

# Smoke Monitoring from Space

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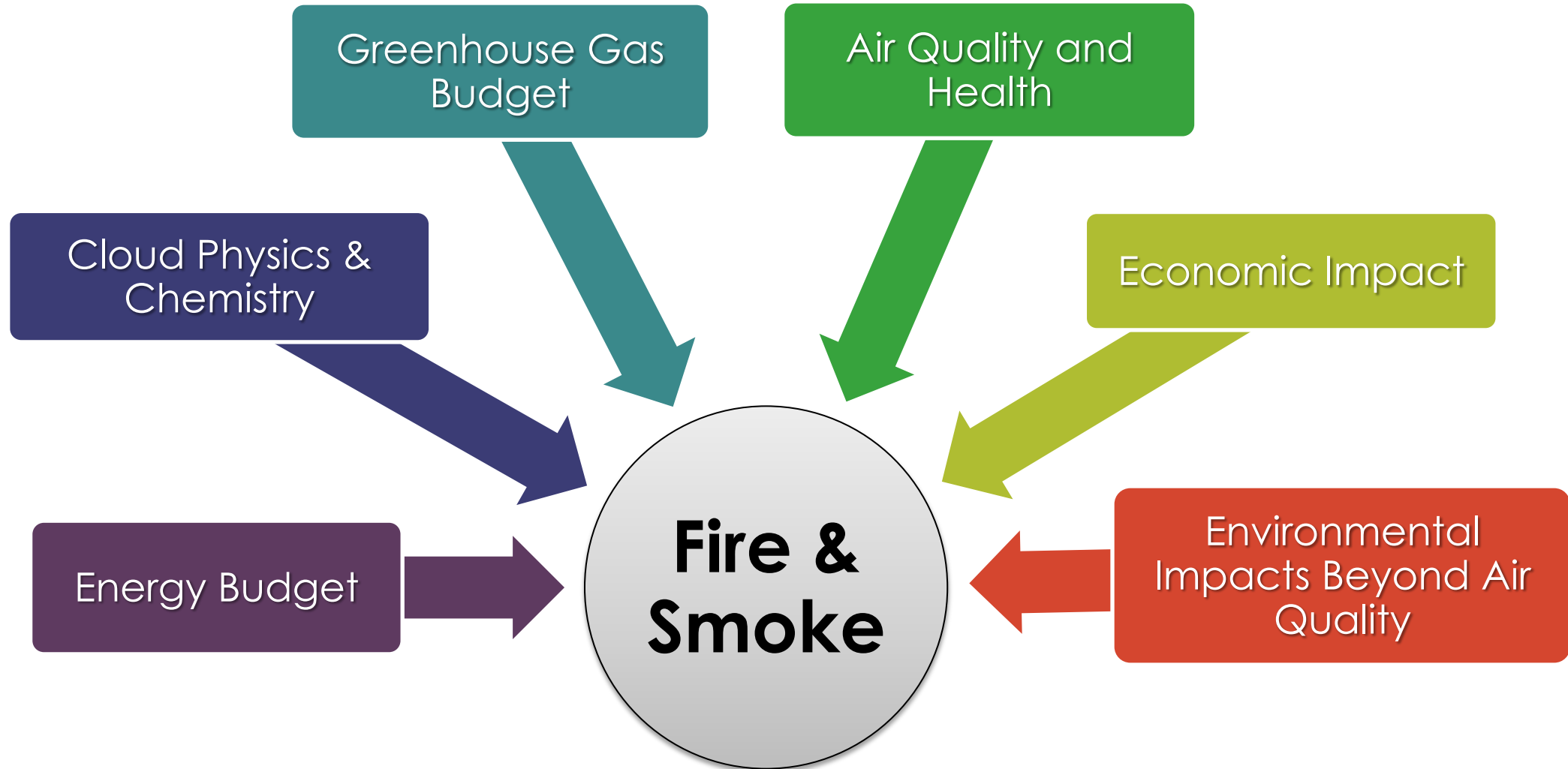
# Learning Objectives

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

- Describe how remote sensing observations can be used to detect smoke
- Describe and locate available smoke products



