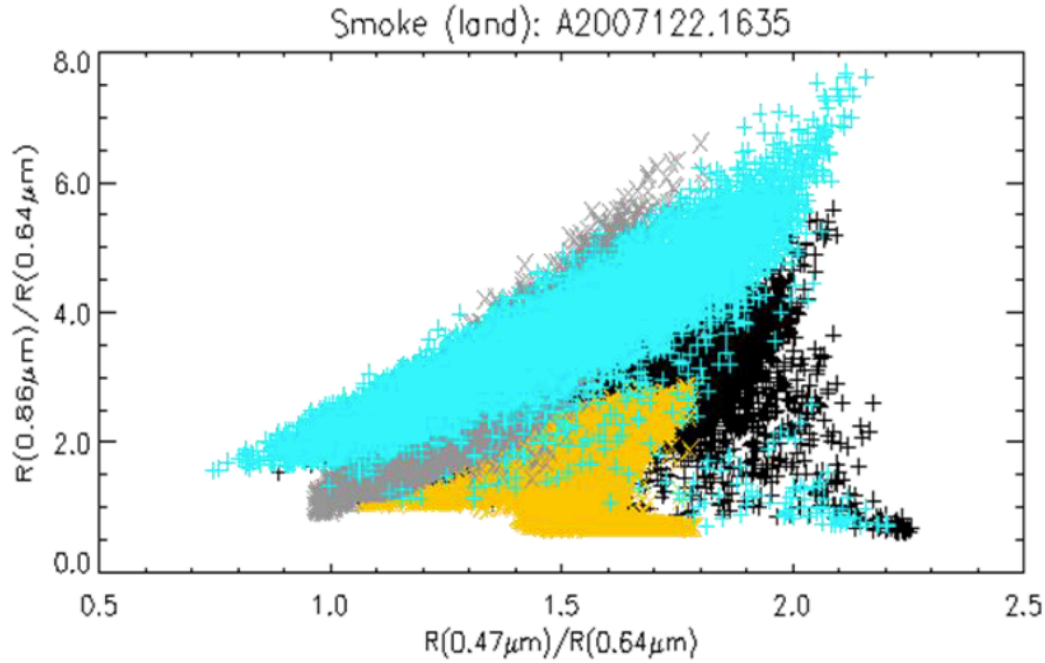


Smoke Transport

Visible Smoke From Fires

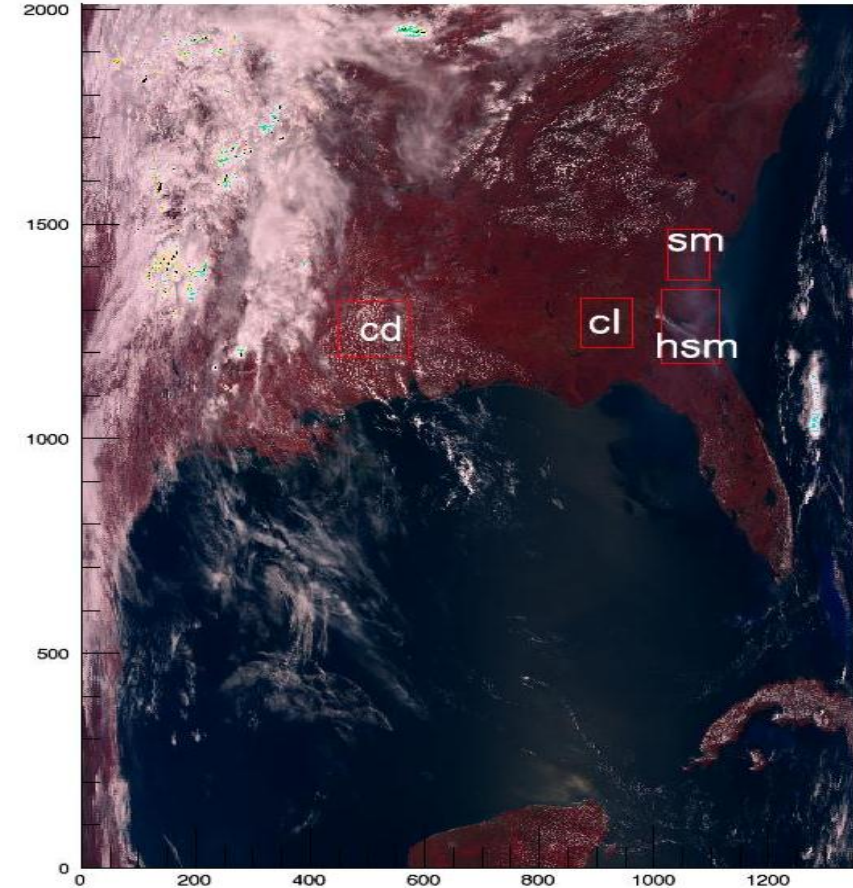


Spectral Signatures - Smoke Over Land

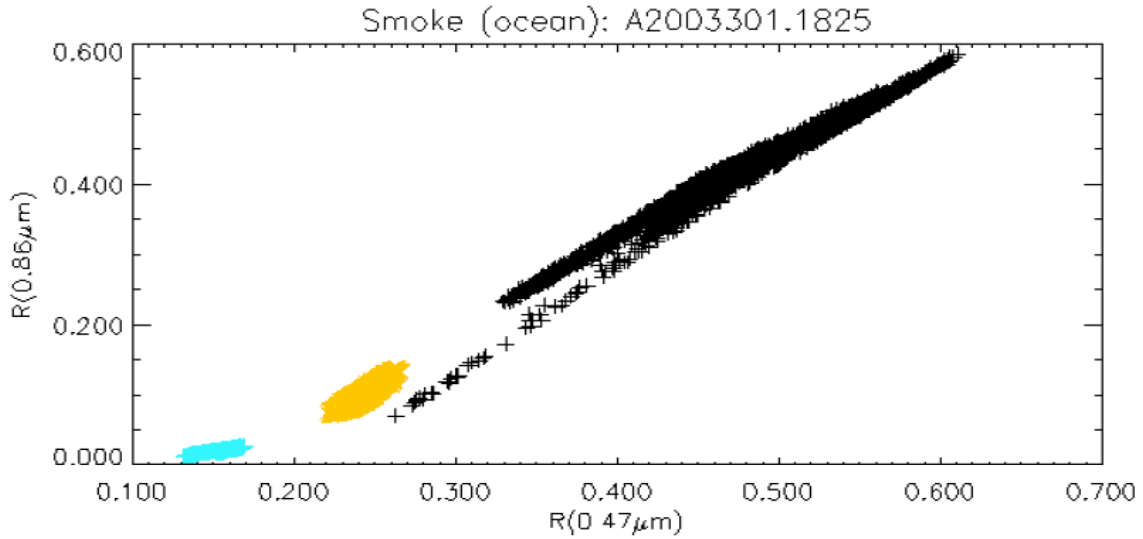


Clear sky
Smoke
Heavy smoke
Clouds

Smoke Case (May 2, 2007; 16:35UTC; Terra)
RGB (2007122.1635)

