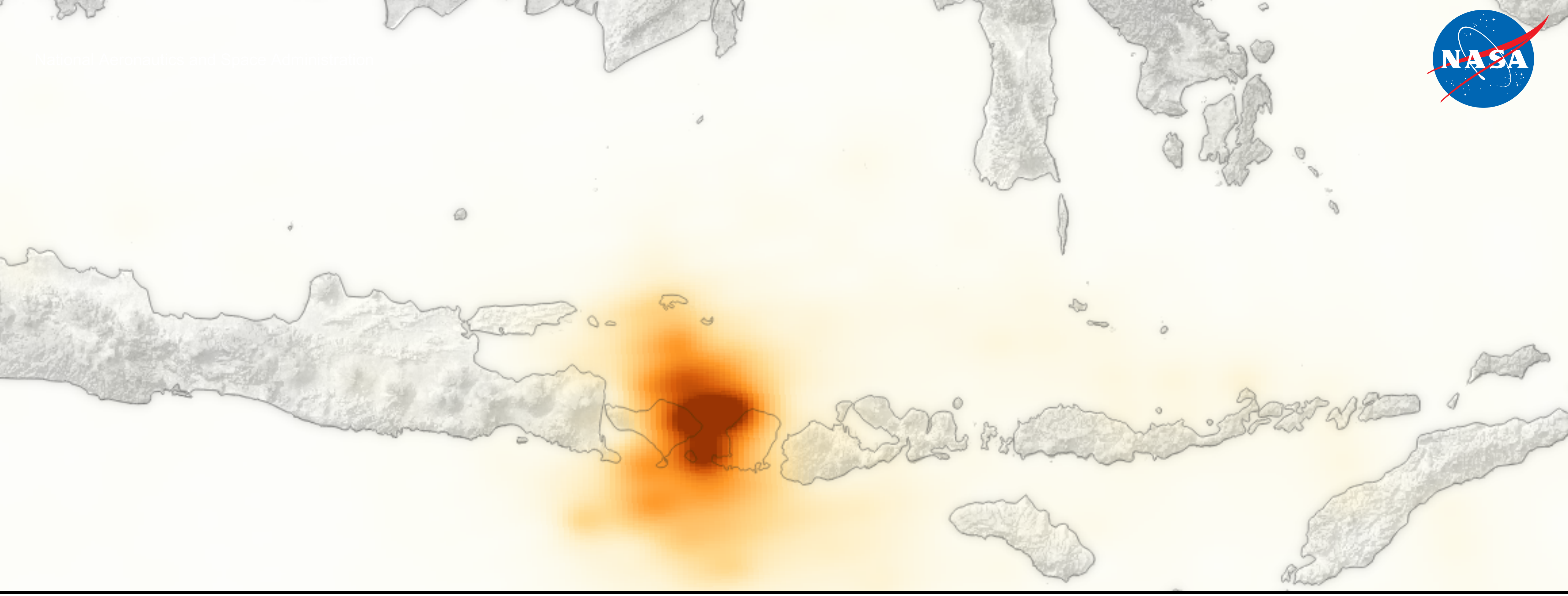


Introduction to Remote Sensing of Air Quality

Data Analysis Tools for High Resolution Air Quality Satellite Datasets

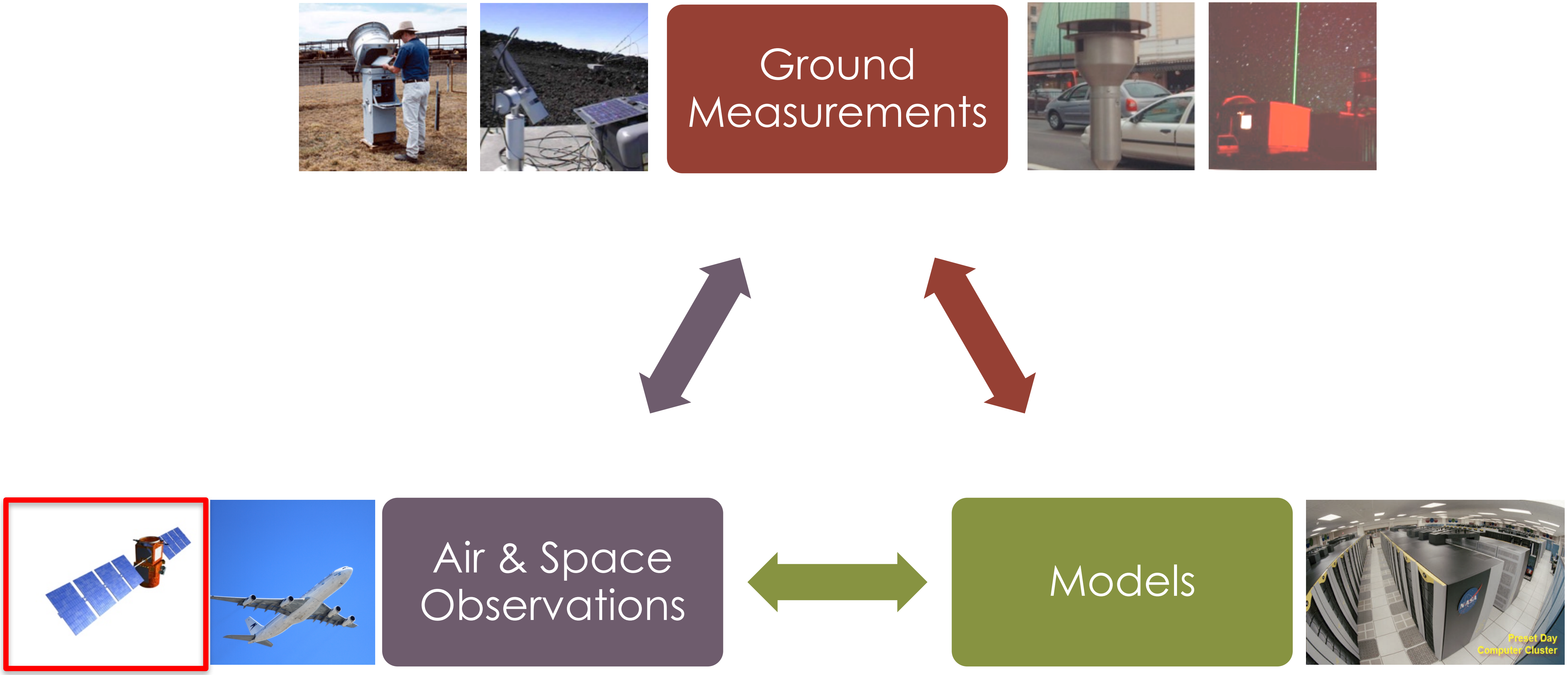
Pawan Gupta & Melanie Follette-Cook, January 17-22, 2018

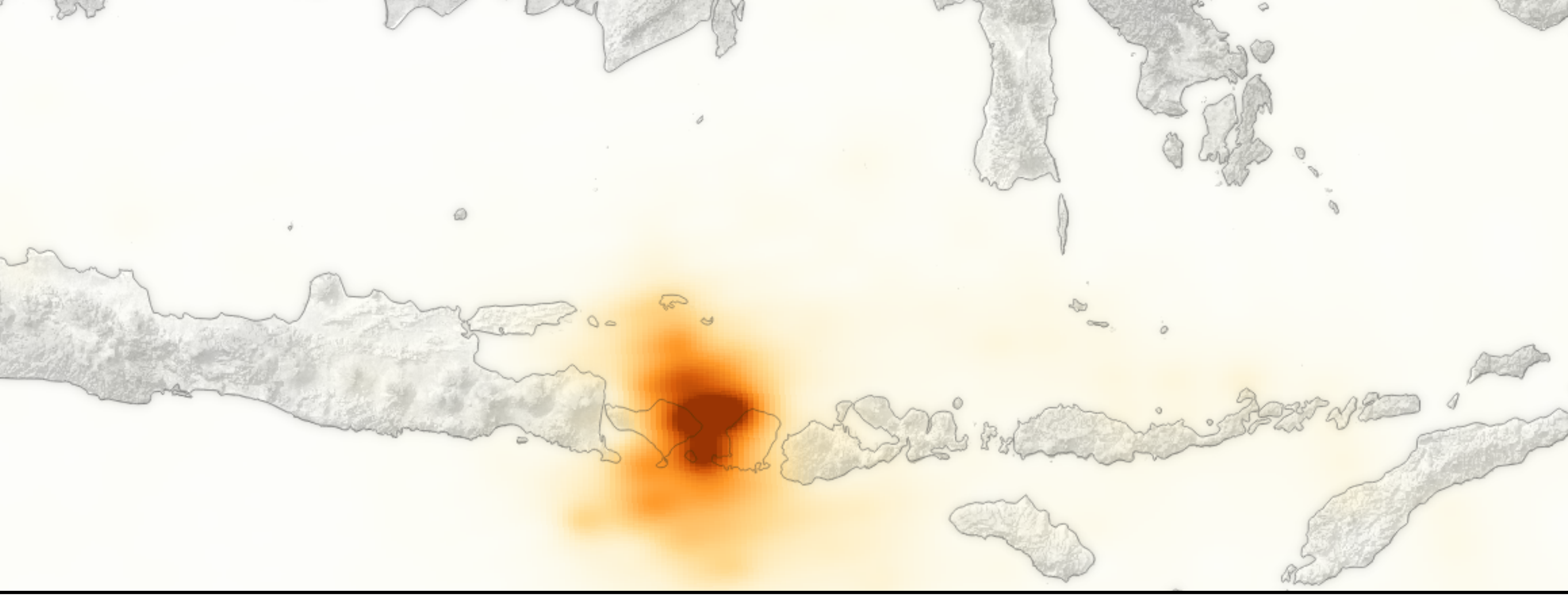
Learning Objectives

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

- outline aerosol and trace gas products
- identify potential applications for air quality monitoring
- describe tools to read and map datasets