# Importance of Smoke and Fire Monitoring



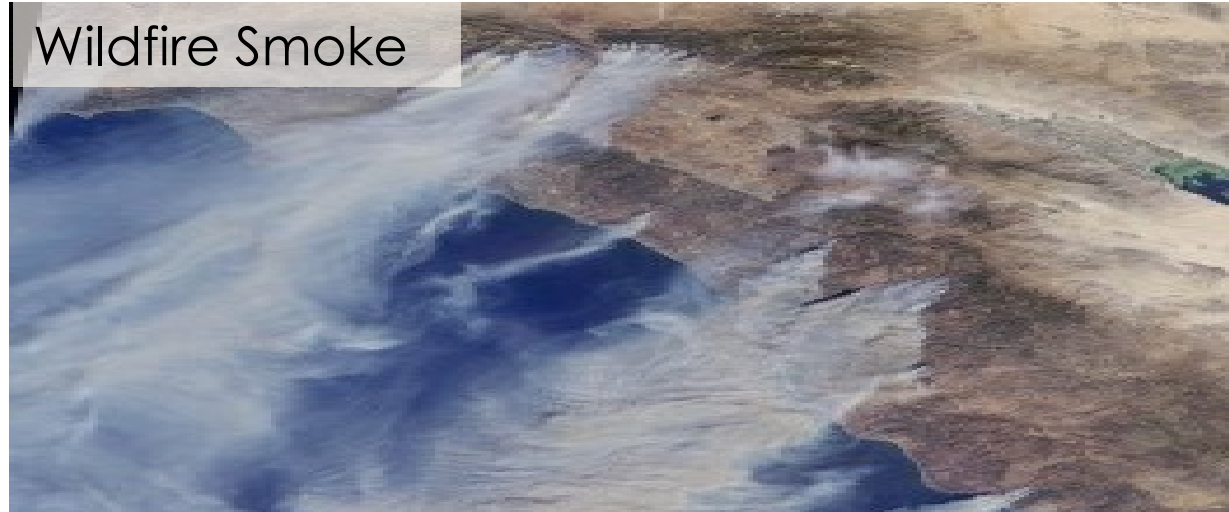


# Smoke Color and Texture in Satellite Images

Smoke from Small Fires



Wildfire Smoke



Oil Fires in Iraq

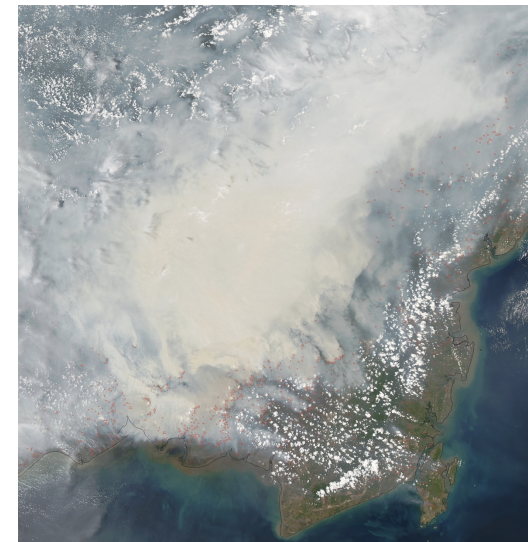
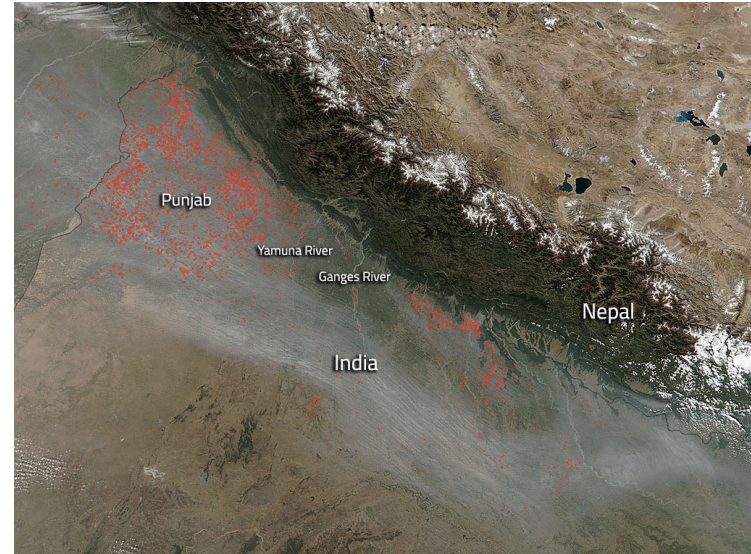


