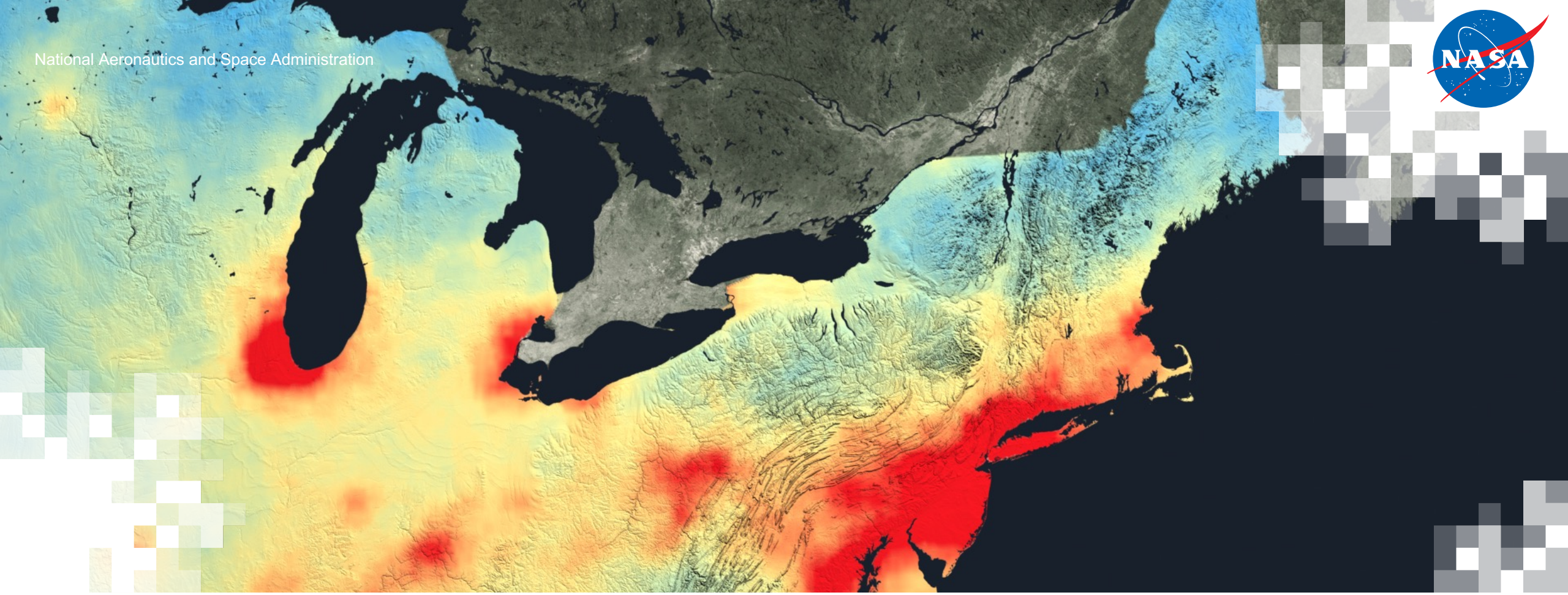


Smoke Monitoring from Space

Melanie Follette-Cook, Pawan Gupta, Carl Malings, Sarah Strode

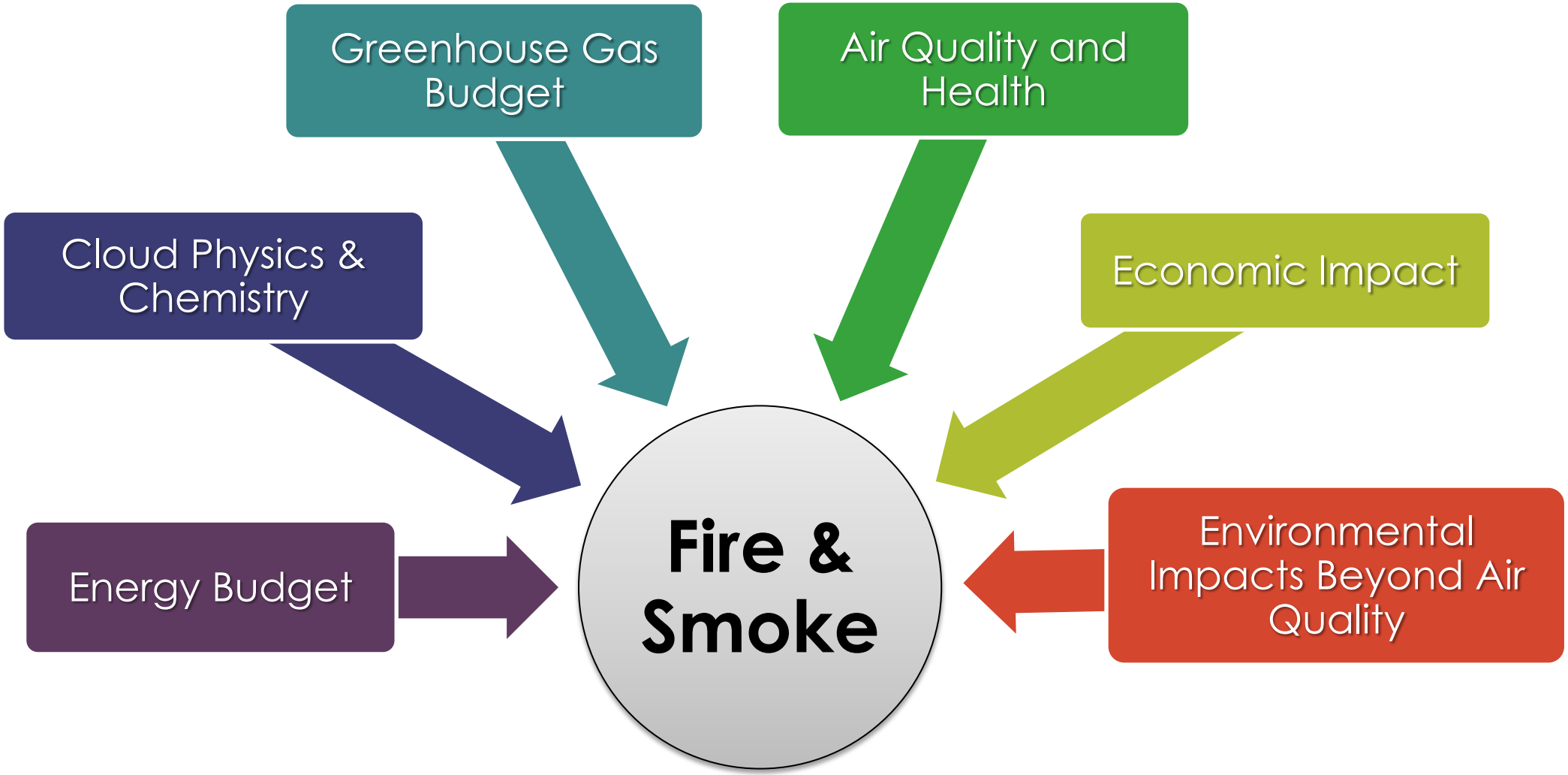
NASA Air Quality Remote Sensing Training for EPA, March 21-23, 2023