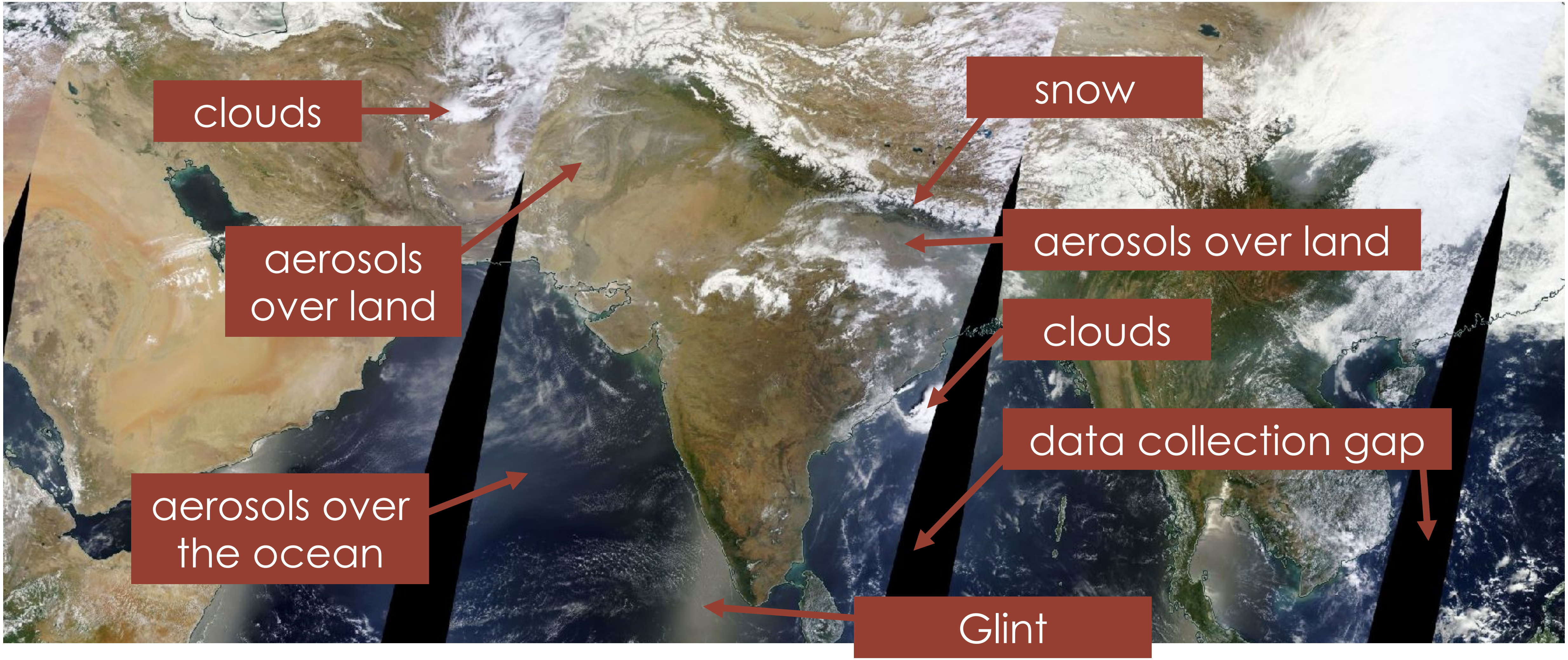
Air Pollution Monitoring





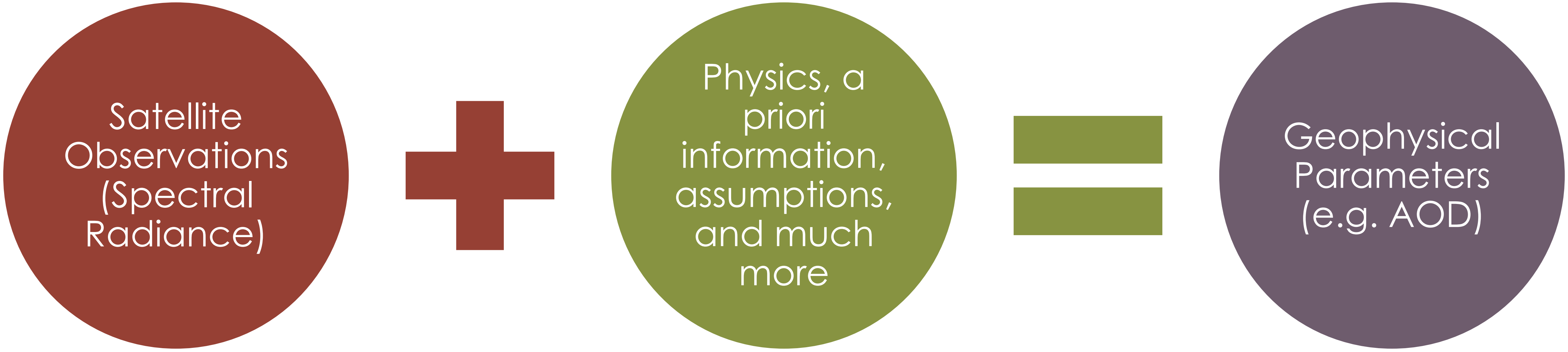
Why use satellite data?

What can we learn from true color imagery?



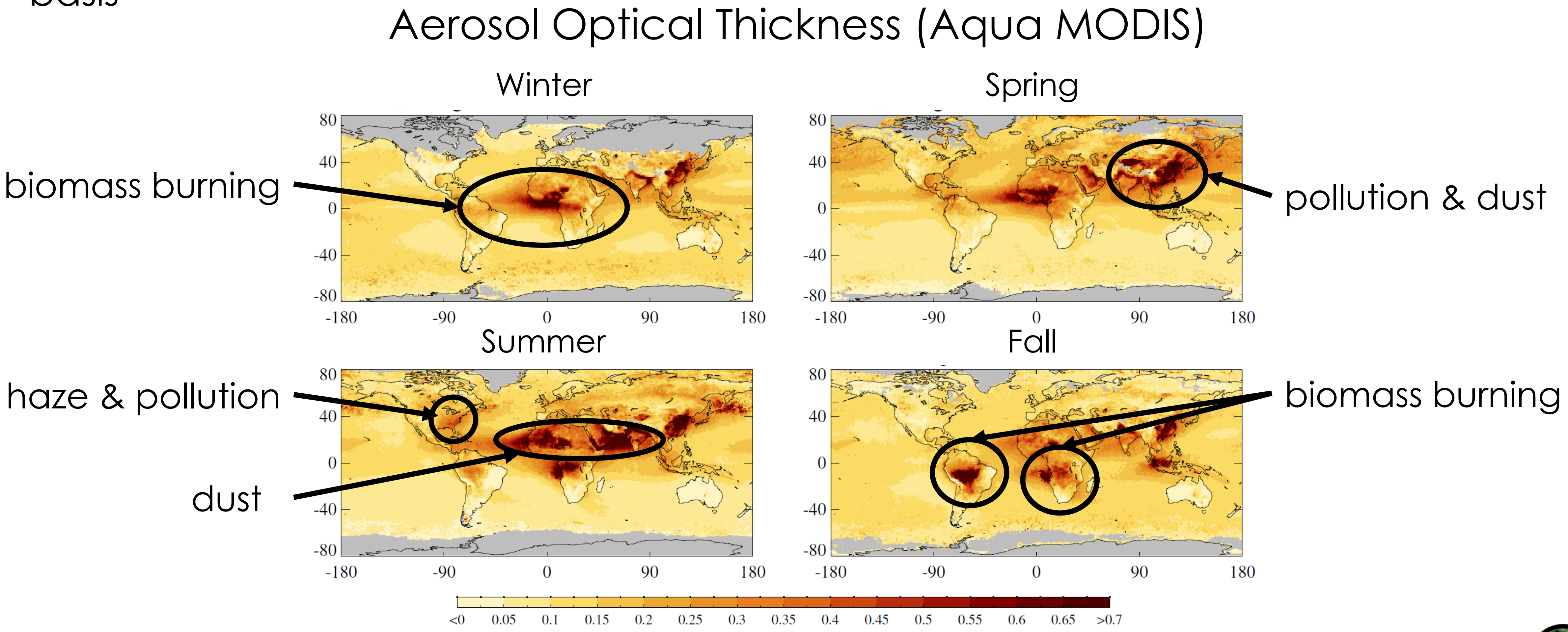
Terra (MODIS) image, April 19, 2013

Radiance to Geophysical Parameter



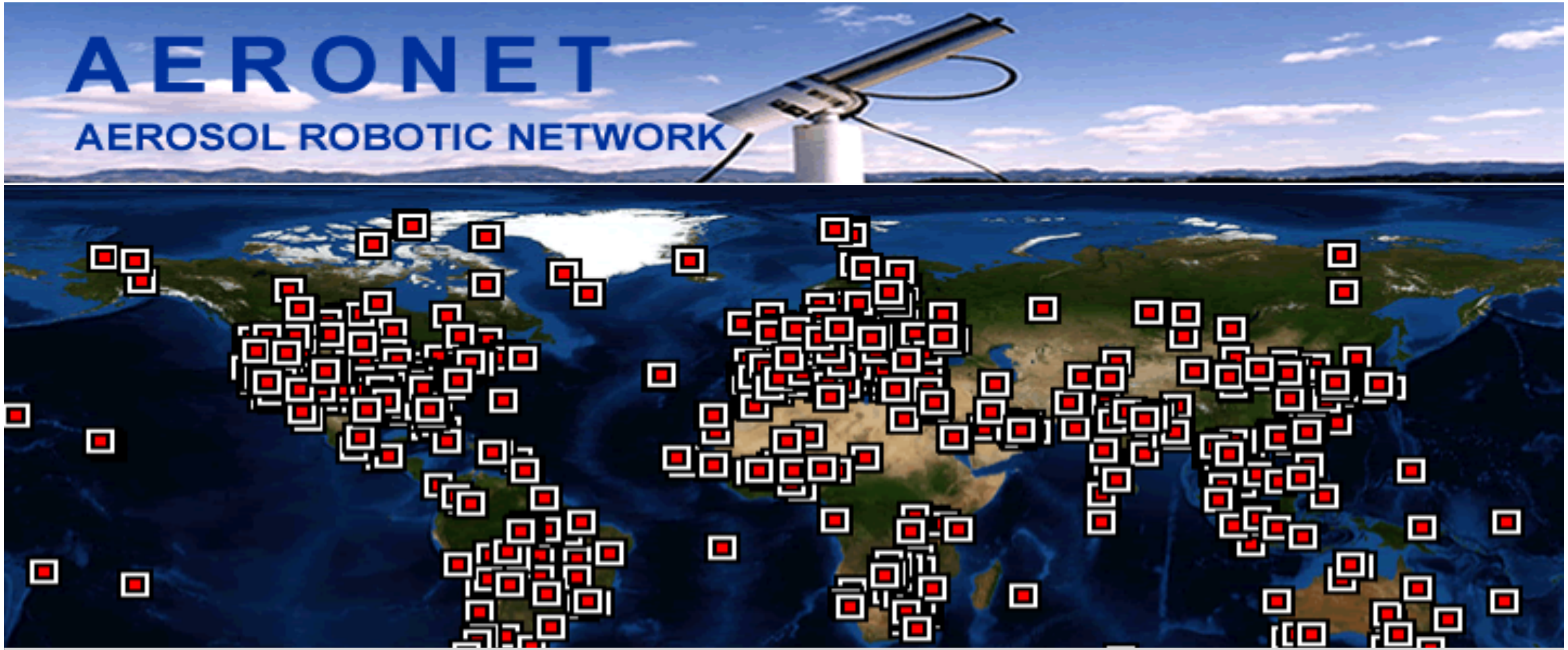
Aerosols from Satellites

- Several satellites provide state-of-the-art aerosol measurements globally, on a daily basis