Urban-Industrial/Smoke Pollution





# Visible Smoke from Fires

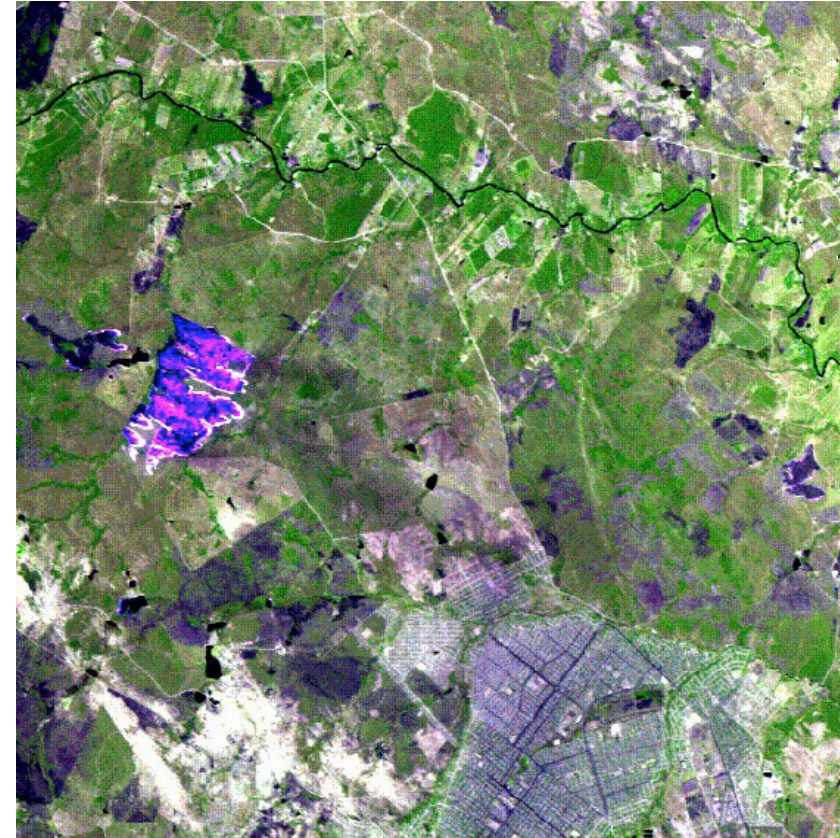




# Selection of Spectral Bands for Smoke Detection



R = 0.66  $\mu\text{m}$   
G = 0.55  $\mu\text{m}$   
B = 0.47  $\mu\text{m}$



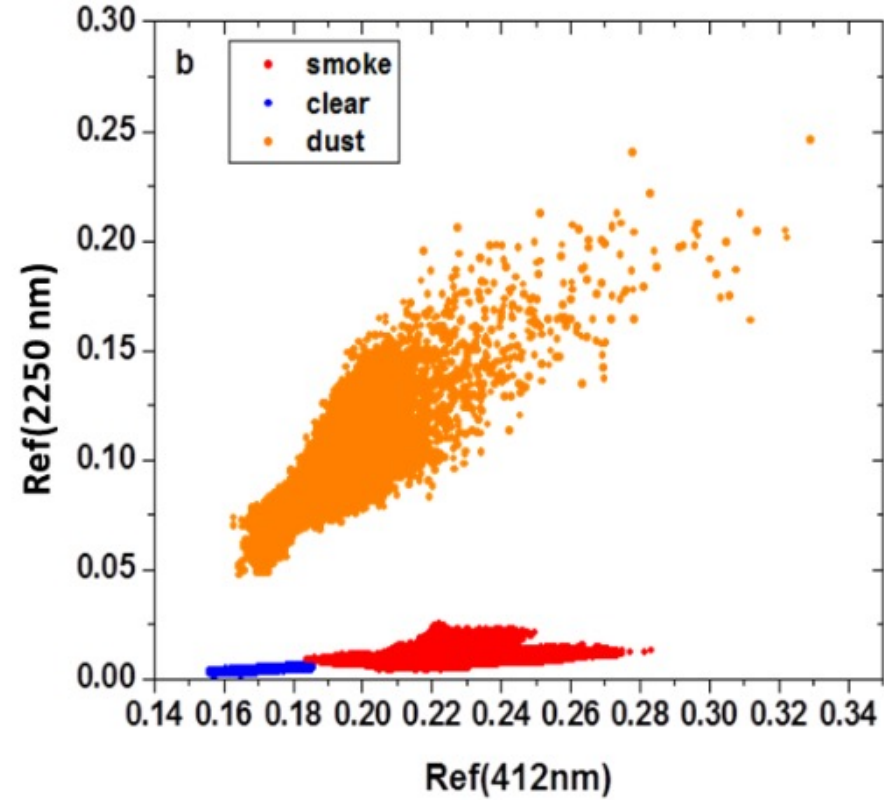
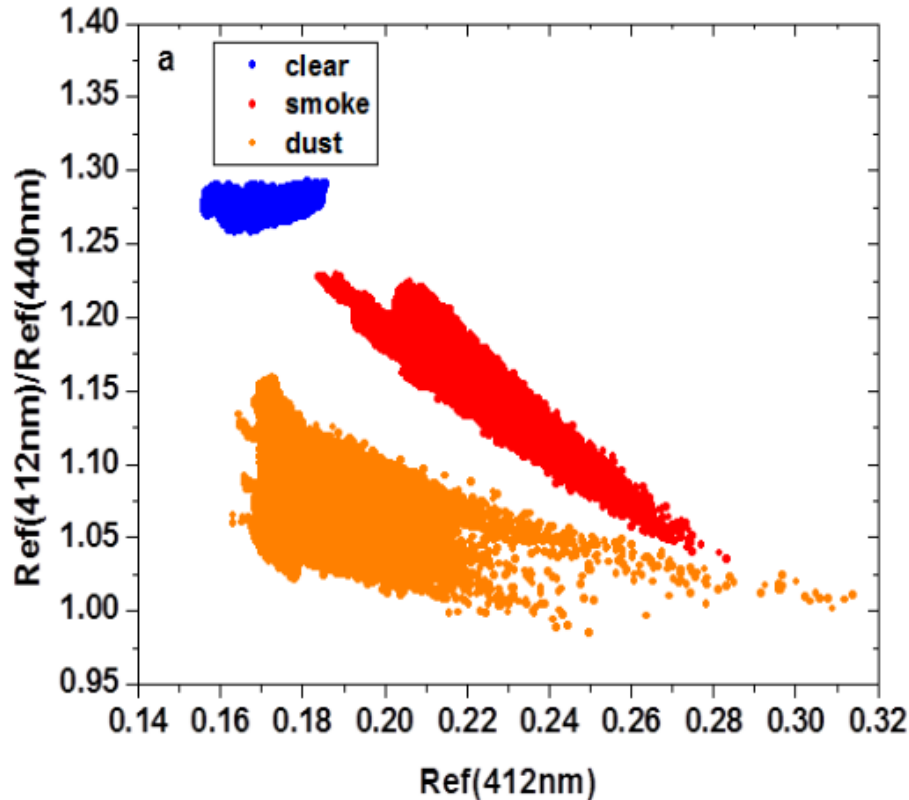
R = 1.6  $\mu\text{m}$   
G = 1.2  $\mu\text{m}$   
B = 2.1  $\mu\text{m}$





# Smoke Detection – Spectral Signature

[https://www.star.nesdis.noaa.gov/jpss/documents/ATBD/ATBD\\_EPS\\_Aerosol\\_ADP\\_v1.5.pdf](https://www.star.nesdis.noaa.gov/jpss/documents/ATBD/ATBD_EPS_Aerosol_ADP_v1.5.pdf)



Specific spectral responses of dust, smoke, clear, and cloudy parts of the atmosphere allow us to separate and classify different features in a satellite image.



# How is smoke/dust detected?

- Smoke/dust reduces the contrast between 412 nm and 440 nm as the absorption increases with the decreasing wavelength.