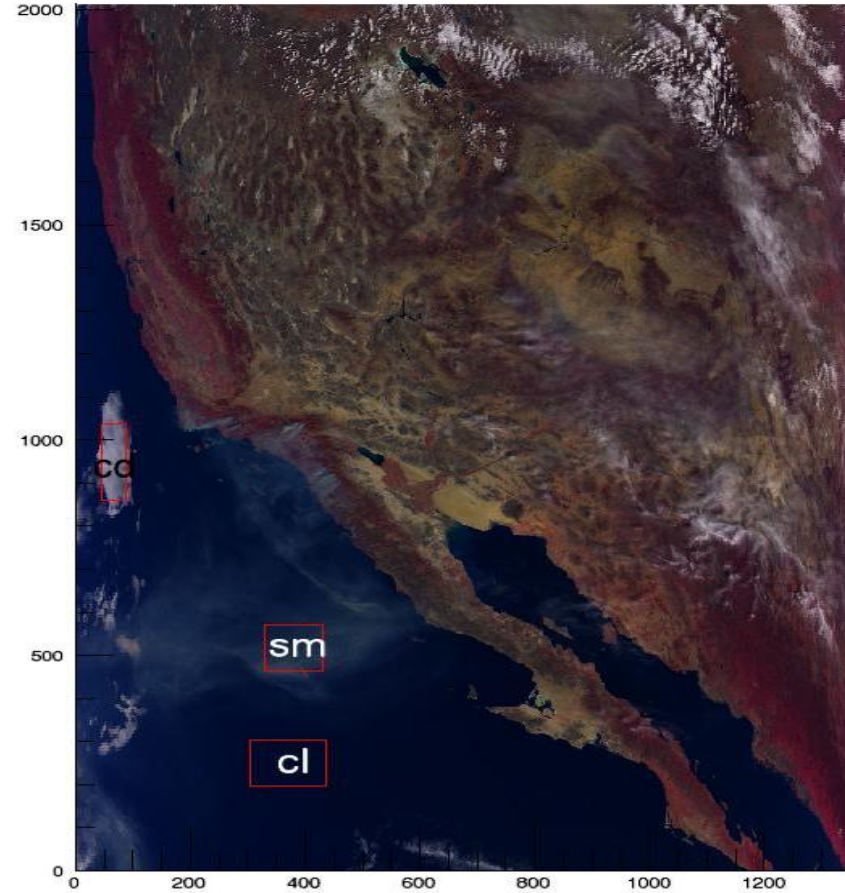


Spectral Signatures - Smoke Over Ocean

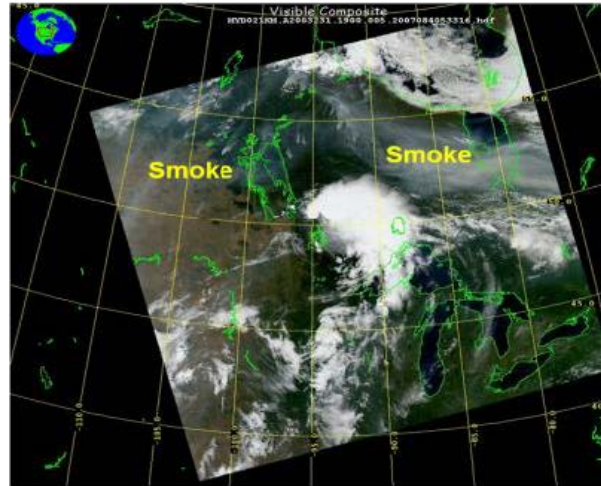


Clear sky
Cloud
Smoke

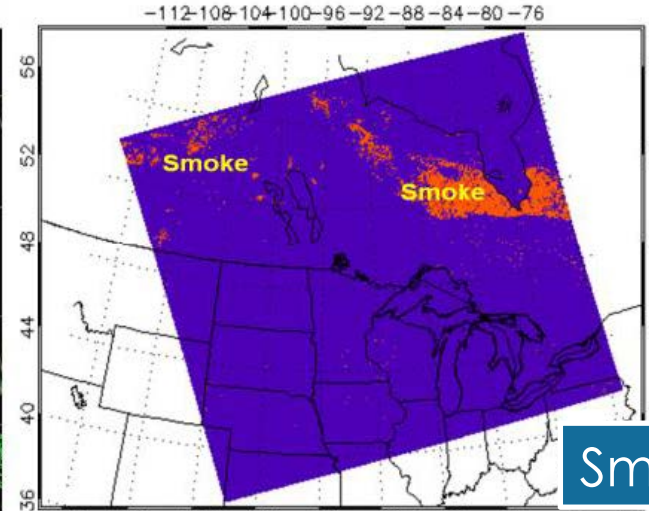
Smoke Case (Oct. 28, 2003; 18:25UTC; Terra)
RGB (2003301.1825)



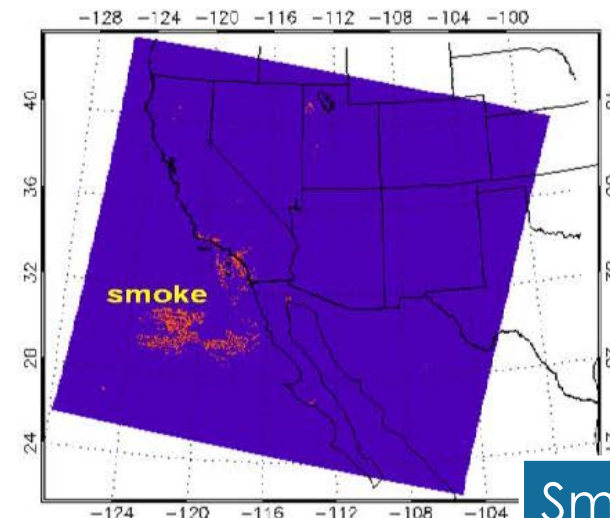
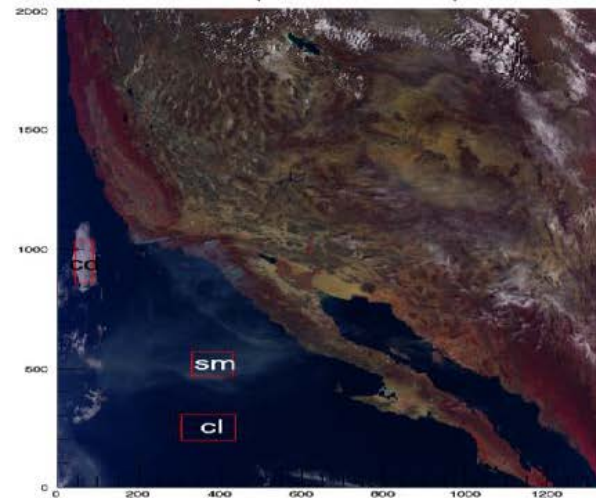
Smoke Detection Example (Zhao et al., 2010)



RGB (2003301.1825)