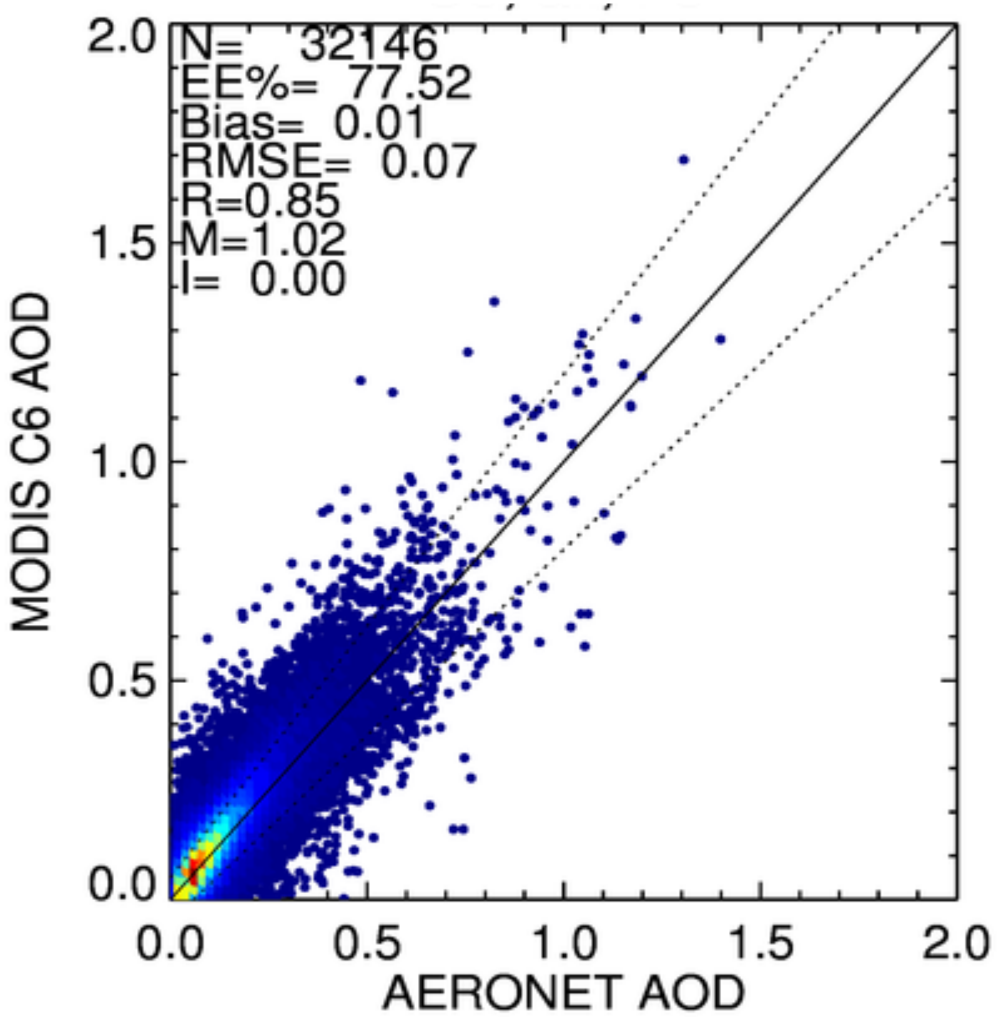
AERONET

http://aeronet.gsfc.nasa.gov/

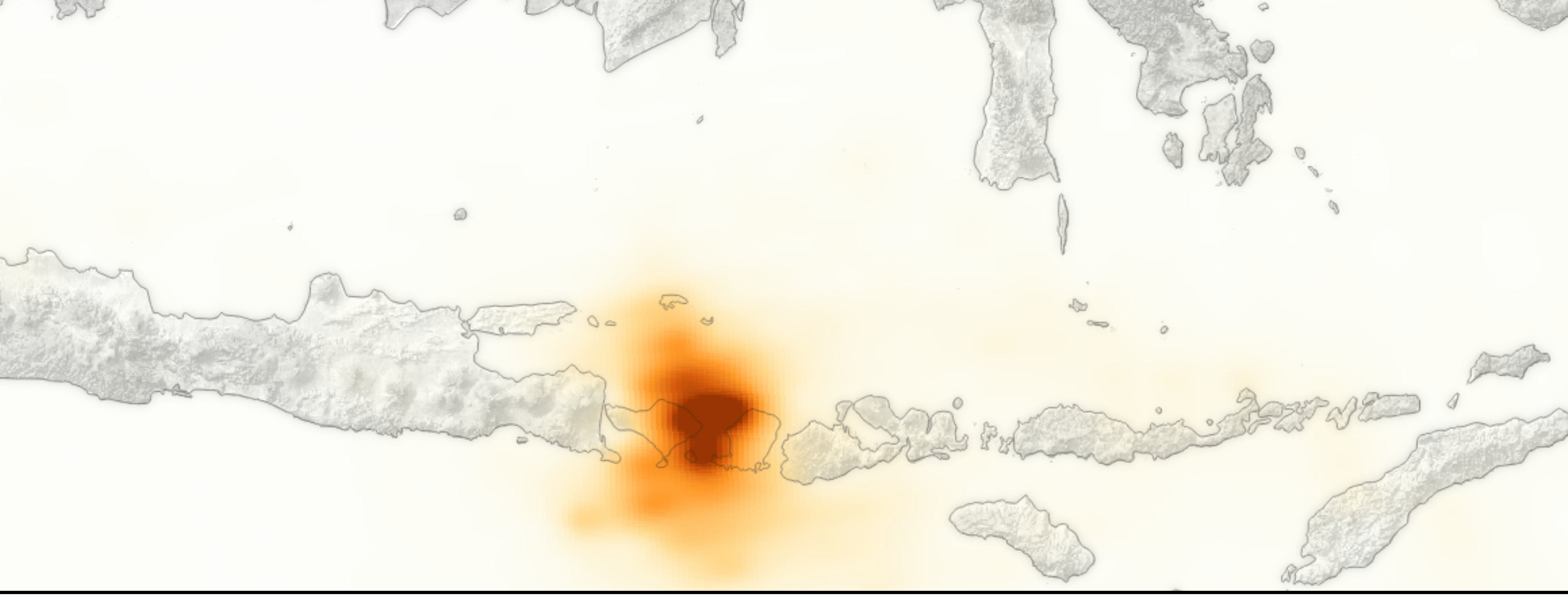


AERONET measurements of aerosol optical depth are considered ground truth and are used to validate satellite aerosol retrievals