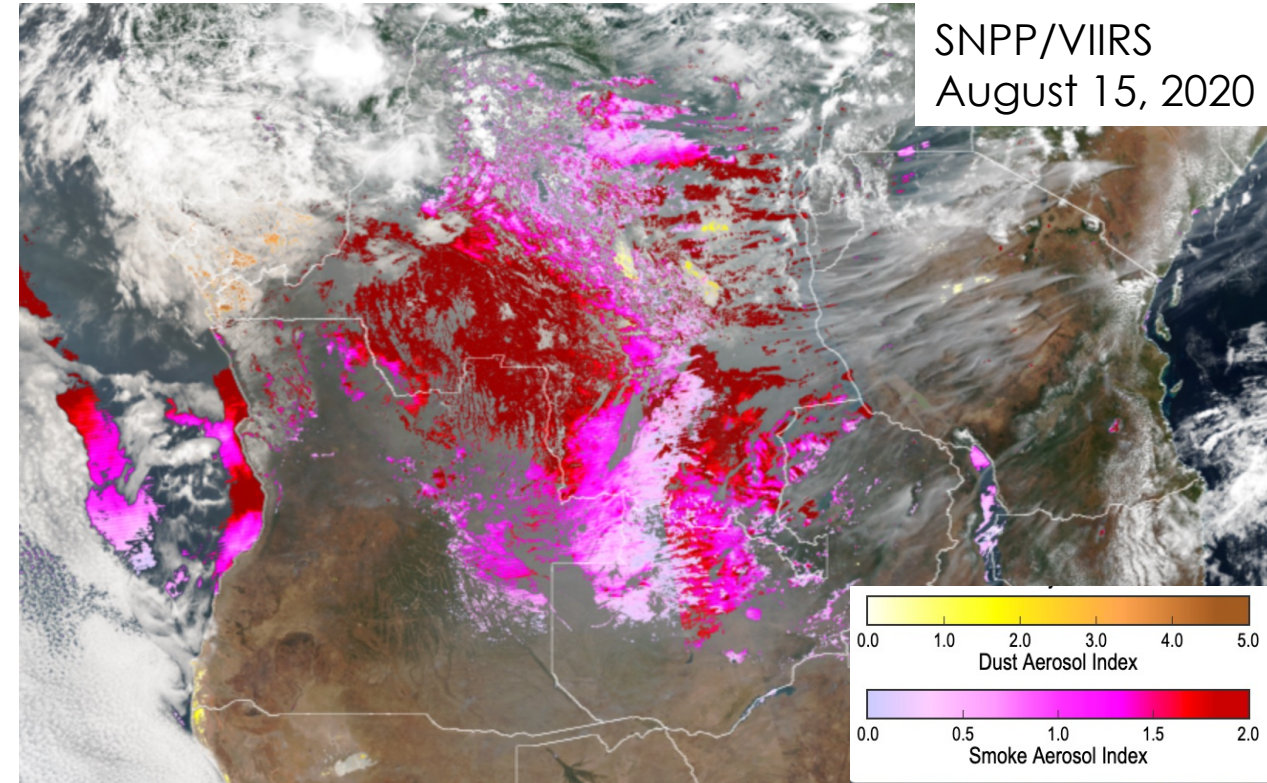
## Absorbing Aerosol Index

$$AAI = -100[1 \log_{10}(R_{412}/R_{440}) - \log_{10}(R'_{412}/R'_{440})]$$

- Difference in particle size enables us to pick-out the smoke by introducing the short-wave IR channel (2.25  $\mu\text{m}$ ).

## Dust, Smoke Discrimination Index

$$DSDI = -10[1 \log_{10}(R_{412}/R_{2250})]$$



## References:

- Algorithm Theoretical Basis Document  
[https://www.star.nesdis.noaa.gov/jpss/documents/ATBD/ATBD\\_EPS\\_Aerosol\\_ADP\\_v1.5.pdf](https://www.star.nesdis.noaa.gov/jpss/documents/ATBD/ATBD_EPS_Aerosol_ADP_v1.5.pdf)
- [Zhang et al., 2018, J. of Applied Remote Sensing](#)





# NOAA's Aerosol Detection Product (ADP)

- Absorption Aerosol Index
- Dust, Smoke Discrimination Index
- 6 Type Flags: (1=Presence; 0=Absence)
  1. Volcanic Ash Flag
  2. Dust Flag
  3. Smoke Flag
  4. None/Unknown/Clear
  5. Cloud Flag
  6. Snow/Ice Flag
- Quality Flags