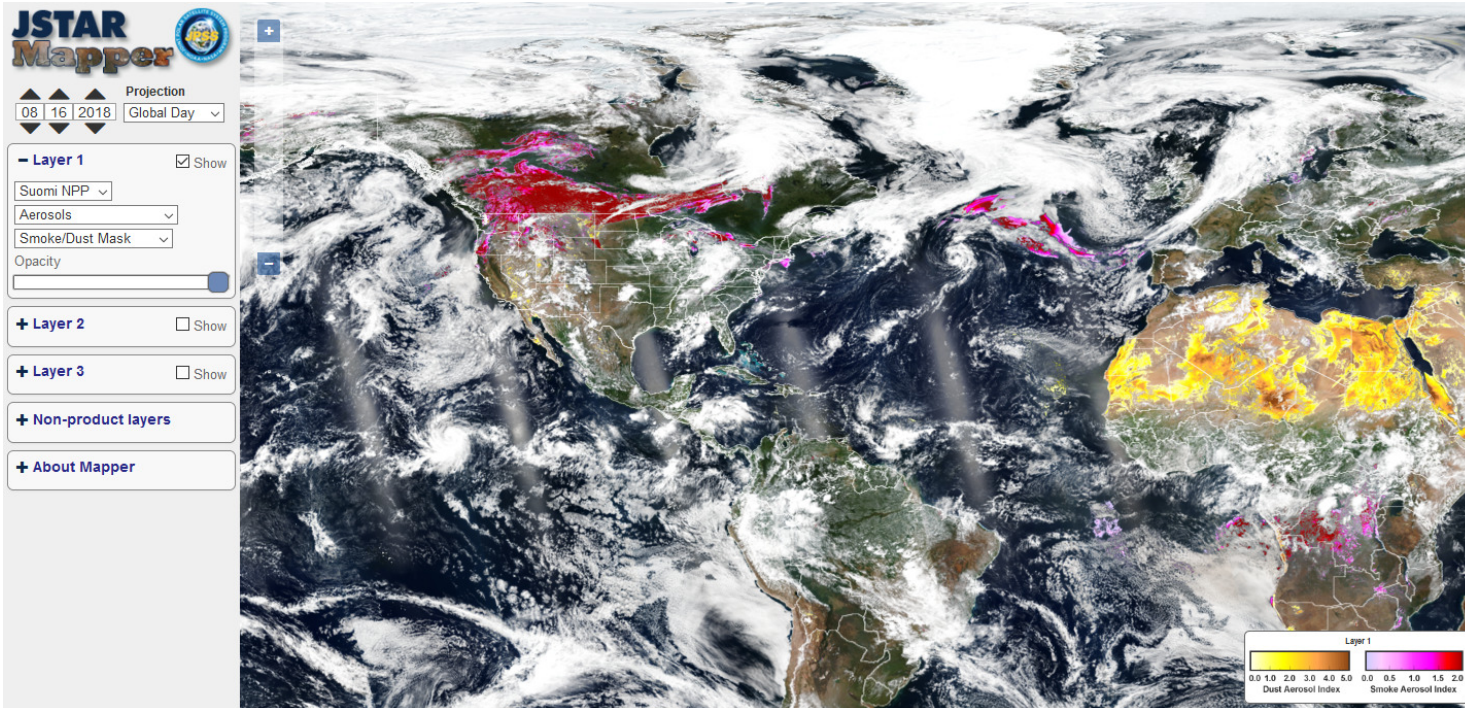
Smoke Over Land



Smoke Over Water

Smoke Monitoring Tools – NOAA Aerosol Detection Algorithm (ADP)

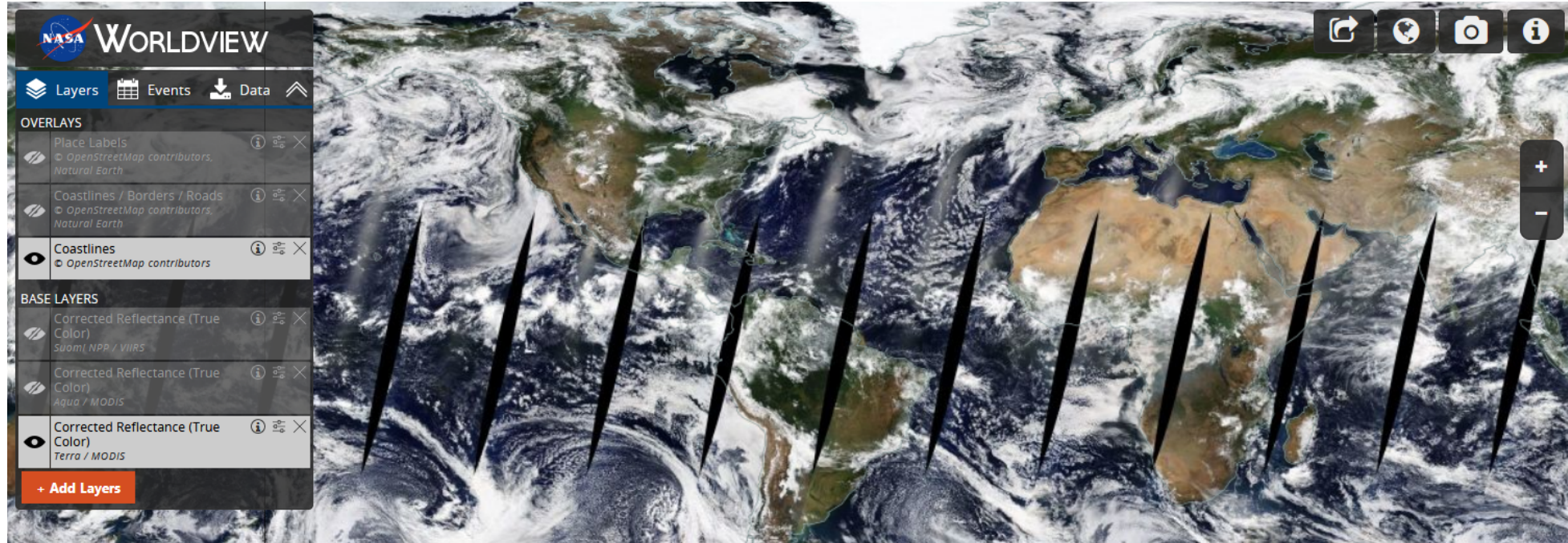
<https://www.star.nesdis.noaa.gov/jpss/mapper/>



- The NOAA ADP product consists of six type flags:
 - Volcanic ash
 - Smoke
 - Dust
 - None/unknown/clear
 - Clouds
 - Snow/ice
- And four quality flags:
 - Volcanic ash, smoke, dust, and none/unknown/clear