MODIS Aerosol Validation

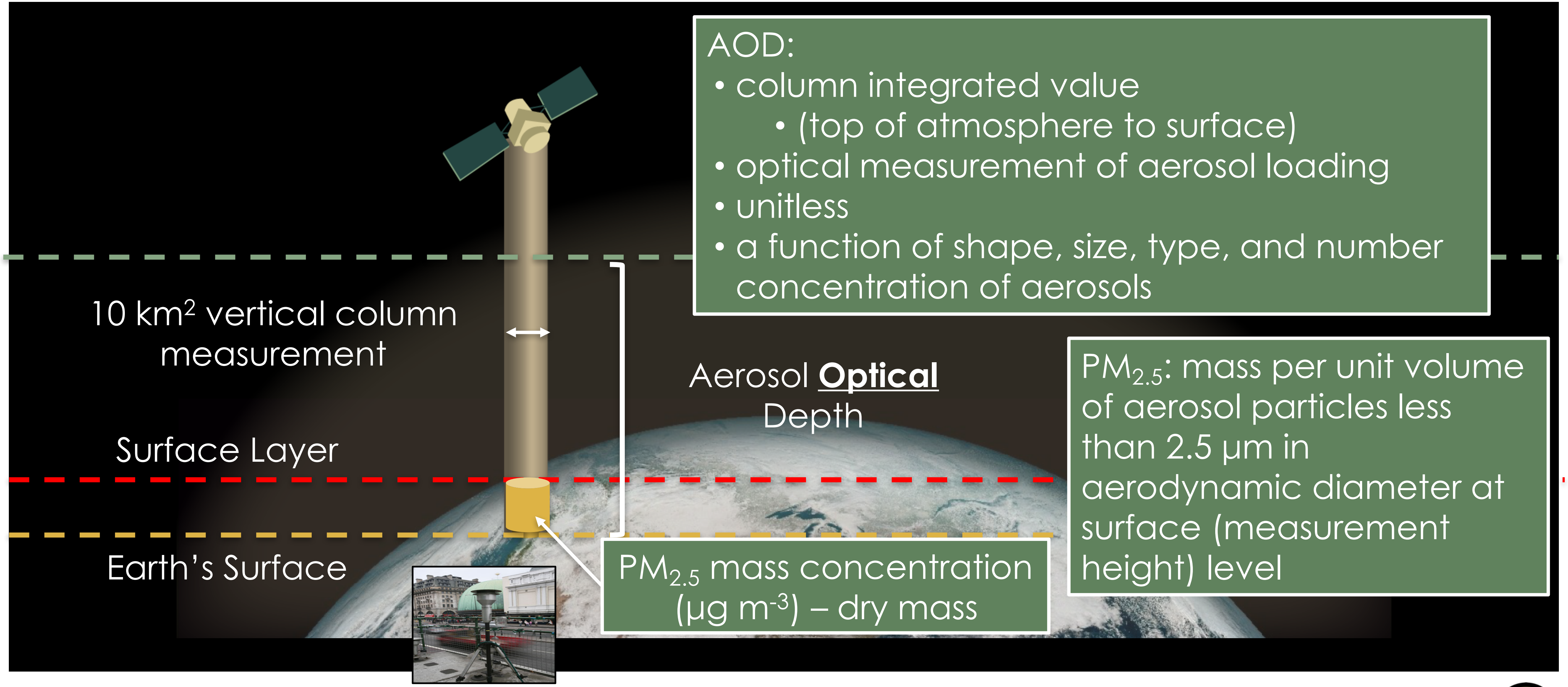


Credit: Gupta



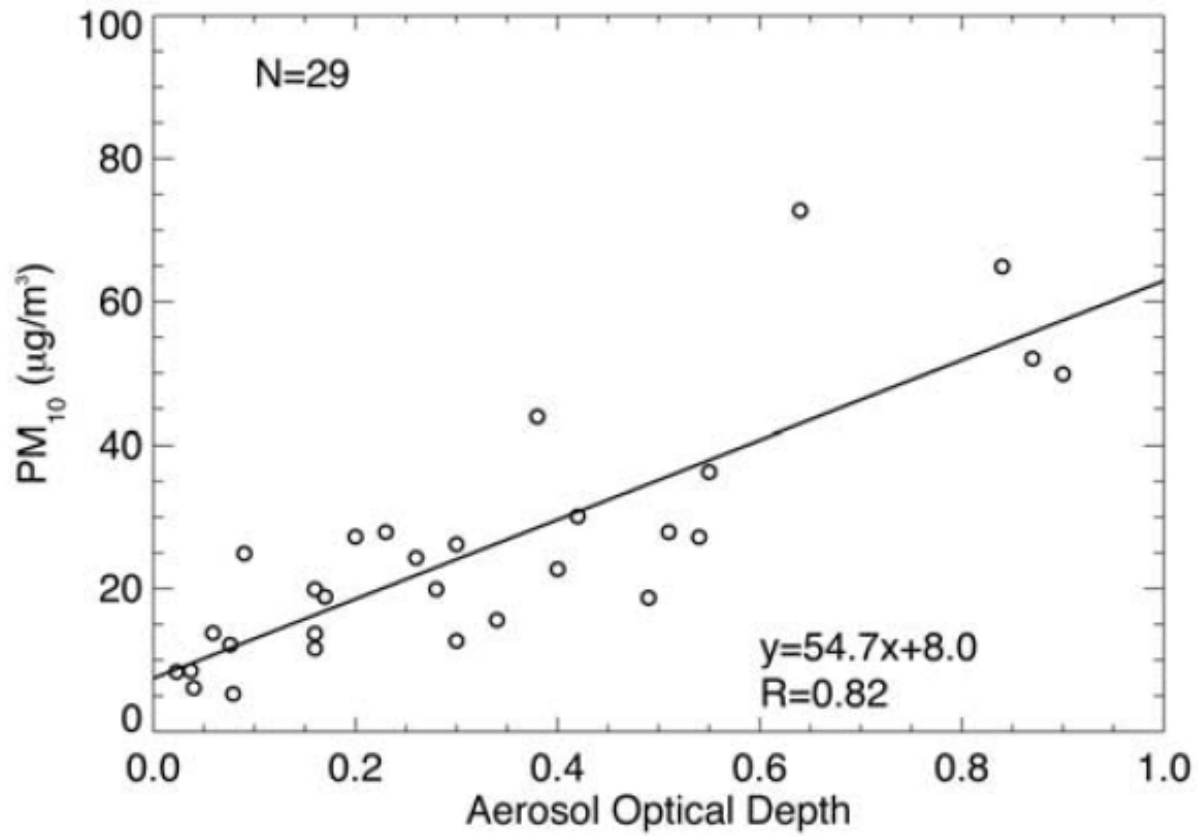
Applications

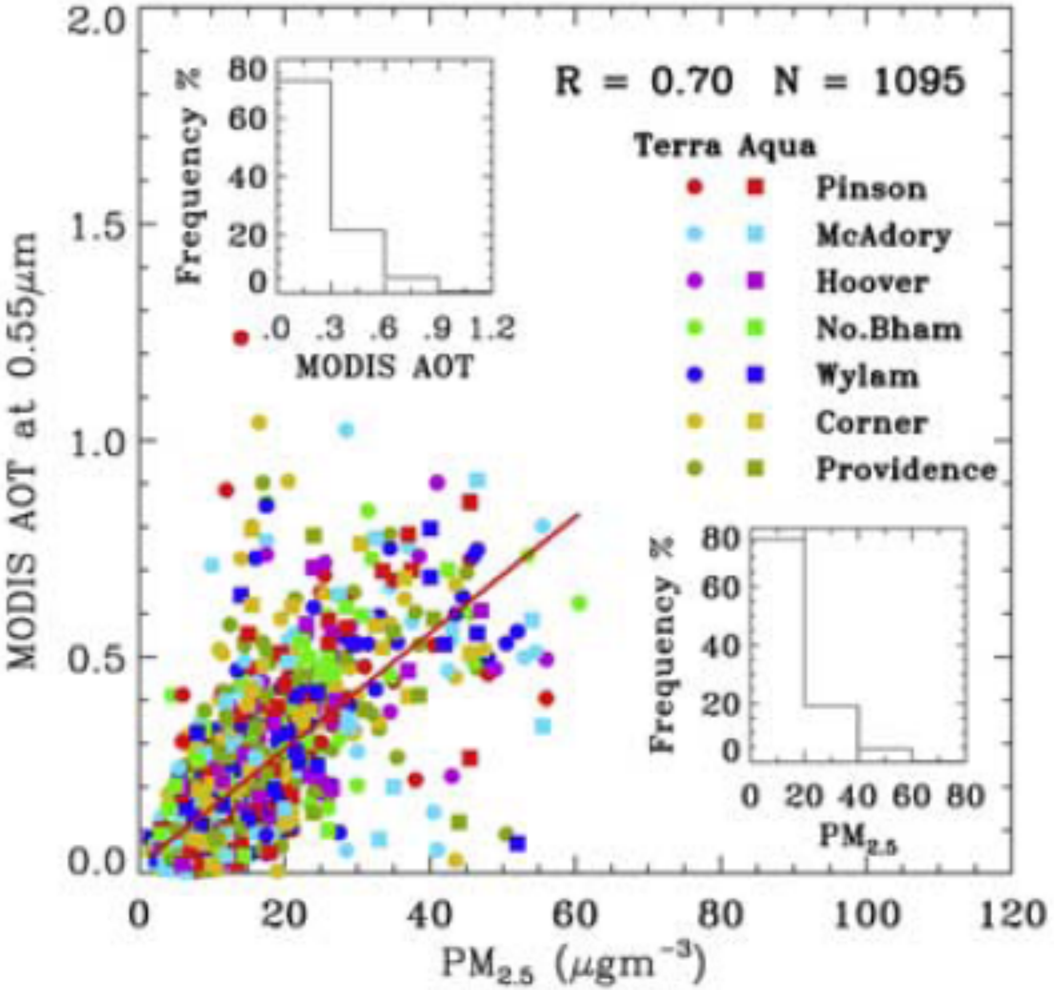
Satellite vs. Ground Observation



Satellite vs. Ground Observation

Simple Models from Early Days



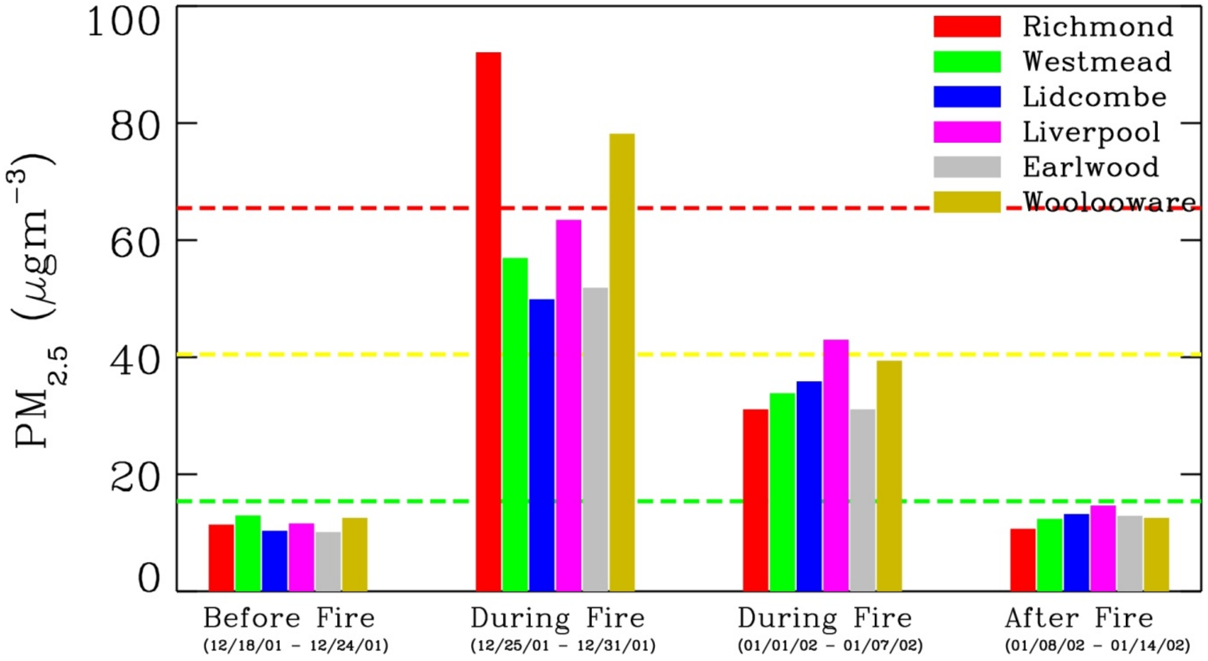


Source (right): Wang et al., 2003 and Chu et al., 2003 (left)