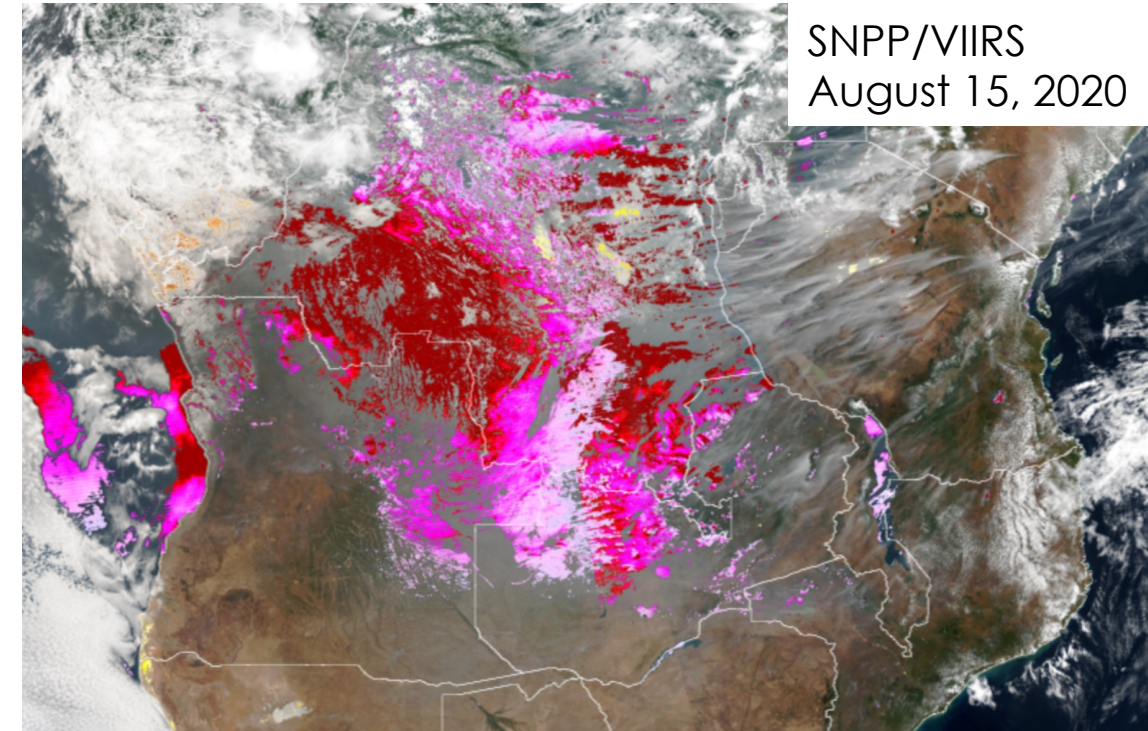


Image: <https://www.star.nesdis.noaa.gov/jpss/mapper>

Low, medium, and high confidence for each type

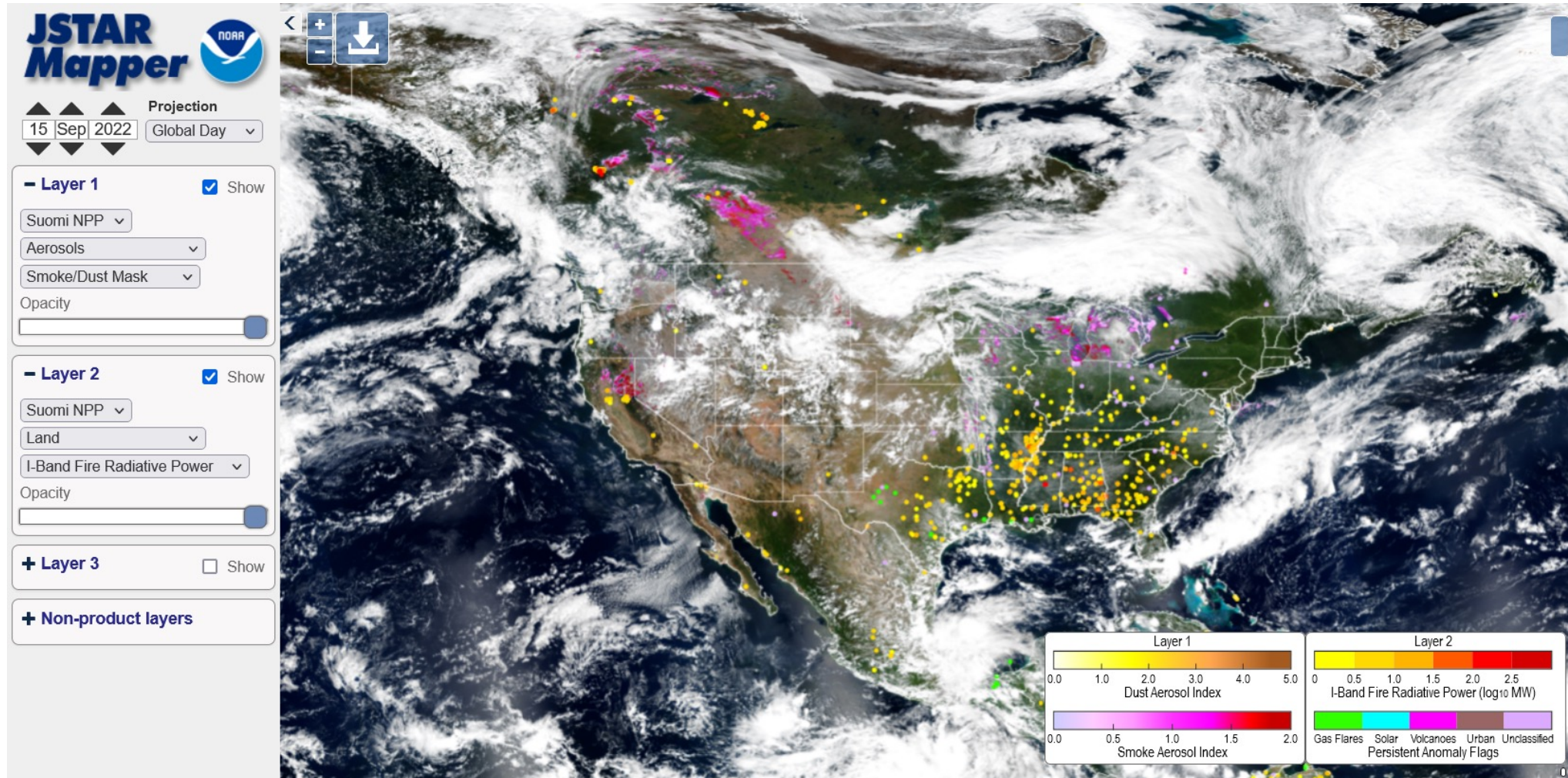
File Example - **JRR-ADP\_v2r1\_npp\_s201911010742162\_e201911010743404\_c201911010834210.nc**





# NOAA's Mapper - NPP, NOAA20, S5P

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





# NOAA's Aerosol Watch

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

The screenshot displays the NOAA Aerosol Watch interface. At the top left, the logo reads "AerosolWatch" with the tagline "Every 10 minutes...". A date selector shows "20230310" and a time stamp "20230310 1650 UTC". A navigation bar includes play, pause, and stop buttons, along with zoom and share icons. On the right, a "GOES-East Layers" menu is open, showing options: "GeoColor" (checked), "Dust RGB", "Fire RGB", "AOD", "AOD Composite", "Smoke Dust Mask", and "Fire". The main view shows a satellite image of Earth with a prominent red aerosol plume over the Americas. The NOAA logo is in the bottom right corner. At the bottom of the interface, a footer contains links for "Dept. of Commerce", "NOAA", "NESDIS", "STAR", "Privacy Policy", "Link & Product Disclaimers", "Information Quality", "Accessibility", and "Customer Survey".

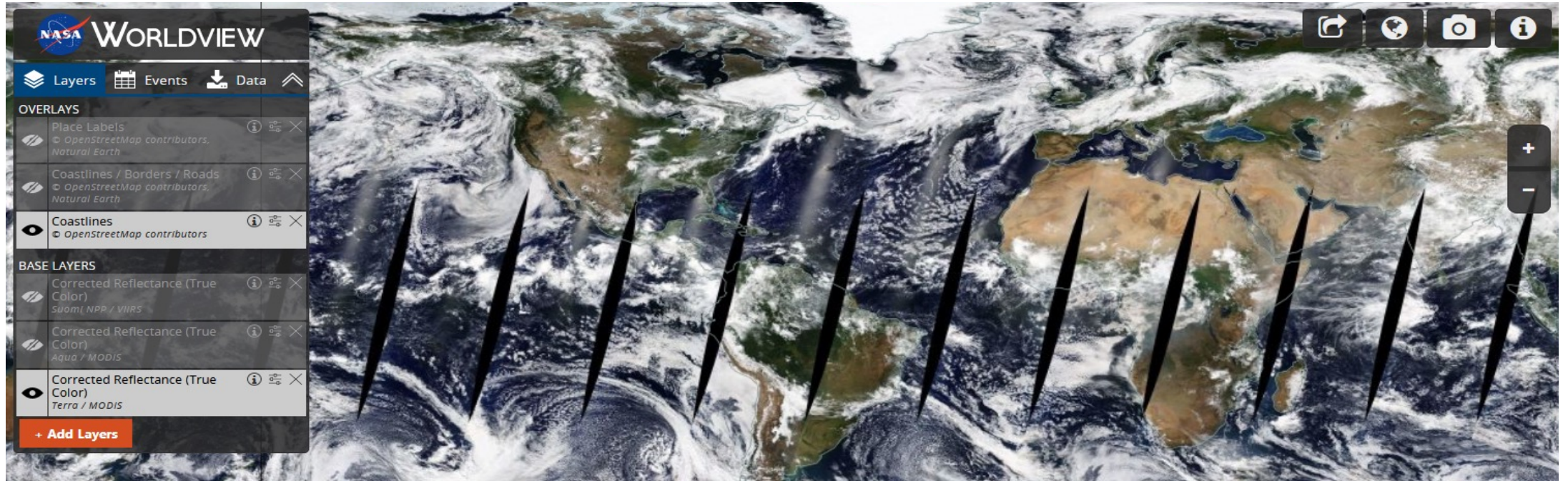




# Smoke Monitoring Tools – Worldview

NRT Data & Image Access

<https://worldview.earthdata.nasa.gov/>



- Visible Imagery (MODIS, VIIRS)
- Fire Detection (MODIS, VIIRS)
- Aerosol Optical Depth (MODIS - 1, 3, 6, 10km, OMI, MISR)
- Aerosol Index (OMI)
- Day-Night Band (VIIRS)