Smoke Monitoring Tools – Worldview

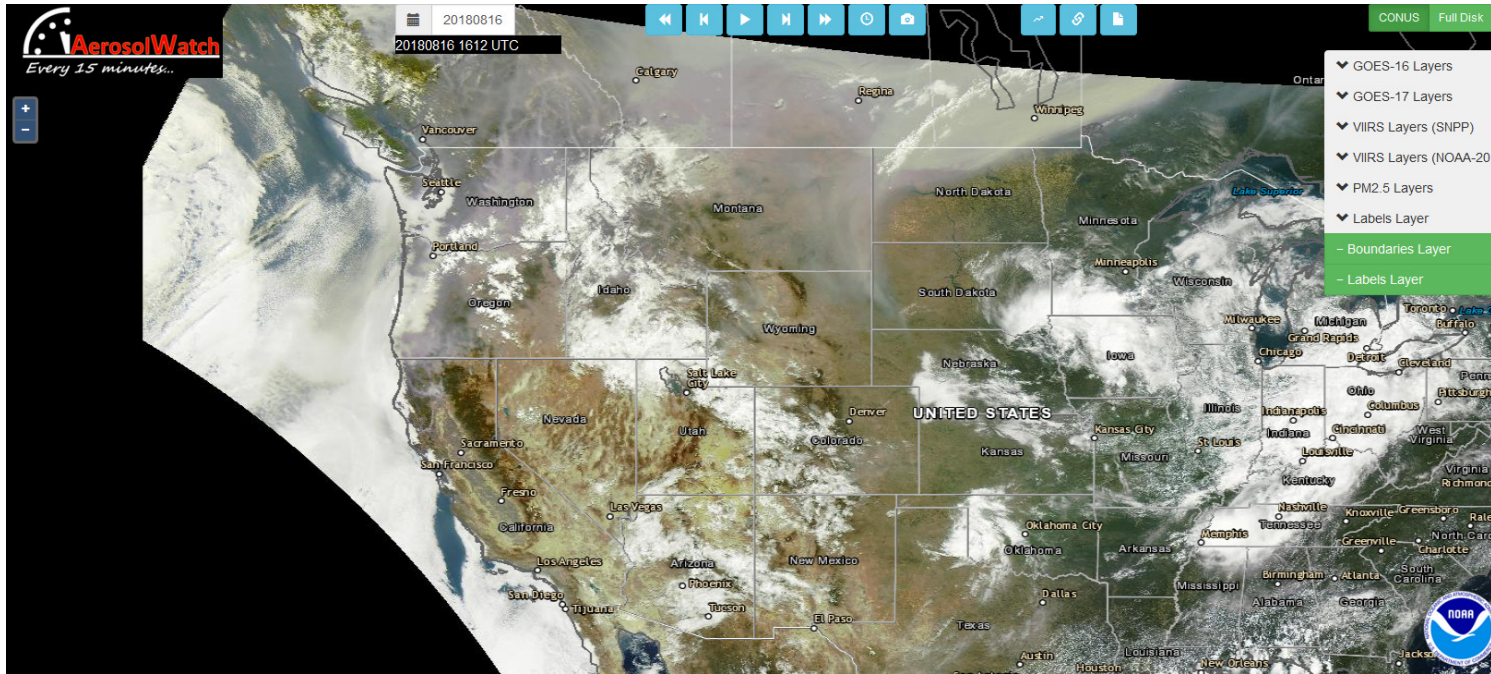
NRT Data & Image Access



- Visible Imagery (MODIS, VIIRS)
- Fire Detection (MODIS, VIIRS)
- Aerosol Optical Depth (MODIS, OMI, MISR)
- Aerosol Index (OMI)
- Day-Night Band (VIIRS)

NOAA Aerosol Watch