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

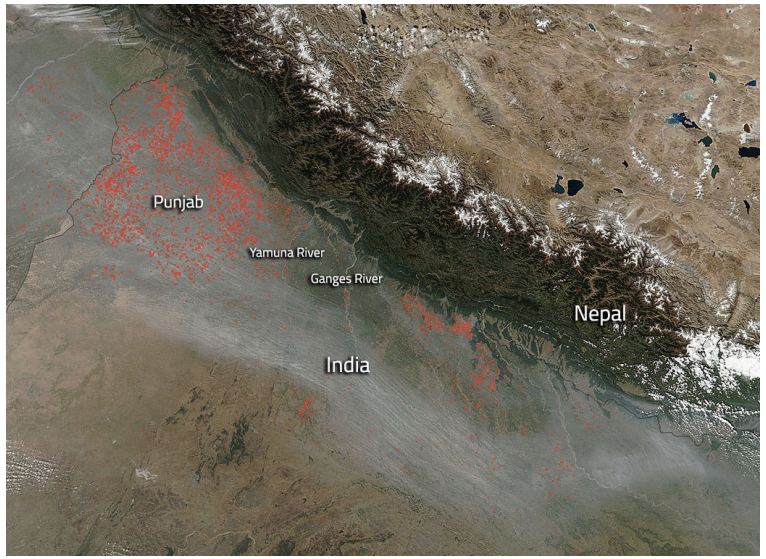
Smoke from Small Fires

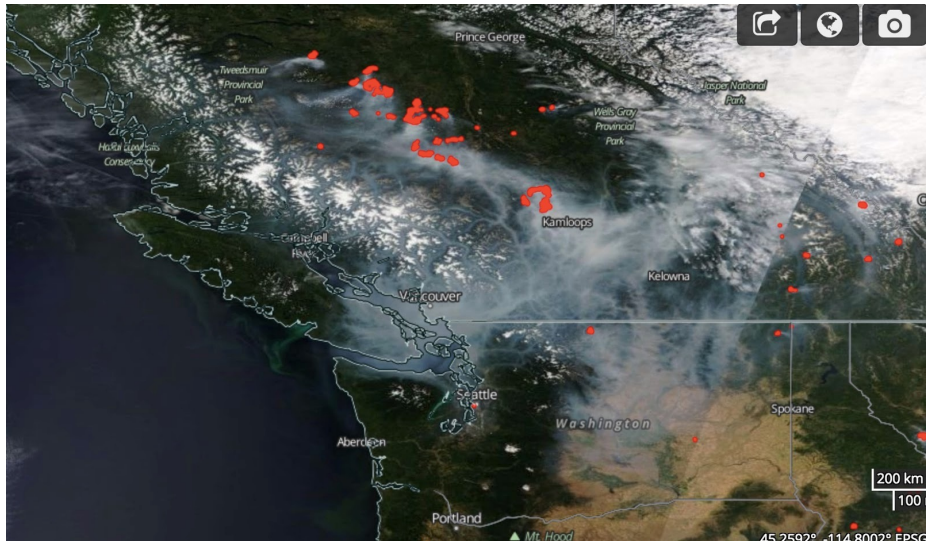
Wildfire Smoke

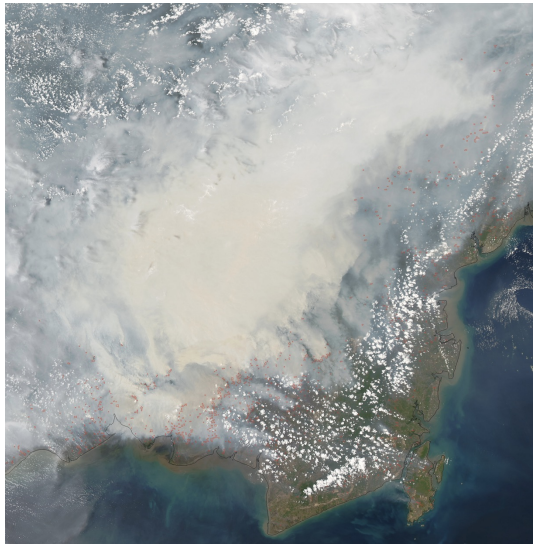
Oil Fires in Iraq

Urban-Industrial/Smoke Pollution

Visible Smoke from Fires

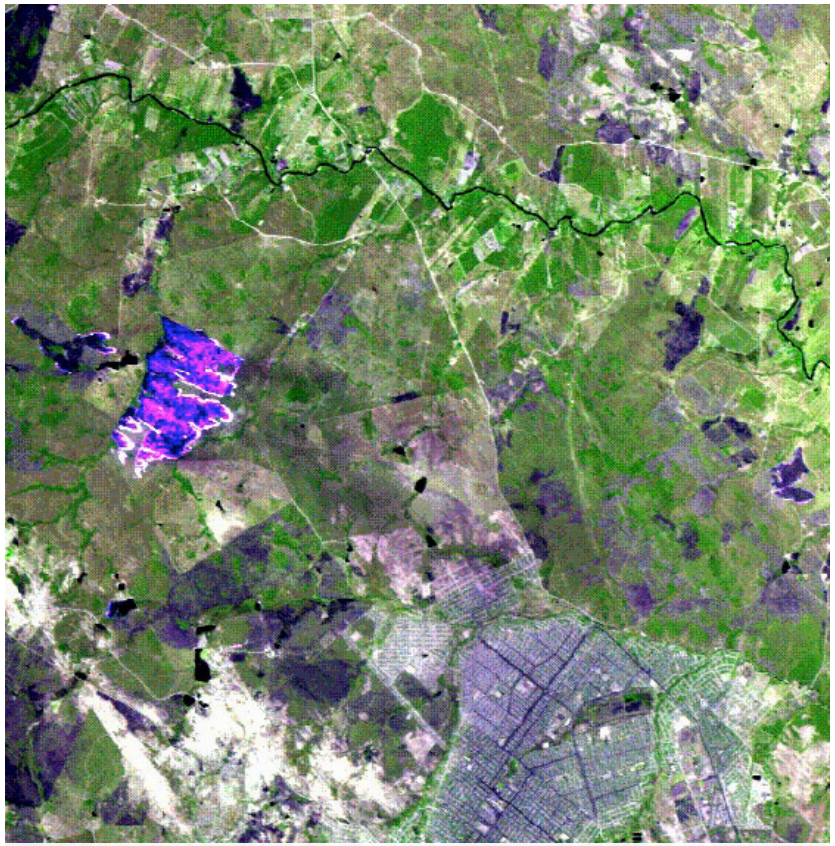