# NOAA's Hazard Mapping System

<https://www.ospo.noaa.gov/Products/land/hms.html#maps>

The screenshot shows the NOAA Hazard Mapping System (HMS) web interface. At the top, there is a navigation bar with 'Organization', 'Services', 'Products', and 'Operations'. Below this is a search bar and a message: 'To go directly to the latest HMS analysis (map section), please bookmark: https://www.ospo.noaa.gov/Products/land/hms.html#maps'. The main heading is 'Hazard Mapping System Fire and Smoke Product' with a sub-heading 'Current Analysis'. The analysis is for 'day 03/12/2023 last updated Mar 12, 2023 15:49:15 GMT'. The map displays fire points (colored dots) and smoke (shaded areas) across North America. A legend indicates smoke levels (Light, Medium, Heavy) and fire point power (MW) ranges (<10 MW, 10-49 MW, 50-149 MW, 150-349 MW, ≥350 MW). Navigation controls like zoom in/out and a home button are visible on the left. At the bottom, there are links for 'Fire KML', 'Smoke KML', 'Smoke Text Product', and 'Archive', along with 'HMS Fire Detection' and 'HMS Smoke Detection' buttons. A disclaimer at the bottom states: 'Disclaimer: The location of the fires displayed may be slightly offset from the actual fire location due to satellite resolution. Read more'. Contact information 'SSDFireTeam@noaa.gov' is also provided.

## Product Information

EXPAND ALL (+) | COLLAPSE ALL (-)

### GOES ACTIVE FIRE DETECTION DATA

NOAA's Geostationary Operational Environmental Satellite (GOES) provides 5min observations over the Conterminous U.S. (CONUS)

[More](#)

### VIIRS ACTIVE FIRE DETECTION DATA

The NOAA/NASA Visible Infrared Imaging Radiometer Suite (VIIRS) was launched onboard the S-NPP polar satellite on October/2011,

[More](#)

### MODIS ACTIVE FIRE DETECTION DATA

NASA's Earth Observing System (EOS) Moderate Resolution Imaging Spectroradiometer (MODIS) can be found onboard the

[More](#)

### AVHRR ACTIVE FIRE DETECTION DATA

NOAA's Advanced Very High Resolution Radiometer (AVHRR) has, for nearly four decades, been an integral part of the NOAA suite

[More](#)

### HAZARD MAPPING SYSTEM

NOAA/NESDIS Satellite Analysis Branch's Hazard Mapping System (HMS) was first implemented in 2002 in response to high demand

[More](#)

### VIIRS FIRE DATA STATISTICS

Cumulative fire data statistics are calculated daily for all 50 U.S. states using science-quality data from a combination of

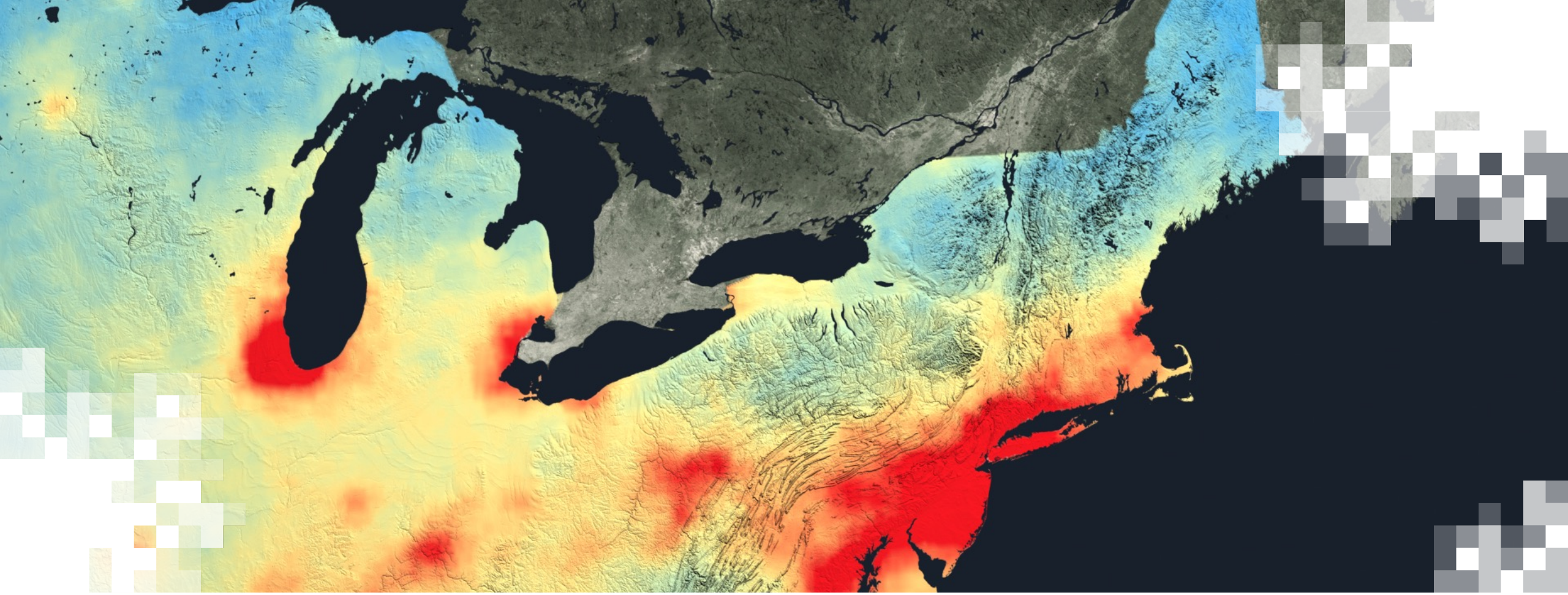
[More](#)