<https://www.star.nesdis.noaa.gov/smcd/spb/aq/AerosolWatch/>

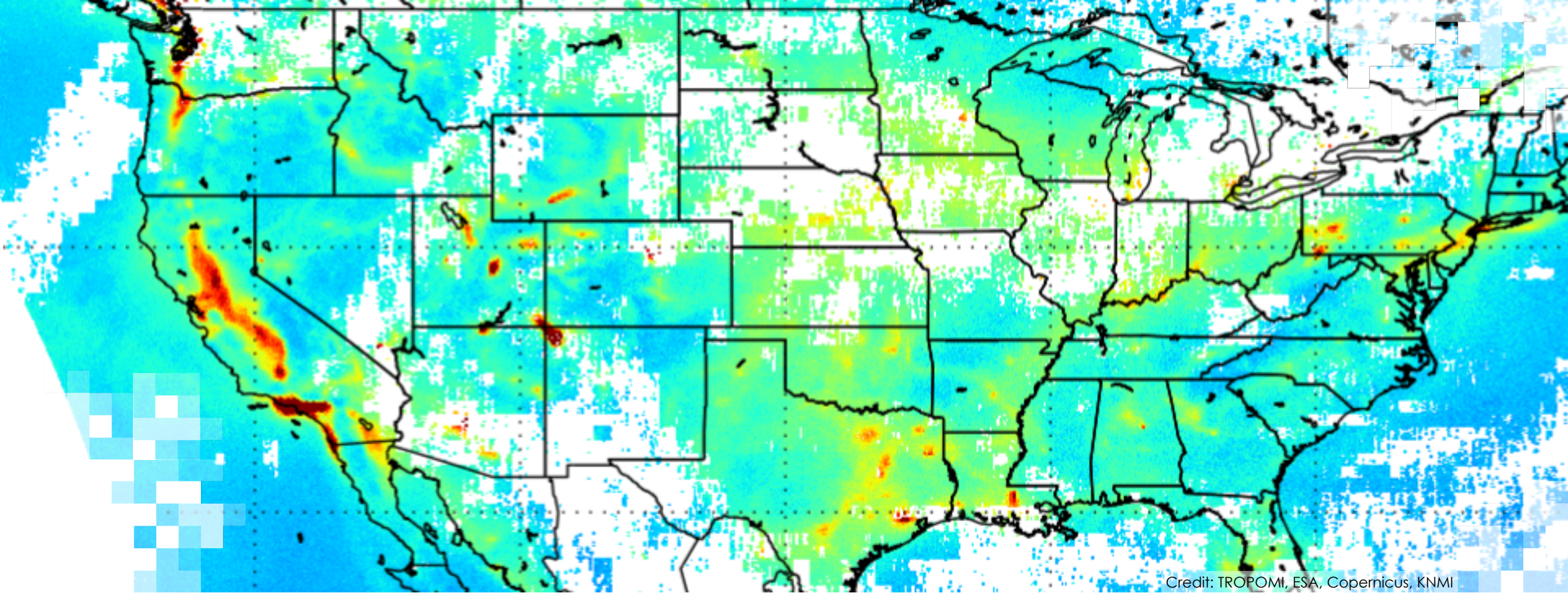


- The Aerosol Watch website has NRT GOES ABI and VIIRS imagery
- Can view:
 - Fire detections
 - AOD
 - Smoke/Dust mask
 - AirNOW hourly and daily $PM_{2.5}$