Selection of Spectral Bands for Smoke Detection

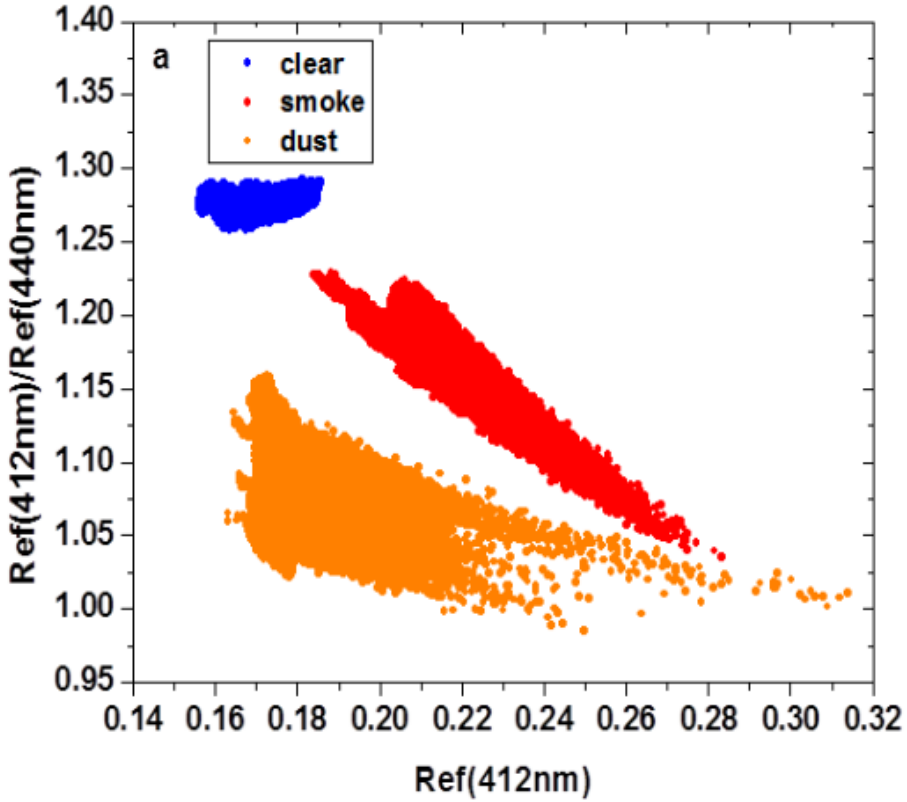
R = 0.66 µm
G = 0.55 µm
B = 0.47 µm

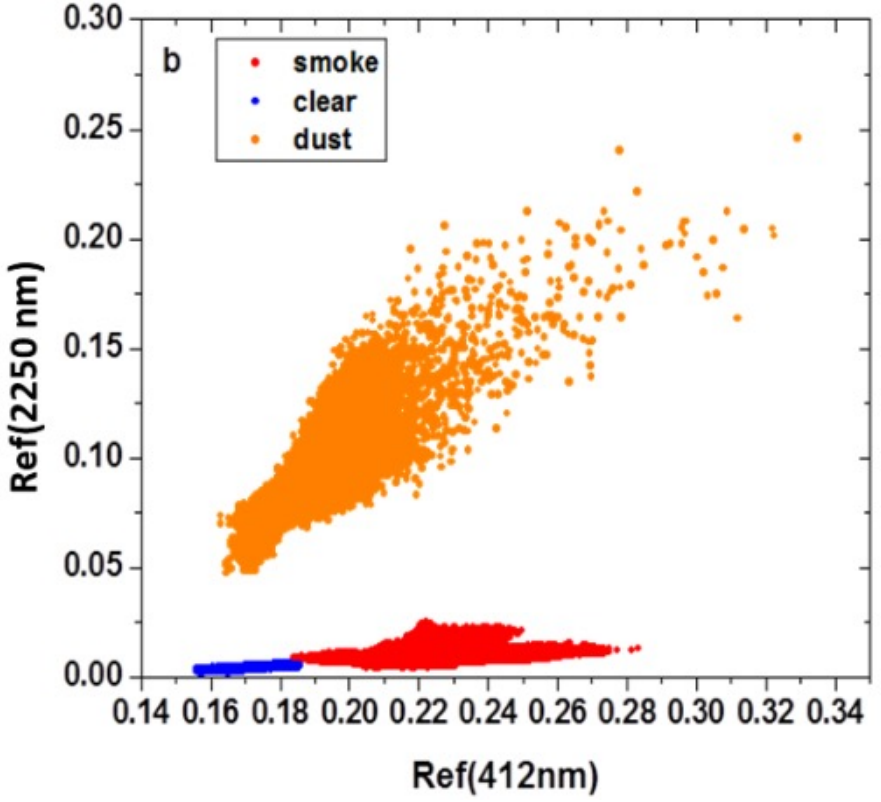


R = 1.6 µm
G = 1.2 µm
B = 2.1 µm

Smoke Detection – Spectral Signature

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.