### HMS SMOKE DATA STATISTICS

Cumulative smoke data annual statistics are derived by aggregating daily Hazard Mapping System (HMS) smoke polygons

[More](#)





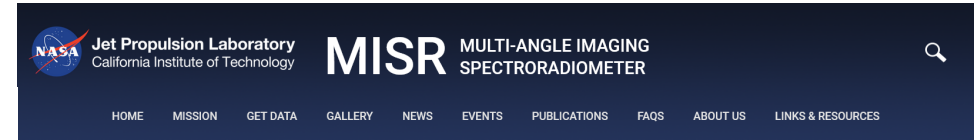
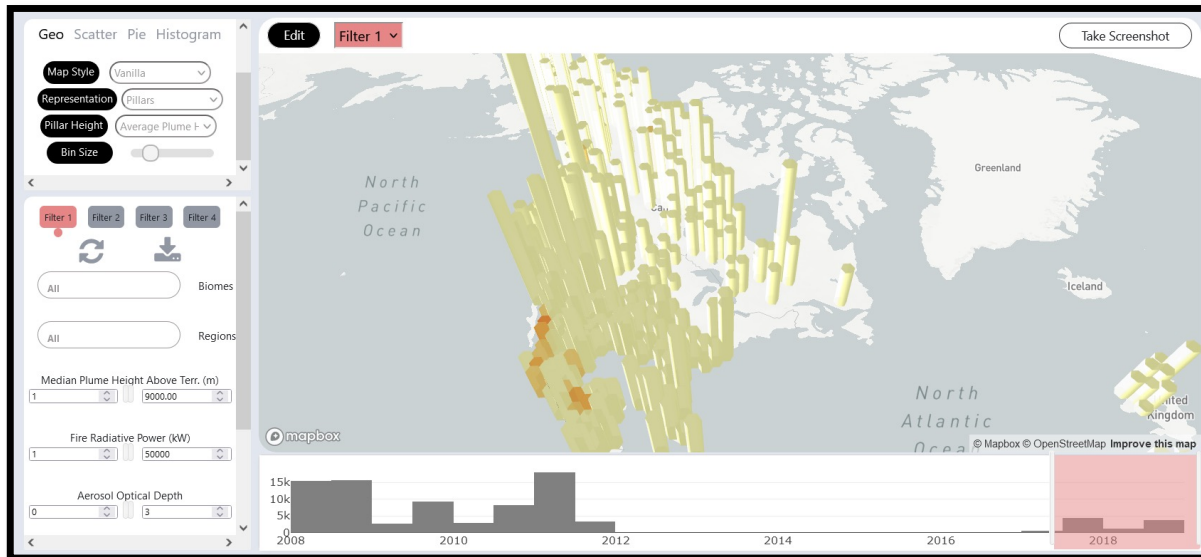
Aerosol Layer Altitude



# Smoke Monitoring Tools – MISR Plume Height

<https://misr.jpl.nasa.gov/get-data/misr-plume-height-project-2/>

- Stereo height algorithm reports plume top heights and wind vectors



## GET DATA

### MISR Plume Height Project 2

Access MISR Plume Height Project data [here](#).

The MISR Plume Height Project is a publicly available database of wildfire smoke plume heights generated by the [MISR Interactive Explorer \(MINX\)](#) software, produced over many years thanks to the contributions of many MISR science team members and student interns. As of this writing, the database includes all digitizable smoke plumes observed by MISR around the world for 2008 – 2011 as well as the summers (June, July, August) of 2017 and 2018. These data have been used to validate plume rise in models and other satellite-derived datasets, as well as to study the dynamics of individual fires and climatology of fire in the environment.

Please note MISR Plume Height Project data is now accessed via the MISR Enhanced Research and Lookup Interface (MERLIN), hosted by the NASA Atmospheric Science Data Center. This online tool provides new search, visualization and analysis capabilities beyond those that were available through the old MISR interface. Users are also able to download individual plume files as before.

Please visit <https://l0dup05.larc.nasa.gov/merlin/merlin#> to access the MERLIN tool.

A user guide for MERLIN is also available at [https://asdc.larc.nasa.gov/documents/misr/guide/MERLIN\\_User\\_Guide.pdf](https://asdc.larc.nasa.gov/documents/misr/guide/MERLIN_User_Guide.pdf).

## MERLIN visualization tool

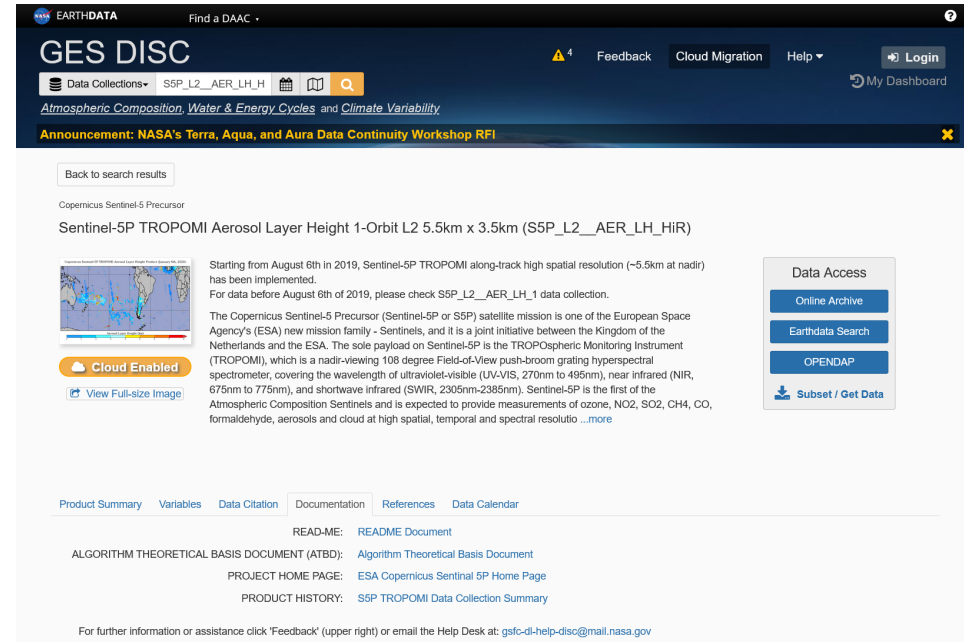




# TROPOMI Aerosol Layer Height

[https://disc.gsfc.nasa.gov/datasets/S5P\\_L2\\_AER\\_LH\\_HiR\\_2/summary?keywords=S5P\\_L2\\_AER\\_LH\\_HiR\\_2](https://disc.gsfc.nasa.gov/datasets/S5P_L2_AER_LH_HiR_2/summary?keywords=S5P_L2_AER_LH_HiR_2)