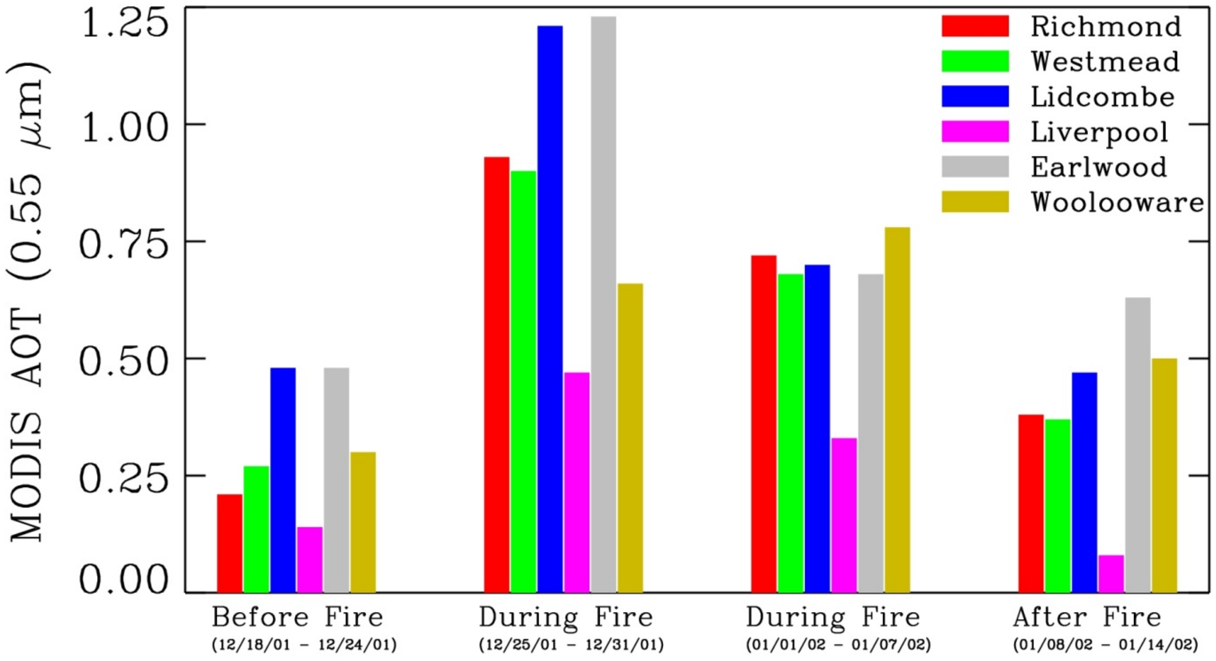
Application of Satellite Observations

Bushfires in Sydney, Australia

Surface $PM_{2.5}$

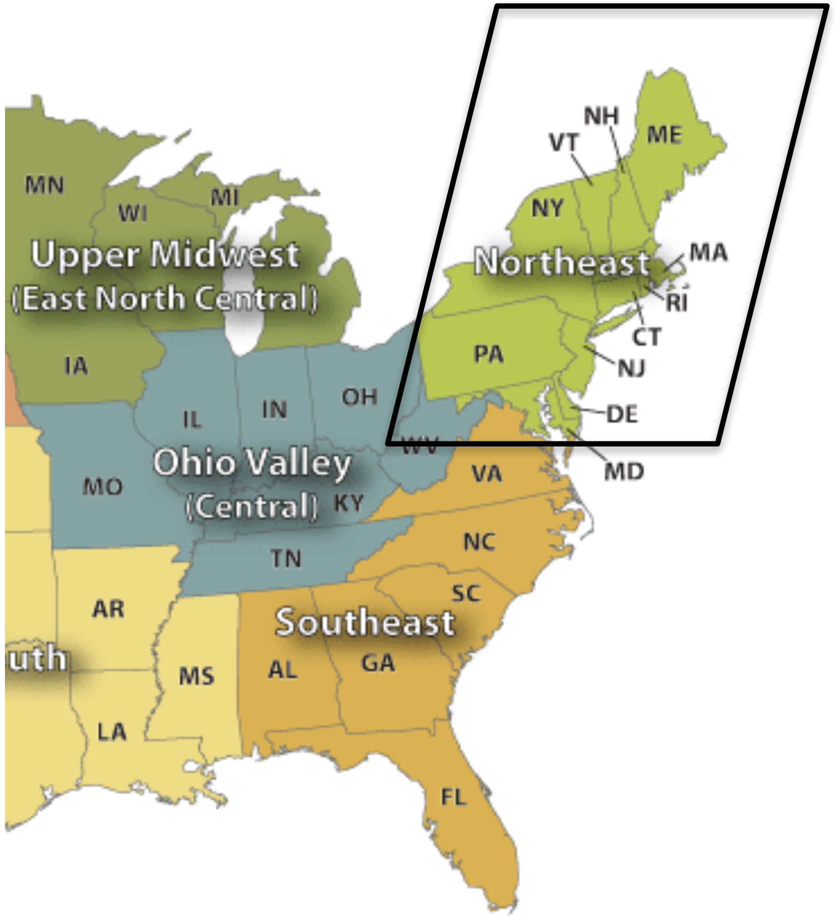


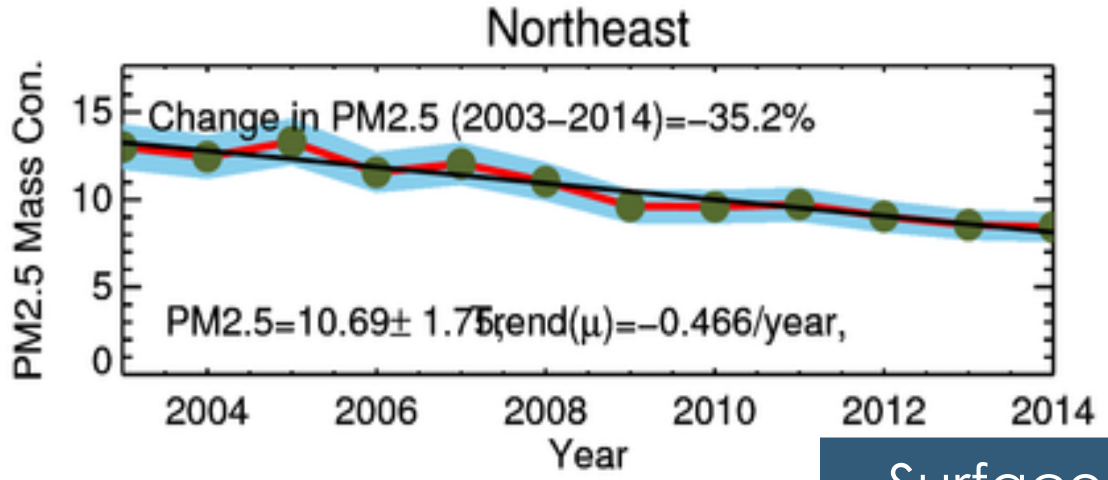
AOD from Satellites



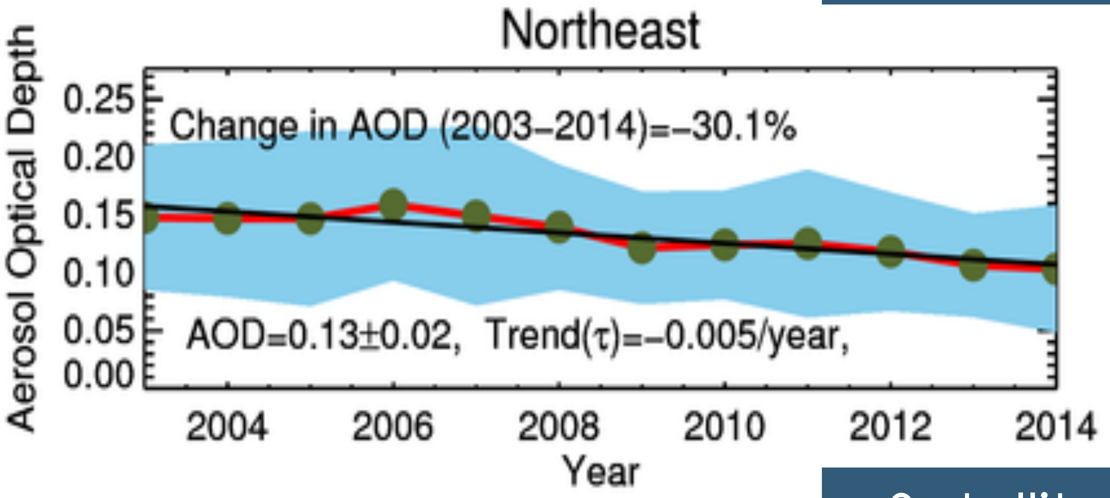
Credit: Gupta and Christopher, 2007

Measurements: Surface vs. Satellite





Surface

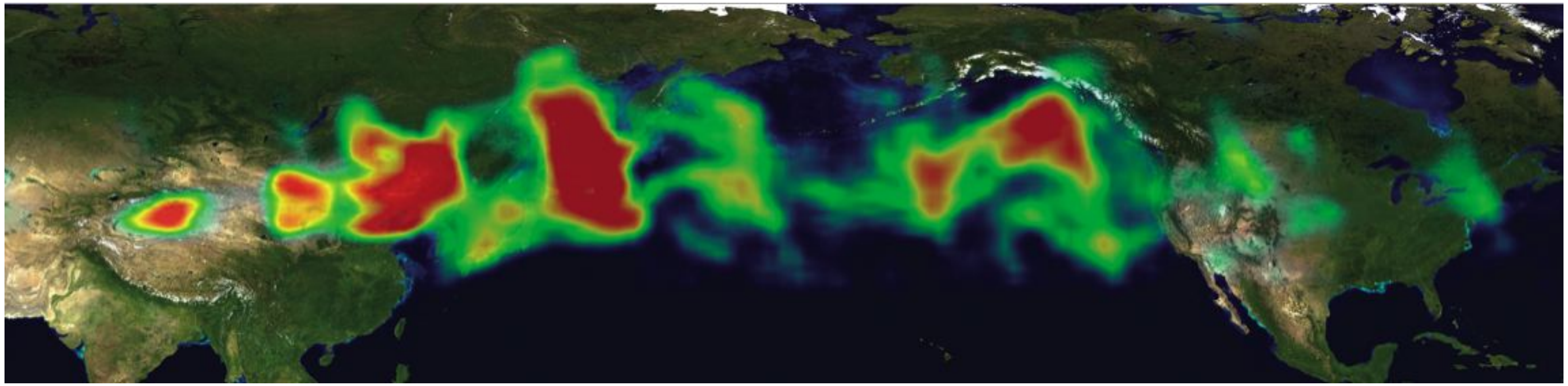


Satellite

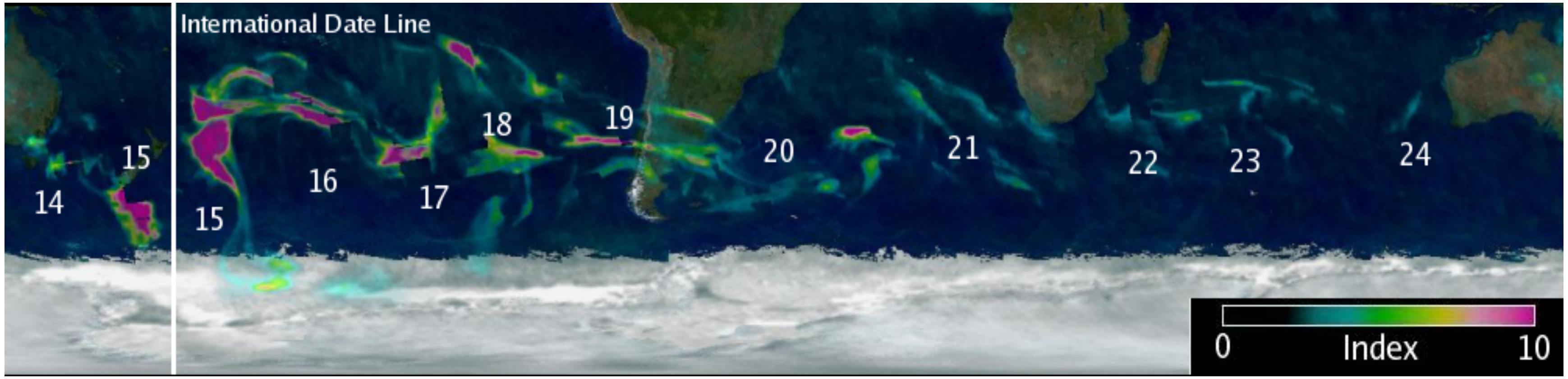
Map Credit: U.S. Climate Regions, NOAA; Time Series Credit: Gupta

Long Range Transport

Dust from Mongolian Deserts Reaches the U.S.