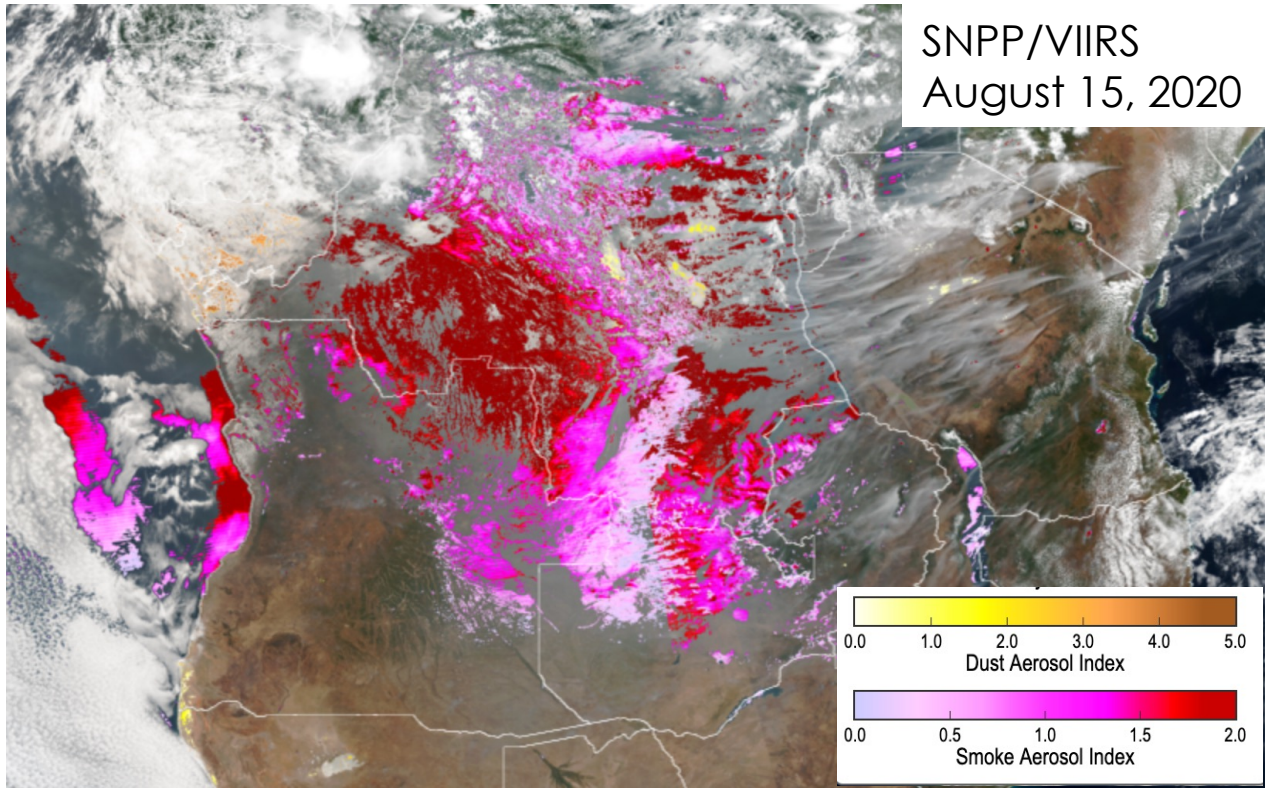
Absorbing Aerosol Index

$AAI = -100[1og10(R412/R440) - log10(R'412/R'440)]$

- Difference in particle size enables us to pick-out the smoke by introducing the short-wave IR channel (2.25 μm).

Dust, Smoke Discrimination Index

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

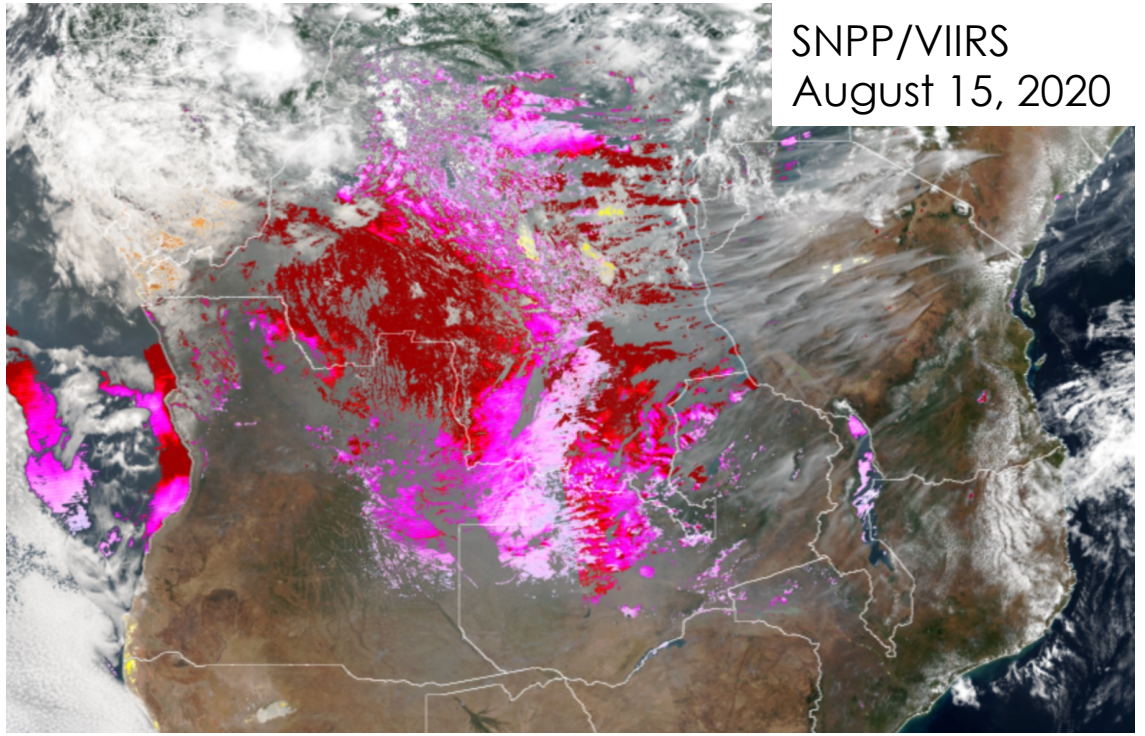


References:

1. Algorithm Theoretical Basis Document https://www.star.nesdis.noaa.gov/jpss/documents/ATBD/ATBD_EPS_Aerosol_ADP_v1.5.pdf
2. 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