Smoke Monitoring Tools – MISR Plume Height

<https://mISR.jpl.nasa.gov/getData/accessData/MisrMinxPlumes2/>

The screenshot shows the NASA Jet Propulsion Laboratory website for the MISR Plume Height Project 2. The header includes the NASA logo, JPL name, and navigation links for JPL HOME, EARTH, SOLAR SYSTEM, STARS & GALAXIES, and SCIENCE & TECHNOLOGY. Below the header is the MISR logo and the text "Multi-angle Imaging SpectroRadiometer". A search bar is present with a "Go" button. A left sidebar menu contains links for Home, Mission, Get Data (with sub-links for Access Data, MISR Plume Height Project, MISR Plume Height Project 2, MISR Data System, Product Maturity Levels, and Local Mode Data), Gallery, News and Events, Publications, FAQs, Ask a Question, About Us, Other Resources, and Internal. The main content area is titled "ACCESS DATA" and "MISR Plume Height Project 2". It lists the project name, a list of team members (David Nelson, Sebastian Val, Ralph Kahn, Ernest Koeberlein, Mike Tosca, David Diner, Cecelia Lawshe), and a date "July, 2015 - see what's changed". Below this is a note "Access data digitized with earlier versions of MINX" and three radio buttons for "Wildfire smoke plumes" (selected), "Volcanic plumes", and "Dust plumes". A "Search" button is located below the radio buttons. Underneath is the heading "Fast Search for All Plumes in a Clicked Region" and a world map with colored regions: NORTH AMERICA, SOUTH AMERICA, EUROPE, AFRICA, ASIA, and OCEANIA. The map also shows the Atlantic Ocean and Indian Ocean.



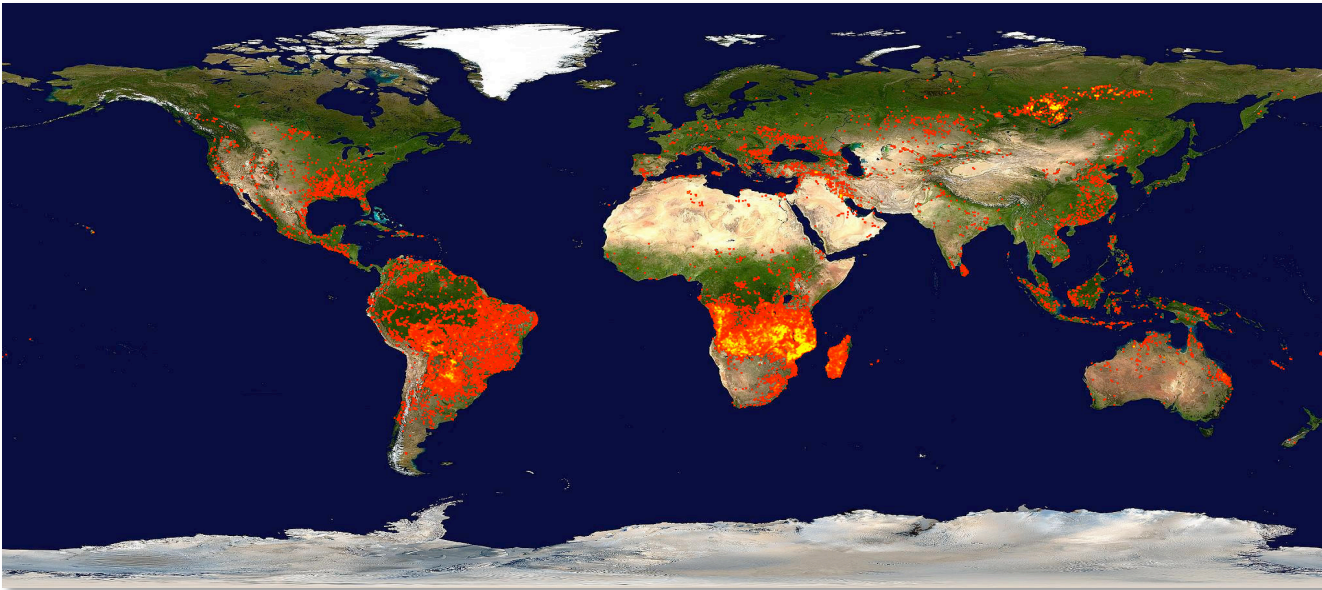
Fire Detection

Several Satellite Instruments Observe Fire Detections

	MODIS	VIIRS	ABI
Platform	Terra , Aqua	Suomi NPP, NOAA-20	GOES 16, GOES 17
Launched	Dec 1999, May 2002	Oct 2011, Nov 2017	Nov 2016, Mar 2018
Swath	2,330 km	3,040 km	---
Equator Crossing Time	10:30 am (des), 1:30 pm (asc)	1:30 pm (asc), 1:30 pm (asc)	Geostationary
Spatial Resolution	250 m, 500 m, 1 km	375 m, 750 m	375 m, 750 m
Temporal Resolution	Global coverage: 1-2 days	Global coverage: Daily	Full Disk: 15 min CONUS: 5 min
Spectral Coverage	36 bands (VIS, IR, NIR, MIR) Band 1-2: 250 m Band 3-7: 500 m Band 8-36: 1 km	22 bands (VIS, IR, NIR, MIR) I-Bands (1-4): 375 m M-Bands (1-16): 750 m Day/Night Band: 750 m	16 bands (VIS, IR, NIR, MIR) 500 m – 2 km