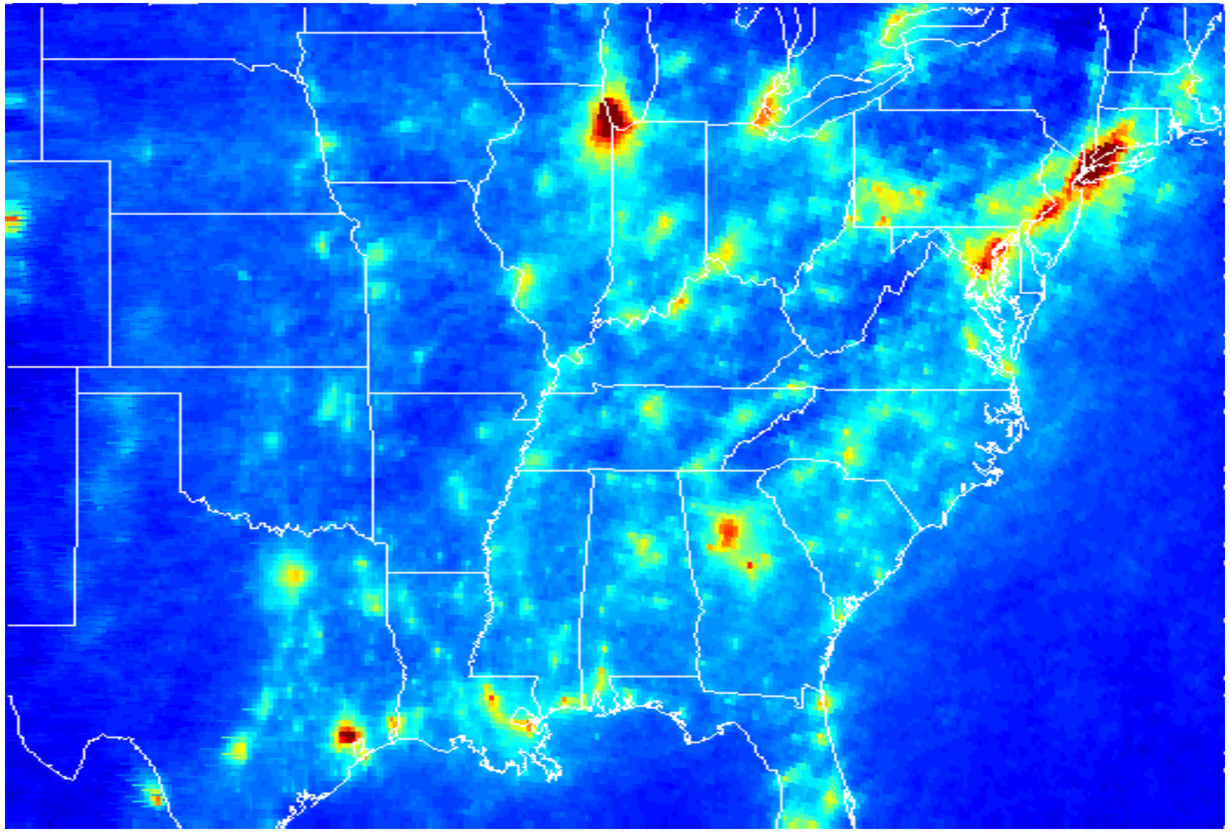


Smoke Travels Around the World in 11 Days

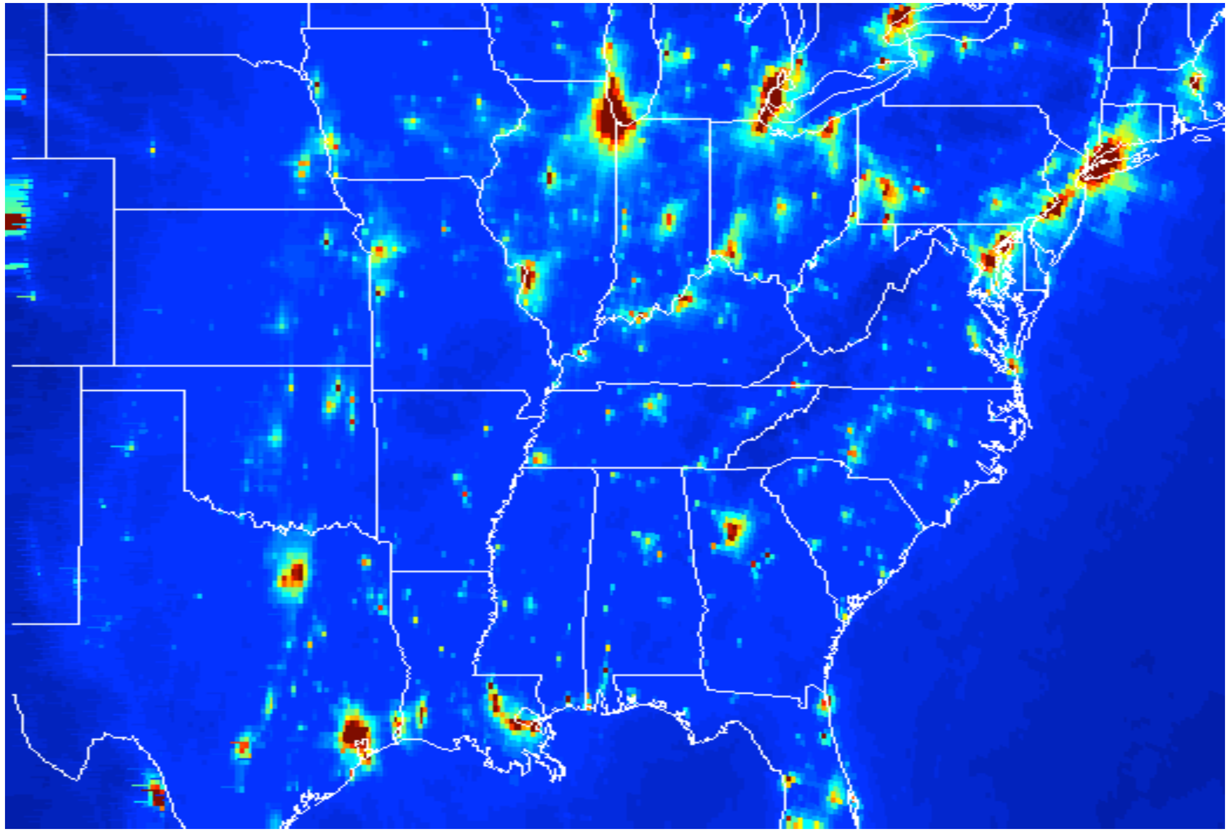


Model-Satellite Inter-Comparison

CMAQ Model NO_2

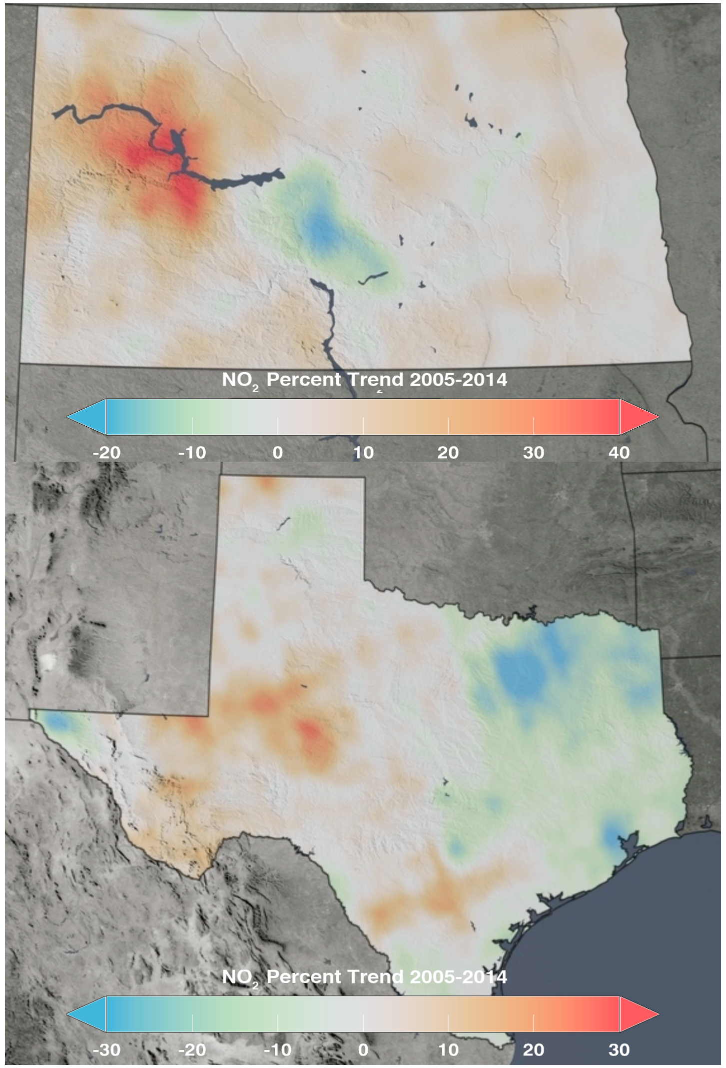


OMI NO_2



OMI Detects NO_2 Increases from ONG Activities

2005-2014

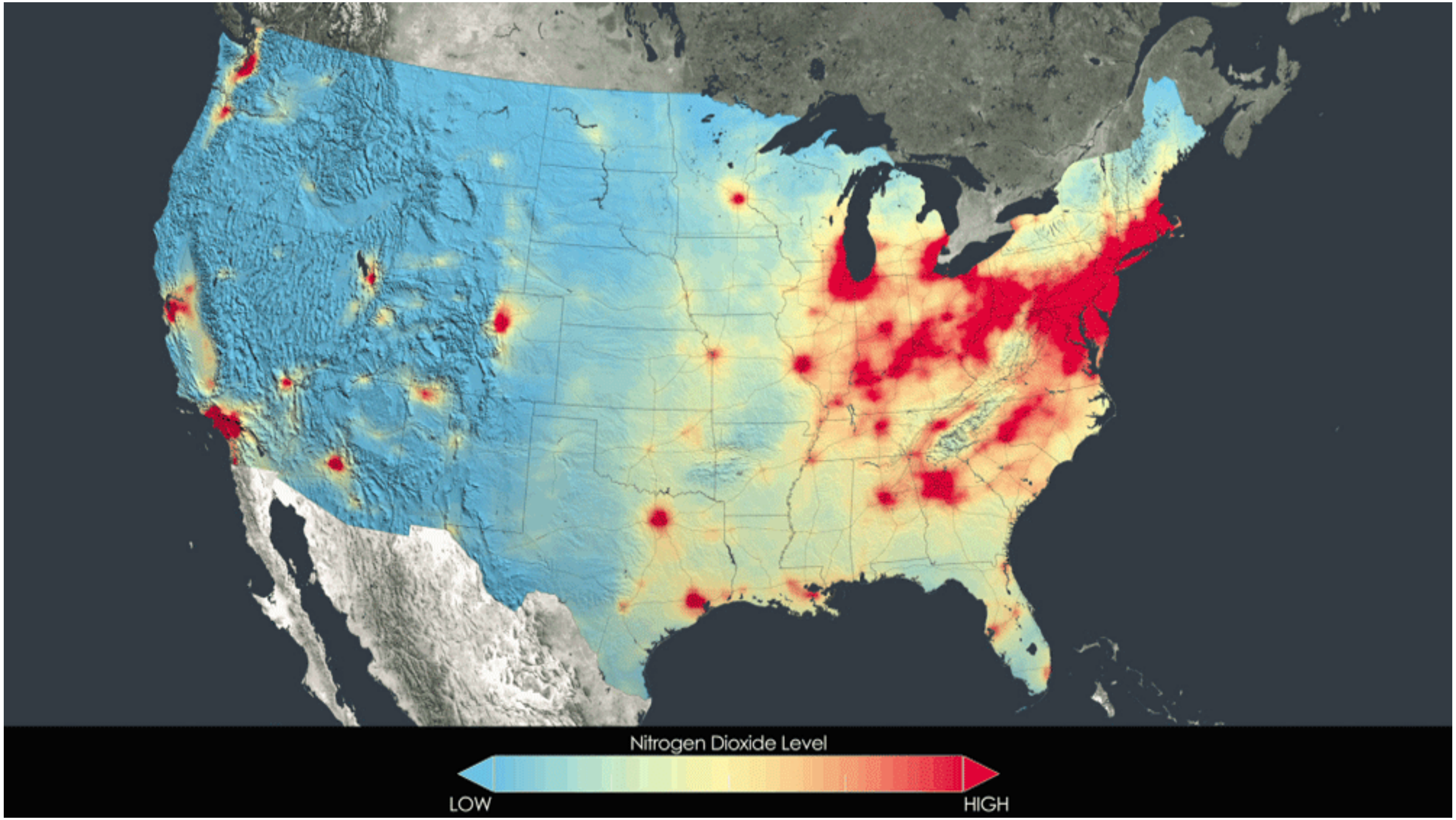


North Dakota

Suomi NPP VIIRS Lights at Night

Texas

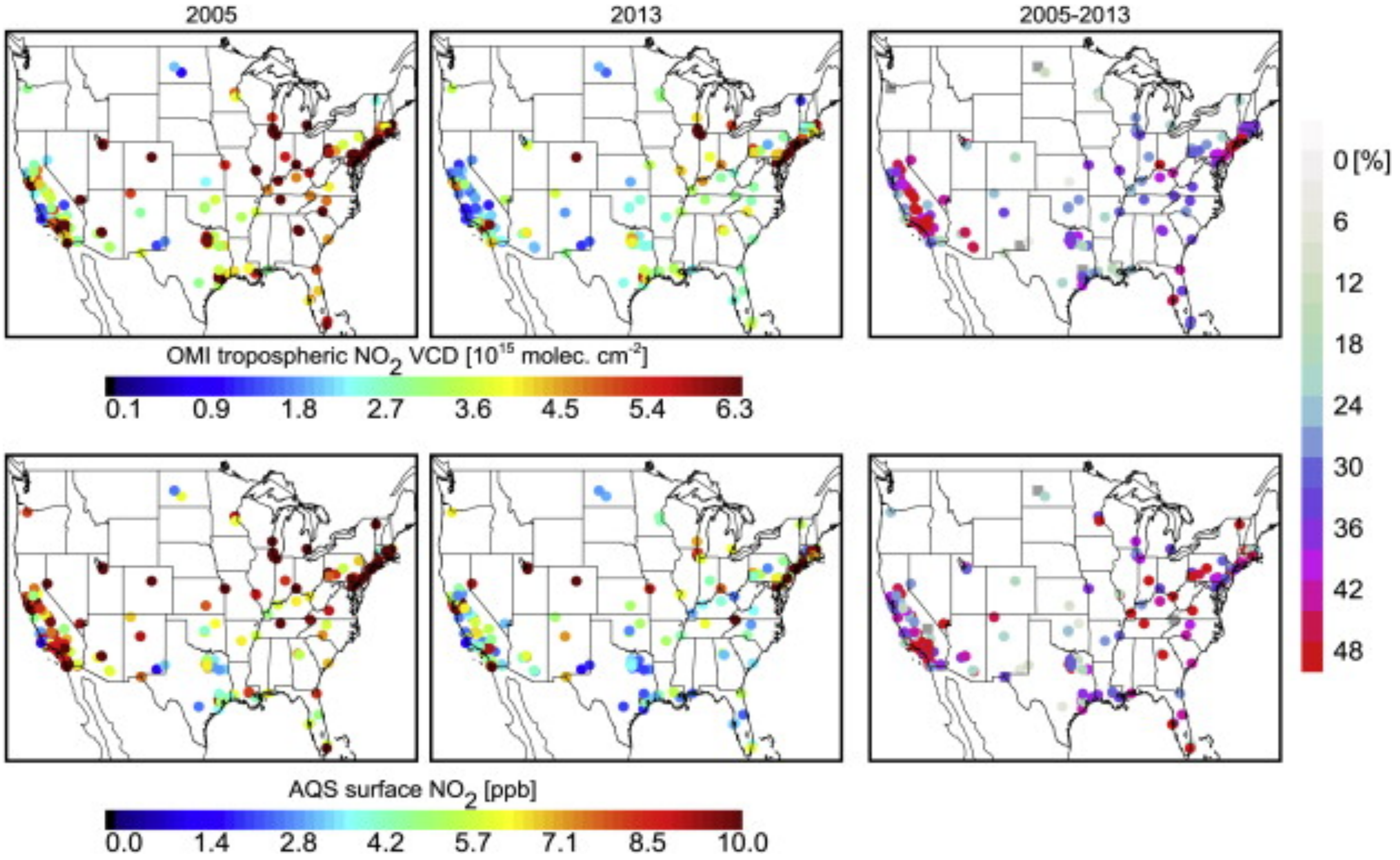
NO_2 Trends Over the United States



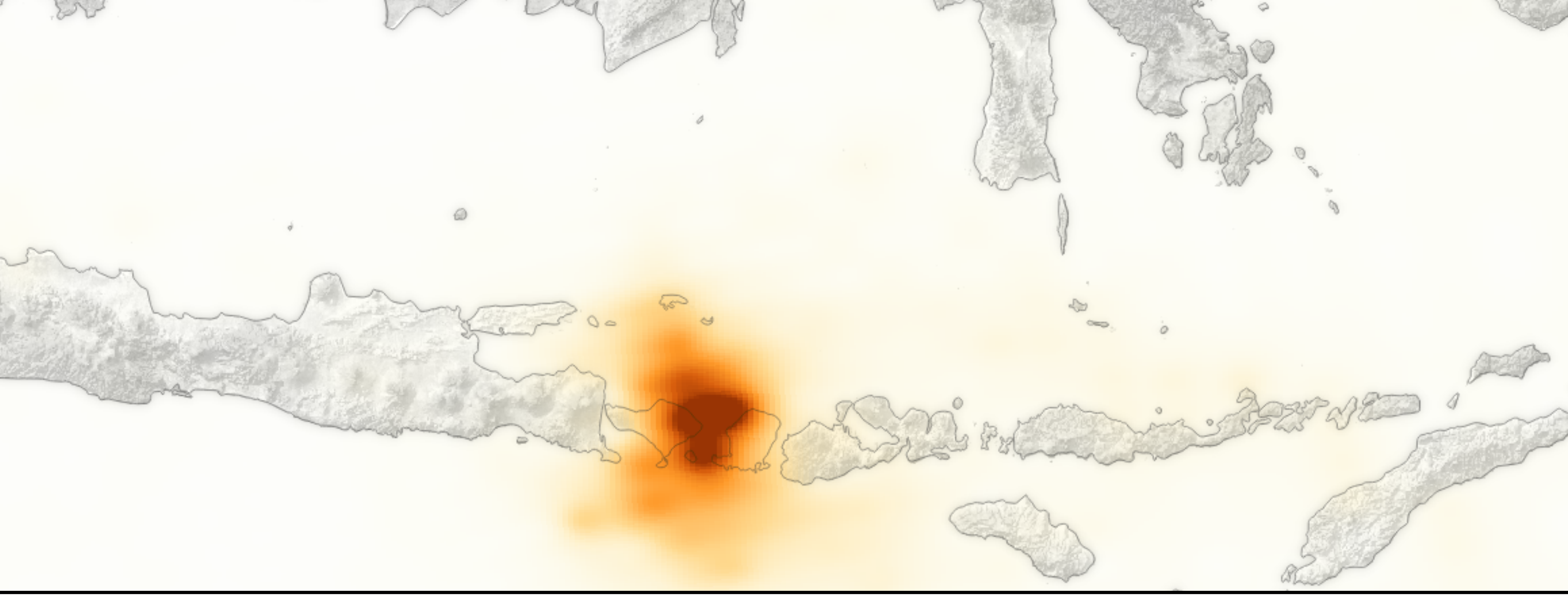