SNPP/VIIRS
August 15, 2020

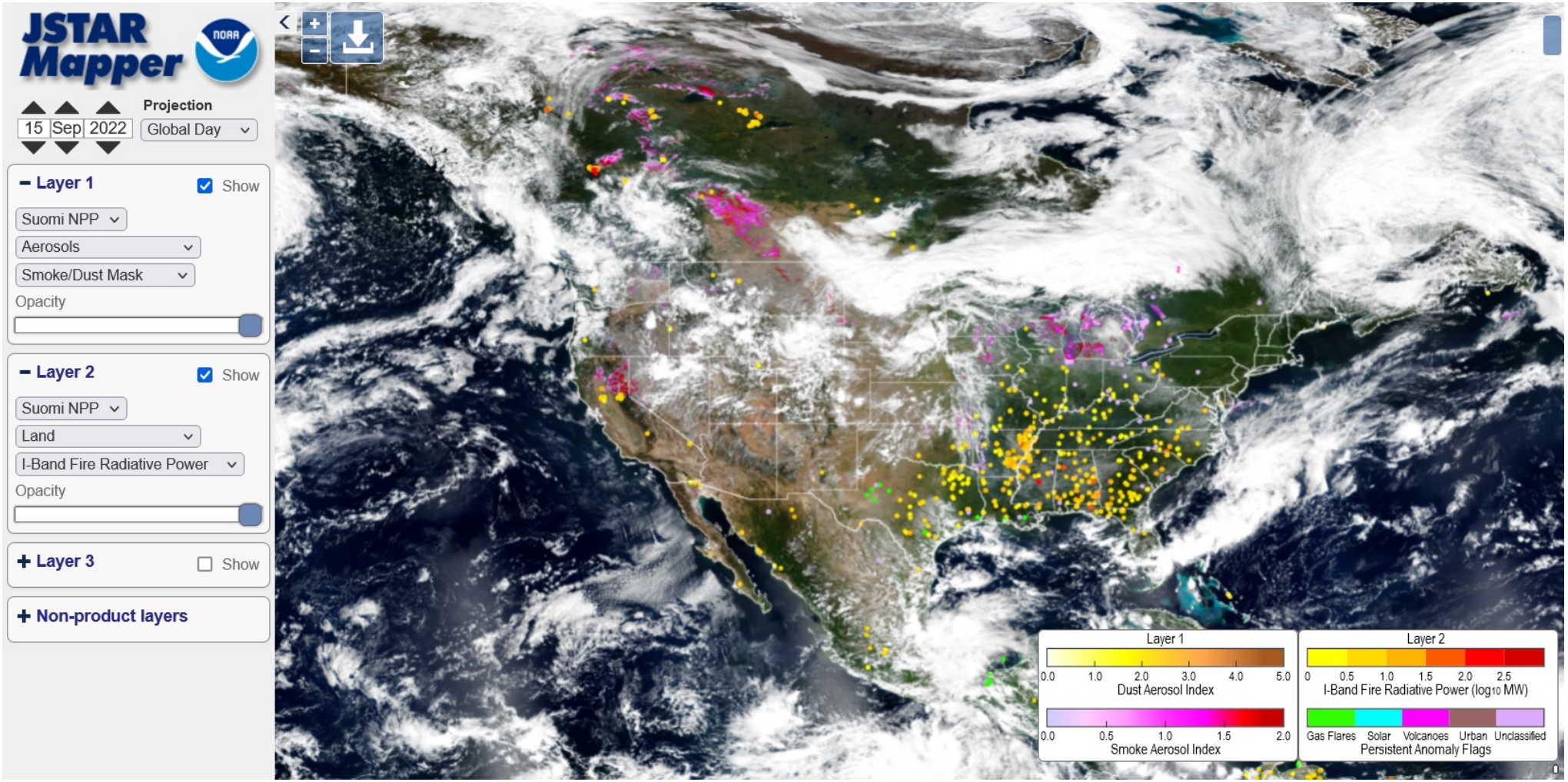
Image: https://www.star.nesdis.noaa.gov/jpss/mapper

Low, medium, and high confidence for each type

File Example - **JRR-ADP_v2r1_npp_s201911010742162_e201911010743404_c201911010834210.nc**