Active Fire Products

- MODIS (MOD04A1/MYD04A1), VIIRS (VNP14IMGTDL_NRT), and ABI (FDC)
- Near Real-Time (NRT) thermal anomalies and fire locations
- Provides snapshots of active burning fires
- The Active Fire products deliver actively burning locations on a daily basis at 2 km (ABI), 1 km (MODIS) or 375 m (VIIRS) resolution



**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

Thermal Anomalies Algorithms

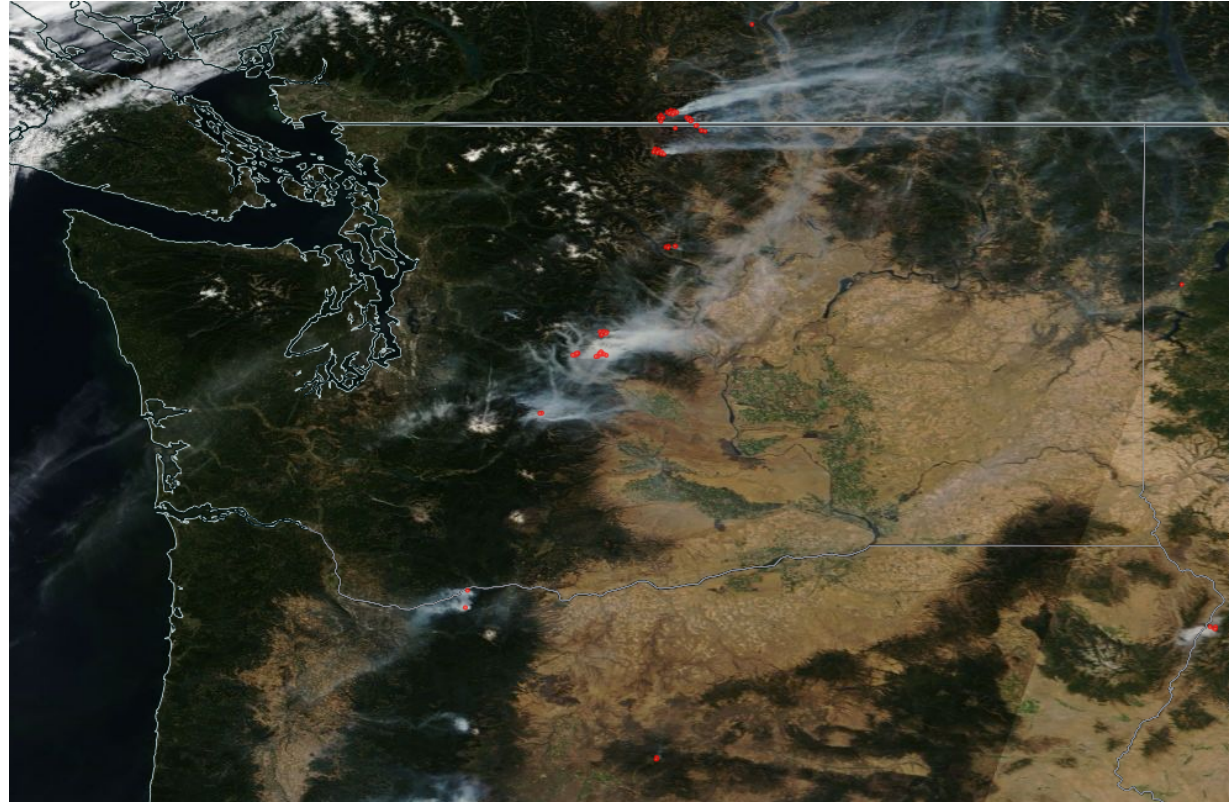
- Fire Detection:
 - pixel flagged as containing one or more fires
 - MODIS: 1 km
 - VIIRS: 750 m and 375 m
 - ABI: 2 km
 - can also detect volcanic signatures
- Significant increase in absolute radiance at $\sim 4 \mu\text{m}$ and $\sim 11 \mu\text{m}$
 - Cloud masks applied
 - Use other wavelength bands to filter out sun glint and coastal regions
- All algorithms are similar