- Cloud-free conditions
  - Dust, smoke, volcanic ash
- Optimal Estimation algorithm assumes a single layer (50 hPa) with constant extinction and scattering properties
  - Assumption impacts AOD more than height retrieval
- Reports the height as the mid-pressure and mid-altitude of the layer at pixel resolution: 5.5 km x 3.5 km
- Also reports the AOD at 760 nm and error estimates
- Tends to be biased low over bright surfaces



The screenshot shows the NASA Earth Data GES DISC website. The main heading is "Sentinel-5P TROPOMI Aerosol Layer Height 1-Orbit L2 5.5km x 3.5km (S5P\_L2\_AER\_LH\_HiR)". A map of the globe shows the satellite's orbit. The text describes the data collection starting from August 6th, 2019, and provides information about the Copernicus Sentinel-5 Precursor mission. It also includes a "Data Access" section with buttons for "Online Archive", "Earthdata Search", "OPENDAP", and "Subset / Get Data".

ATBD:

<https://sentinel.esa.int/documents/247904/2476257/Sentinel-5P-TROPOMI-ATBD-Aerosol-Height>



# MAIAC Smoke Injection Height

<https://lpdaac.usgs.gov/products/mcd19a2v061/>

- Derive smoke plume heights using thermal contrast of smoke for pixels:
  - AOD at 470 nm must be  $> 0.8$
  - Must have smoke-free ground brightness temperature
  - Brightness temperature difference between the ground and smoke must be  $> 0$
- Limitations: Dissipating smoke, large areas of thick smoke where background can't be characterized, and small fires
- Thermal technique represents an effective height
- Good agreement with MISR MINX,  $\sim 450\text{m}$  lower on average,  $\sim 200\text{m}$  low with respect to LiDAR (CALIOP)



[Homepage](#) / [Data](#) / [Search Data Catalog](#) / [MCD19A2v061](#)

Lyapustin et al., 2020, IEEE

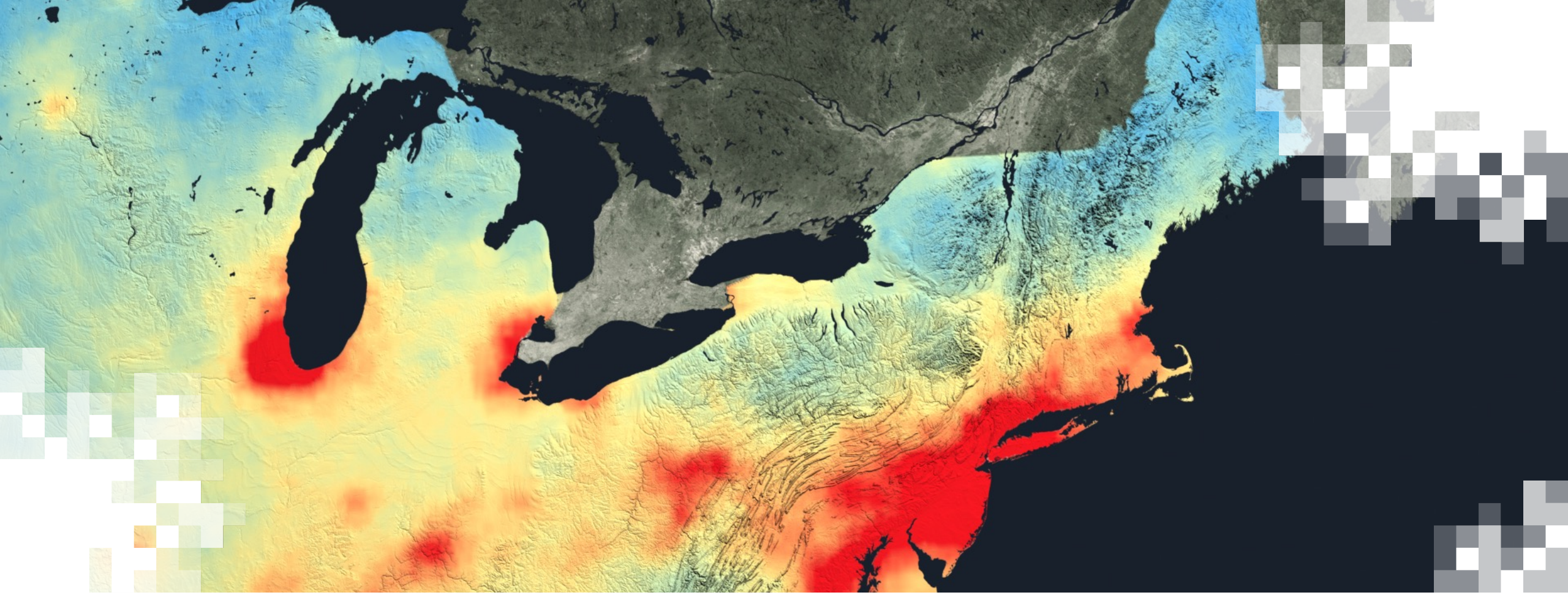
<https://ieeexplore.ieee.org/document/8834856>

MAIAC User Guide:

[https://lpdaac.usgs.gov/documents/1500/MCD19\\_User\\_Guide\\_V61.pdf](https://lpdaac.usgs.gov/documents/1500/MCD19_User_Guide_V61.pdf)







Questions?