OMI Trends in NO_2 Correlate Well With Surface Trends

OMI (Satellite)

AQS (Surface)

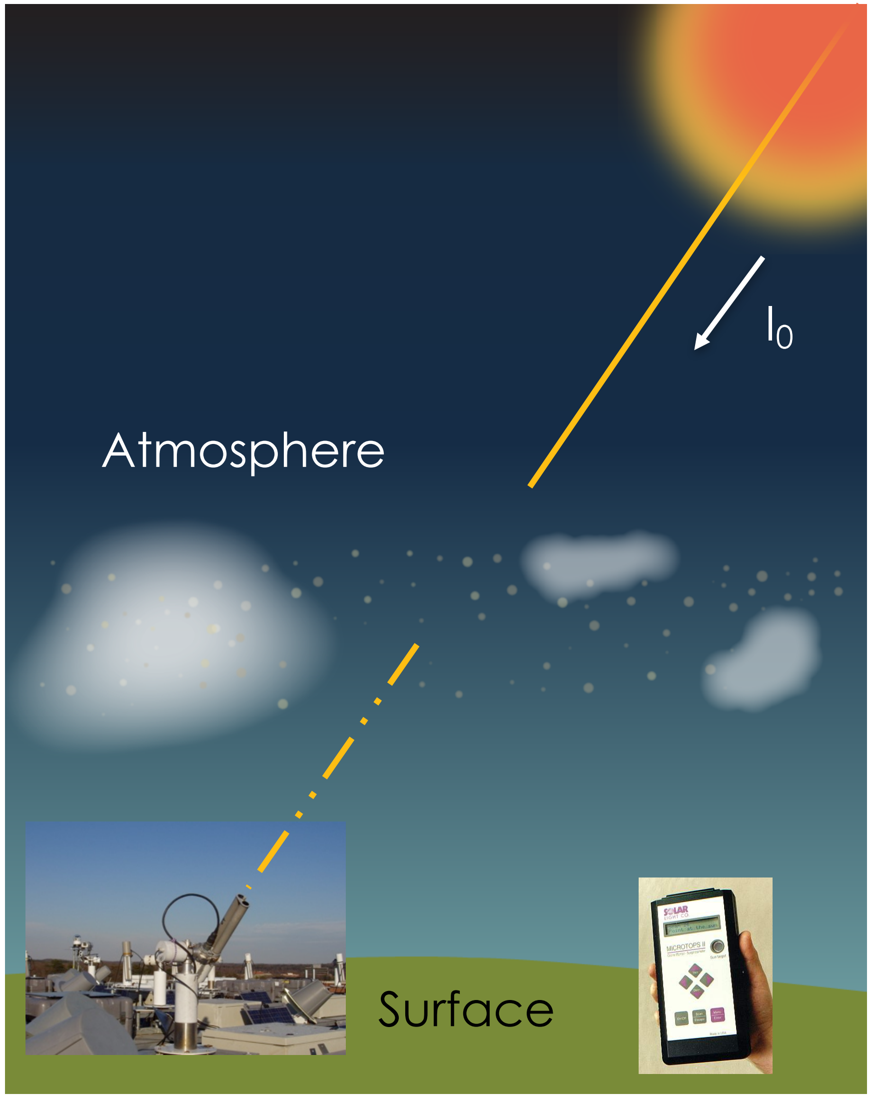


Source: Lamsal, L.N. et al. (2016)



MODIS Aerosol Product

Optical Depth



The optical depth expresses the quantity of light removed from a beam by **scattering** or/and **absorption** during its path through a medium

optical depth τ as:

$$I = I_0 e^{-m\tau}$$

$$m = \sec \theta_0$$

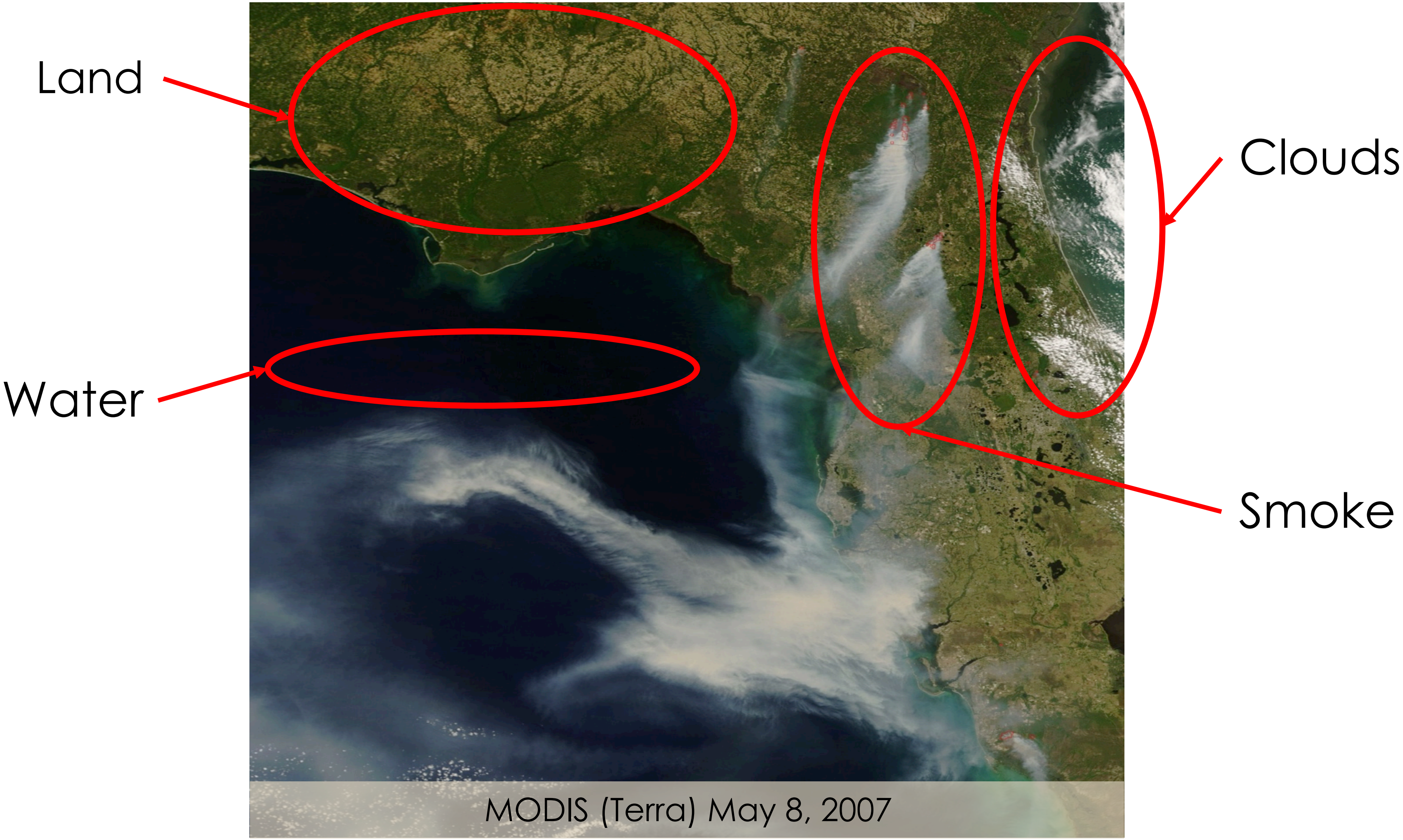
$$\tau = \tau_{Rayl} + \tau_{aer} + \tau_{gas}$$