VIIRS fire detections,
NASA Worldview

Thermal Anomalies Algorithms

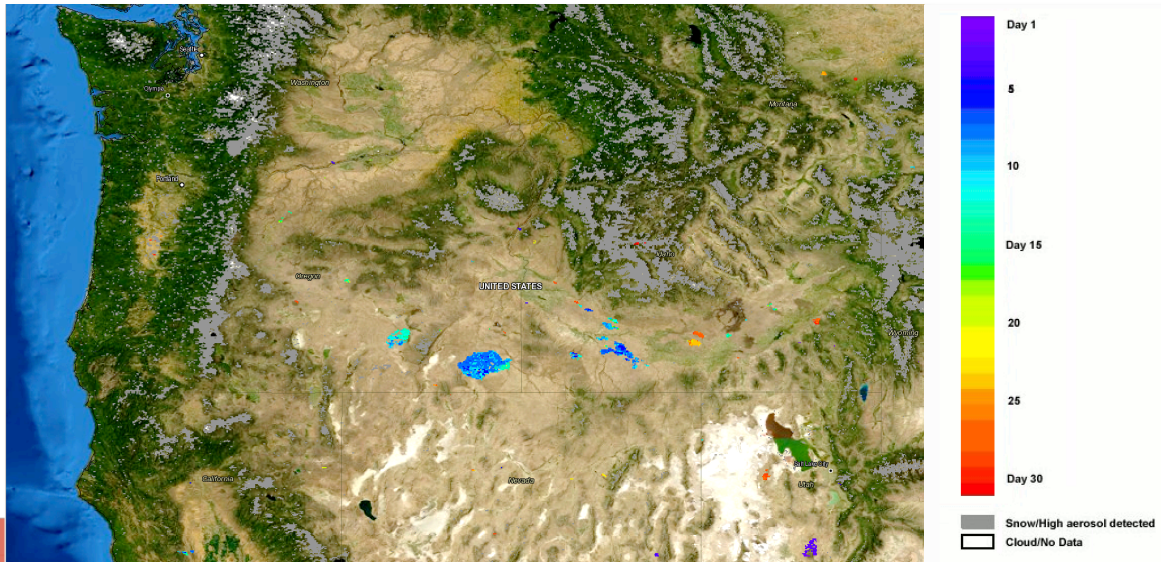
- Limitations
 - False positives: small forest clearings (bare soil)
 - Large fire omissions due to thick smoke
 - Larger pixel size of MODIS and ABI can miss small fires
- MODIS Collection 6 (most recent) improves upon these errors
 - Global commission error of 1.2%



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)

Fire Information for Resource Management System (FIRMS)

<https://earthdata.nasa.gov/earth-observation-data/near-real-time/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
 - Download shapefile, WMS, KML, or txt
 - Visualization in **Web Fire Mapper** or **Worldview**
- FIRMS Webinar
 - <https://www.youtube.com/watch?v=0fPVmnY6pBs&feature=youtu.be>

The screenshot displays the Earth Data website interface for the Fire Information for Resource Management System (FIRMS). The top navigation bar includes 'EARTH DATA Powered by EOSDIS' and links for 'ABOUT', 'DATA', 'COMMUNITY', and 'RESOURCES'. A search bar is present. The main content area is titled 'Fire Information for Resource Management System (FIRMS)' and includes a description: 'FIRMS distributes Near Real-Time (NRT) active fire data within 3 hours of satellite overpass from both MODIS and VIIRS.' Below this, there are two buttons for 'MODIS Active Fire Products' and 'VIIRS Active Fire Products'. A section titled 'Get hotspot/fire locations' contains five options: 'Fire Email Alerts' (with an envelope icon), 'Download Active Fire Data' (with a download icon), 'Web Fire Mapper' (with a fire icon), 'Global Fire Maps' (with a globe icon), and 'Web Services' (with a map icon). A left sidebar contains 'Data', 'Disciplines', 'Related Content' (with links to EOSDIS Data News and Earth Day), and 'More Resources'. A 'Feedback' button is also visible on the left.

Where to Obtain MODIS Fire Products

Archived Data



Land Process Distributed Active Archive (LPDAAC):
<http://lpdaac.usgs.gov/>



NASA Earthdata: <https://earthdata.nasa.gov/>

Near Real Time (NRT)



Worldview: <http://worldview.earthdata.nasa.gov>

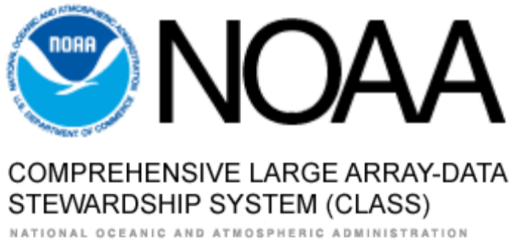
Where to Obtain VIIRS Products



Worldview: <http://worldview.earthdata.nasa.gov>

VIIRS Active Fire

VIIRS Active Fire: <http://viirsfire.geog.umd.edu>

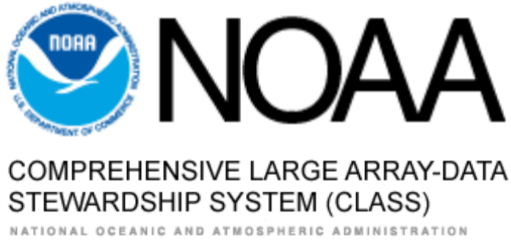


NOAA Comprehensive Large Array-Data Stewardship System (CLASS): <https://www.avl.class.noaa.gov/saa/products/welcome>

LAADS DAAC

Level-1 and Atmosphere Archive & Distribution System: <https://ladsweb.modaps.eosdis.nasa.gov/>

Where to Obtain ABI Products



NOAA Comprehensive Large Array-Data Stewardship System (CLASS): <https://www.avl.class.noaa.gov/saa/products/welcome>



University of Wisconsin GOES page:
<http://cimss.ssec.wisc.edu/goes/goesdata.html>

References

- User guides for the MODIS active fire and burned area products
 - <http://modis-fire.umd.edu/guides.html>
- VIIRS Active Fire page:
 - <http://viirsfire.geog.umd.edu/>
- ABI Fire Detection Fact Sheet (with links)
 - https://www.goes-r.gov/education/docs/fs_fire.pdf
- ABI and VIIRS ADP and AOD documents
 - <https://www.star.nesdis.noaa.gov/smcd/spb/aq/AerosolWatch/documents.php>

Questions & Discussion Prompts

- Changes in what retrieved quantity are used to detect fires?
- What is a source of uncertainty for fire detection?