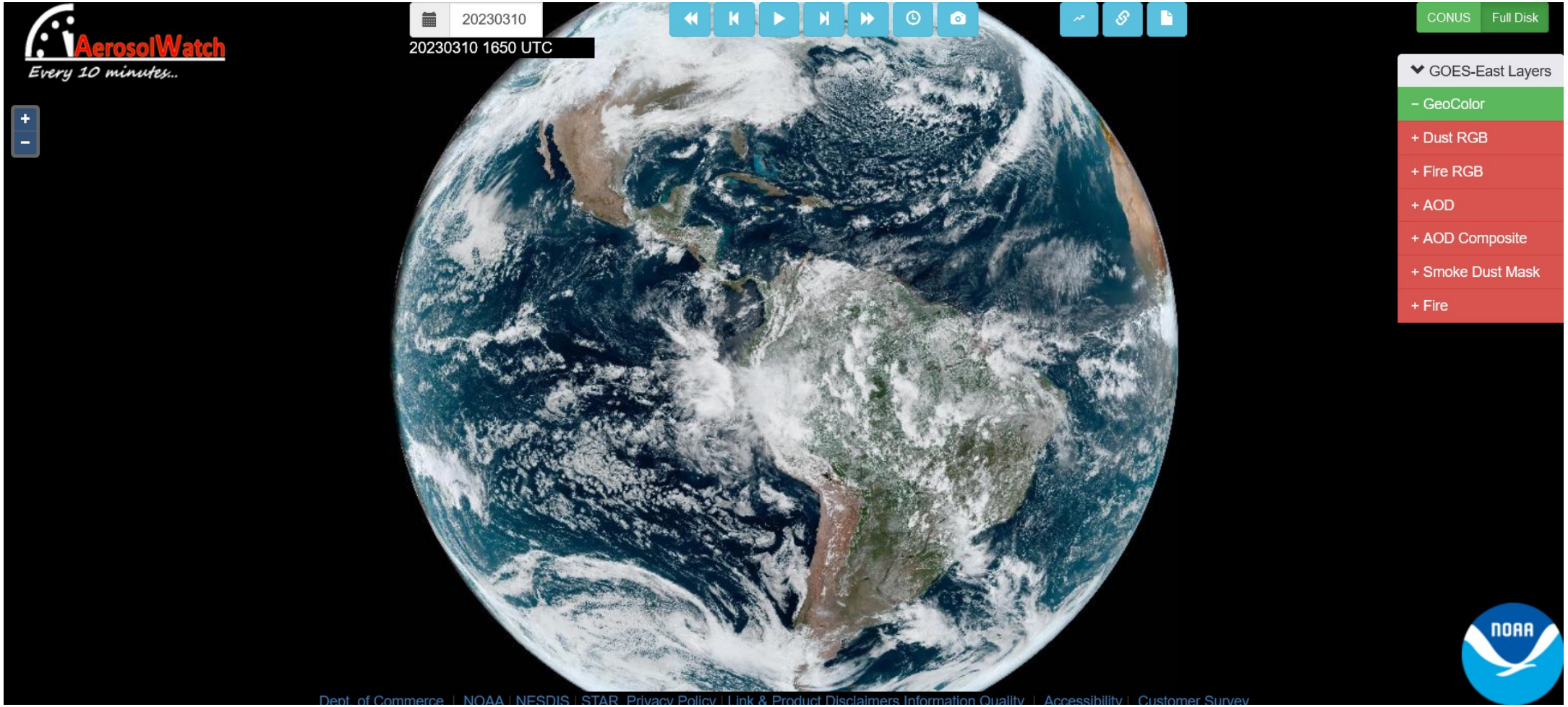
NOAA's Mapper - NPP, NOAA20, S5P

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



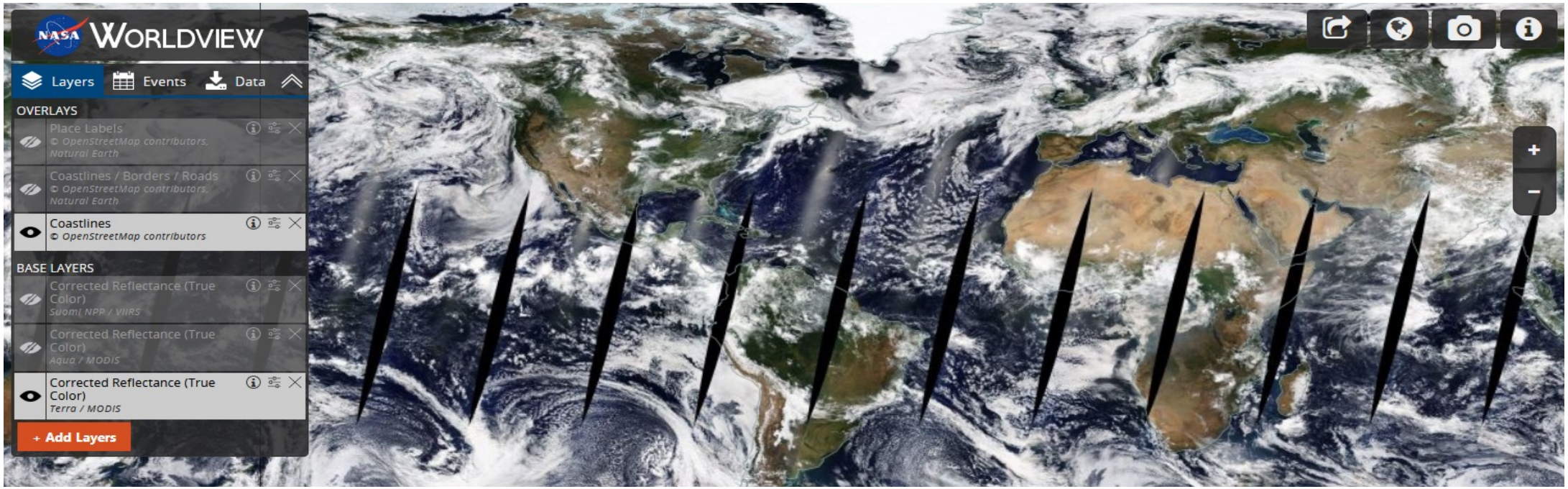
NOAA's Aerosol Watch

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



Smoke Monitoring Tools – Worldview

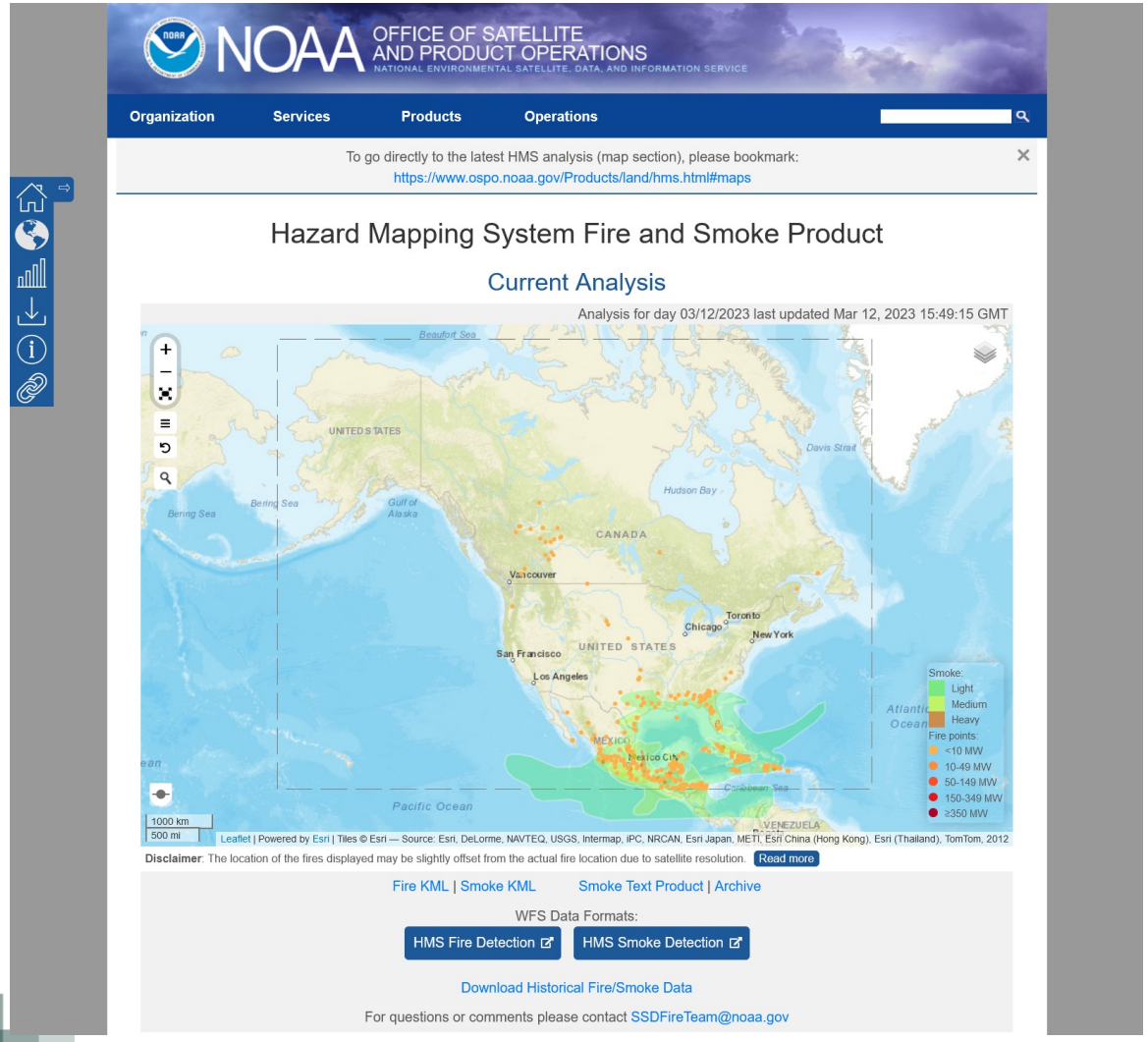
NRT Data & Image Access https://worldview.earthdata.nasa.gov/

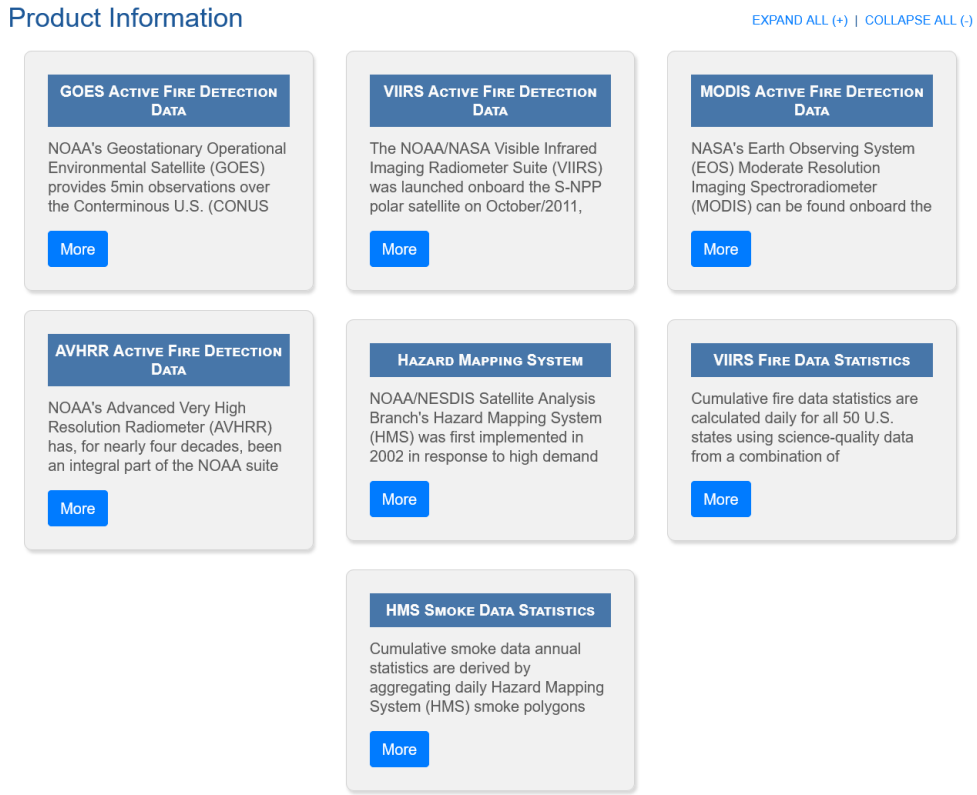


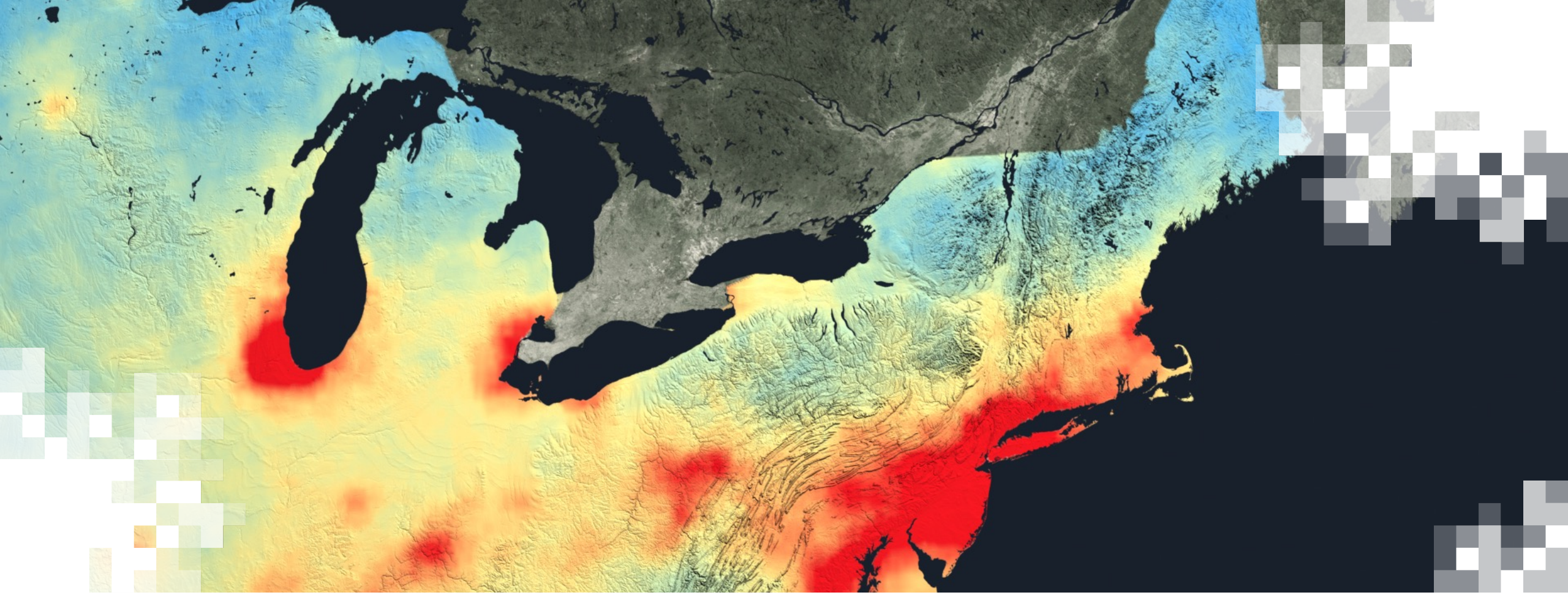
- Visible Imagery (MODIS, VIIRS)
- Fire Detection (MODIS, VIIRS)
- Aerosol Optical Depth (MODIS - 1, 3, 6, 10km, OMI, MISR)
- Aerosol Index (OMI)
- Day-Night Band (VIIRS)

NOAA's Hazard Mapping System

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





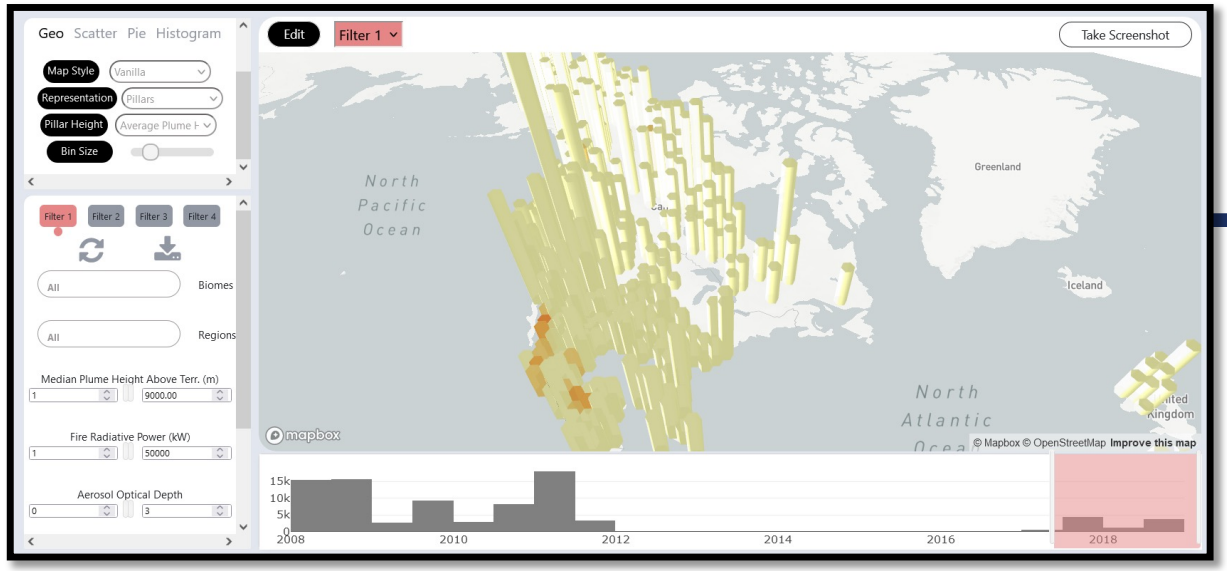


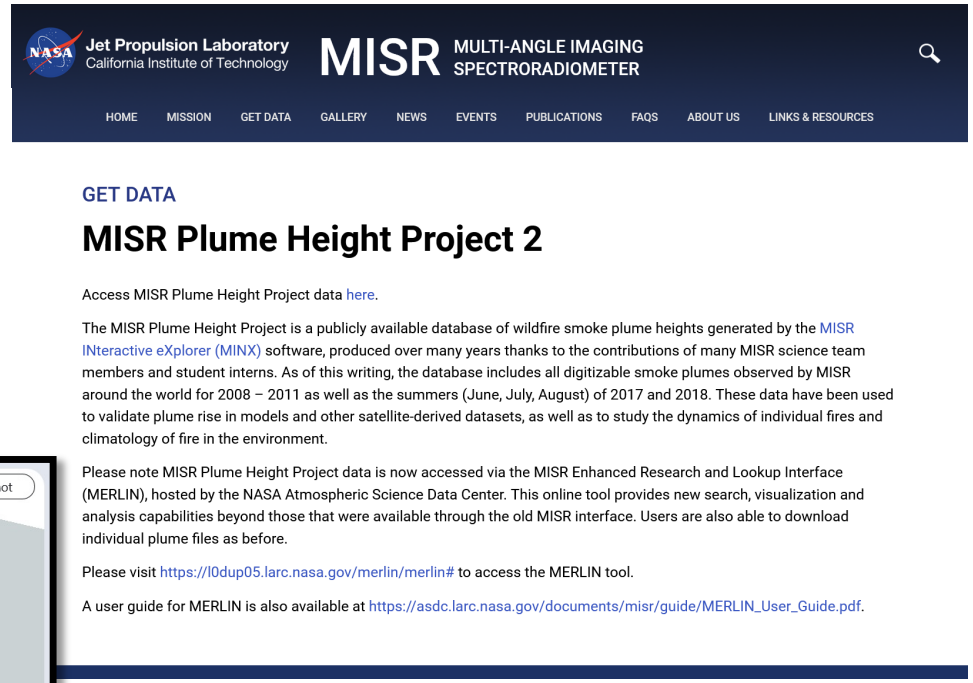
Aerosol Layer Altitude

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





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

- 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

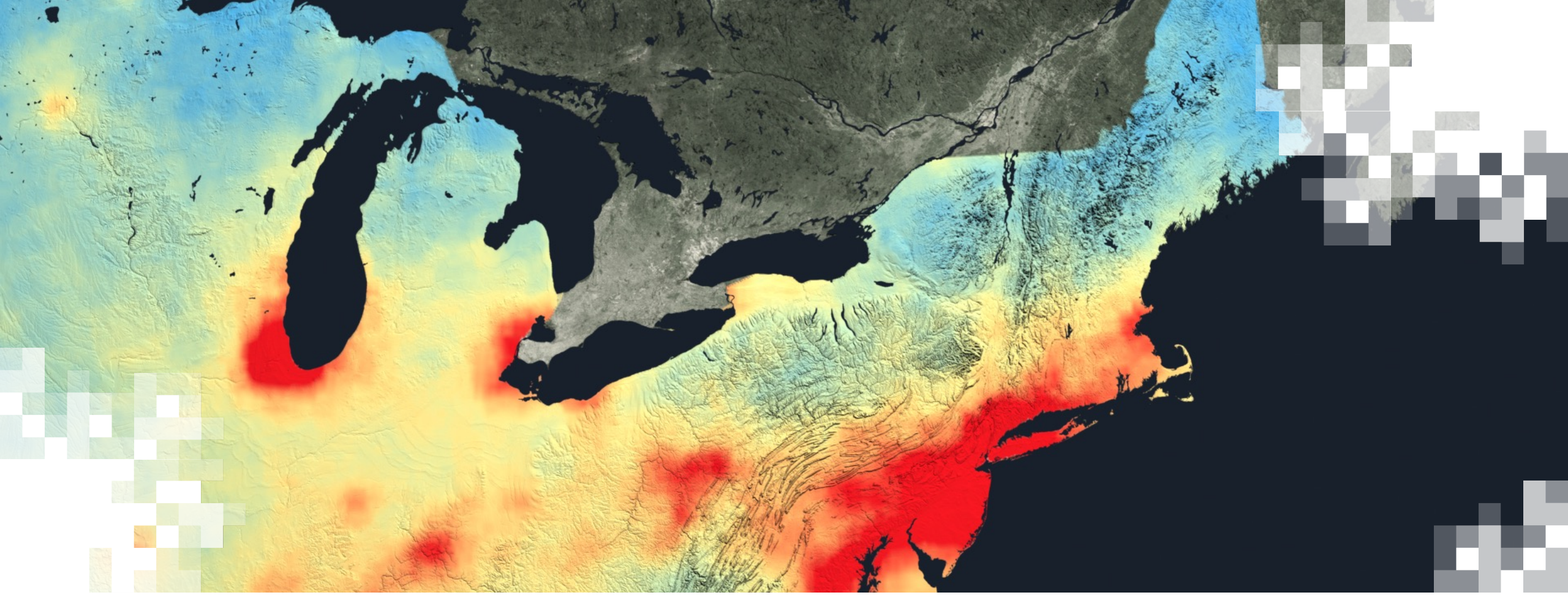
ATBD: https://sentinel.esa.int/documents/247904/2476257/Sentinel-5P-TROPOMI-ATBD-Aerosol-Height

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, ~450m lower on average, ~200m low with respect to LiDAR (CALIOP)

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



Questions?