MODerate resolution Imaging Spectroradiometer

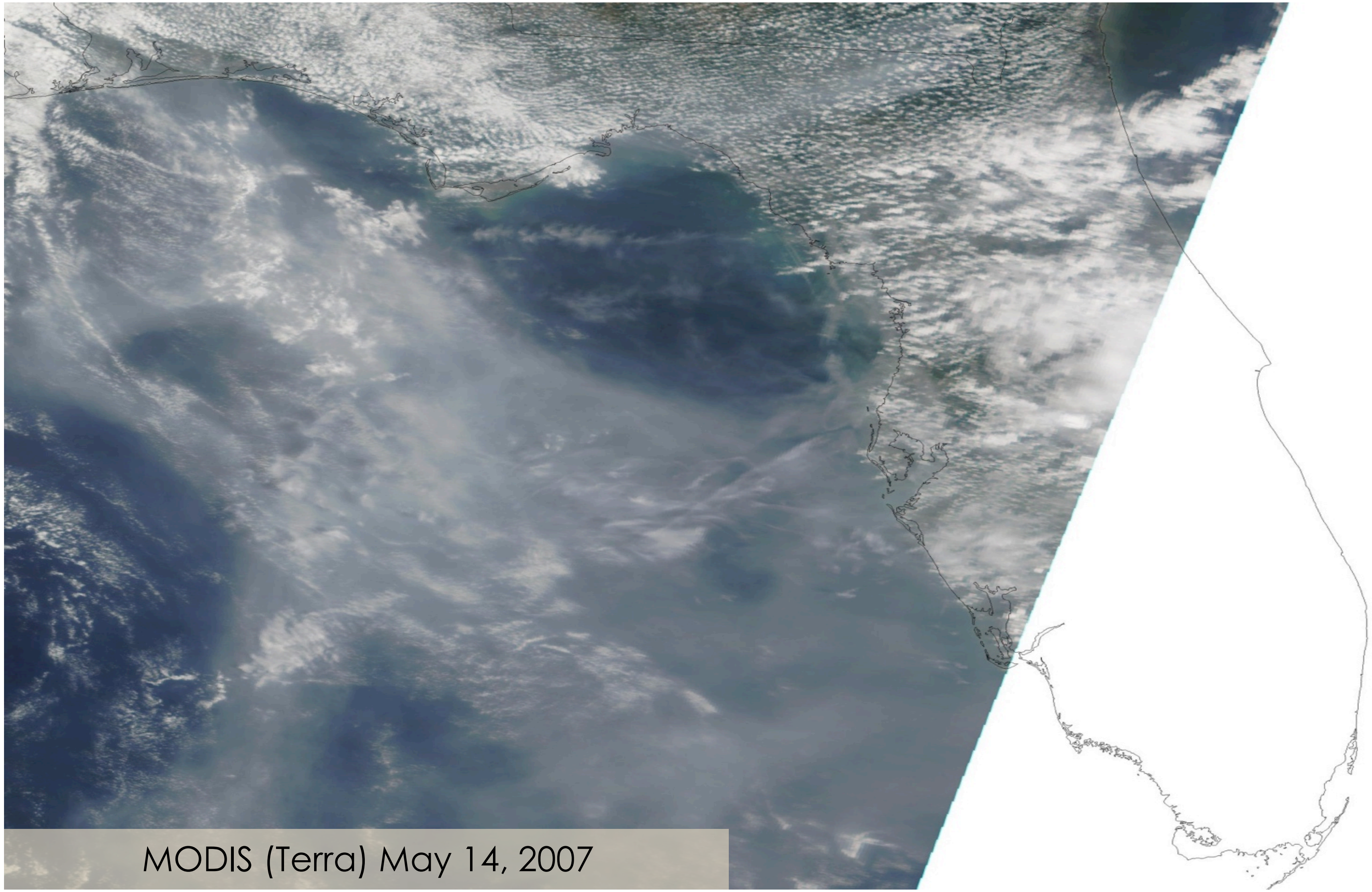
- 2000 - present
- Spatial Resolution
  - 250 m, 500 m, 1 km
- Platform
  - Terra & Aqua
- Temporal Resolution
  - Daily, 8-day, 16-day, monthly, quarterly, yearly
- Data Format
  - Hierarchal Data Format – Earth Observing System Format (HDF-EOS)

- 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

Aerosol Detection

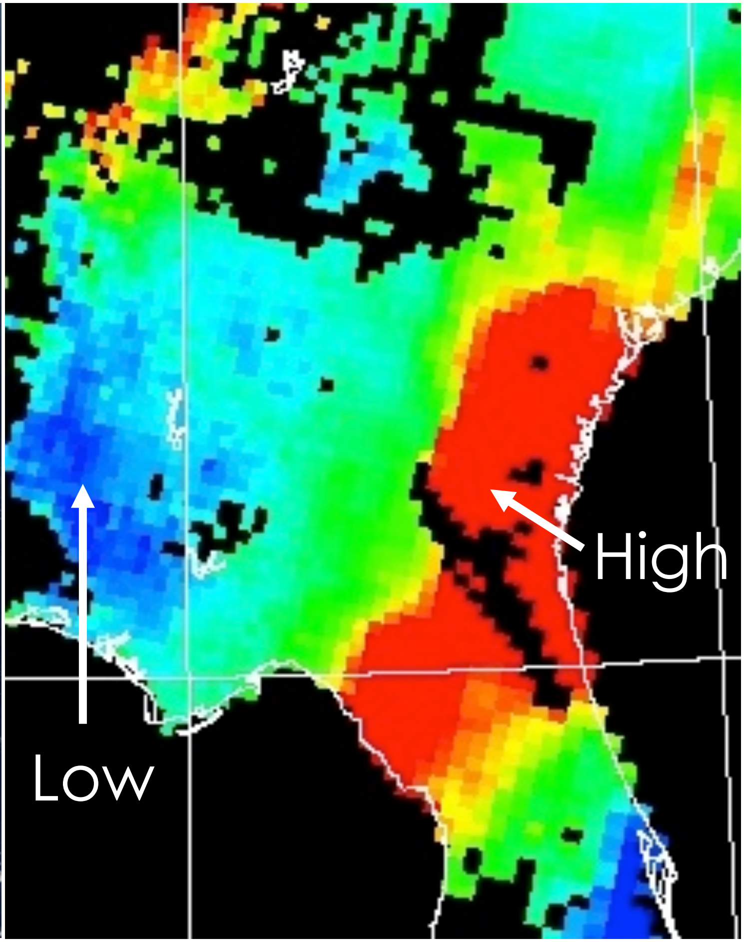


Complex Image: Smoke & Clouds

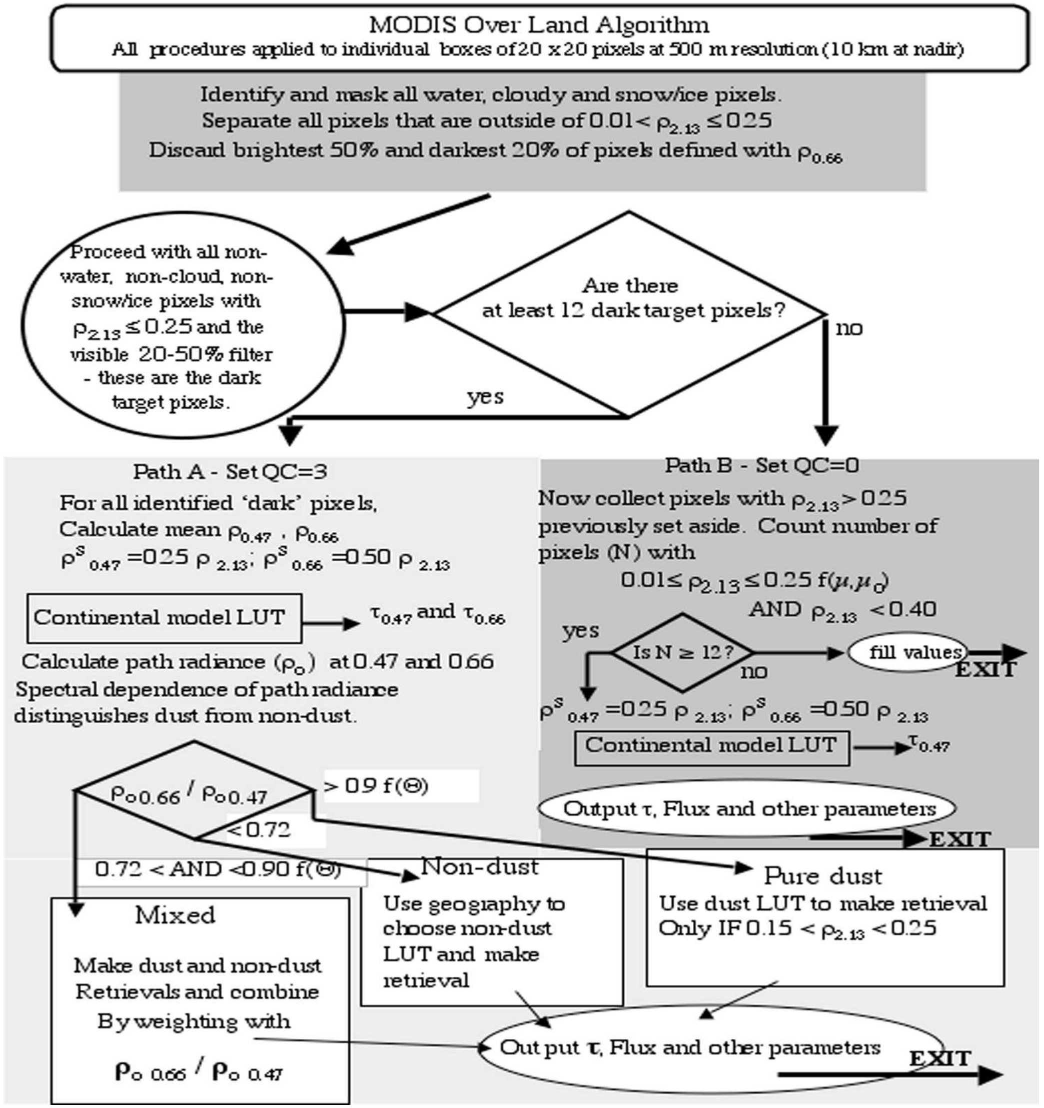


MODIS (Terra) May 14, 2007

Radiance to Aerosol Products



Aerosol Retrieval Algorithm



Aerosol retrieval algorithm is a complex inversion scheme where assumptions are made in simulating satellite observations with advance radiative transfer calculations to retrieve atmospheric aerosol properties

Sources: Remer et al., 2005, Levy et al., 201

MODIS Aerosol Products

Three Separate Algorithms

Land

Dark Target

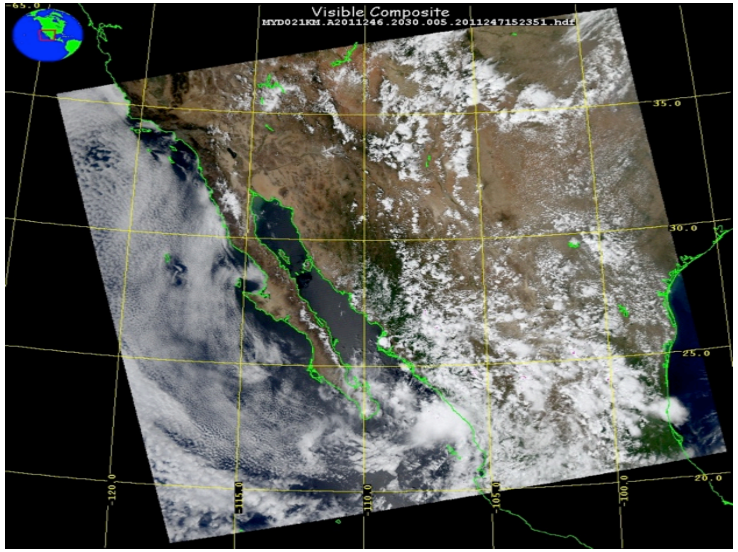
Deep Blue used over bright land surfaces

Ocean

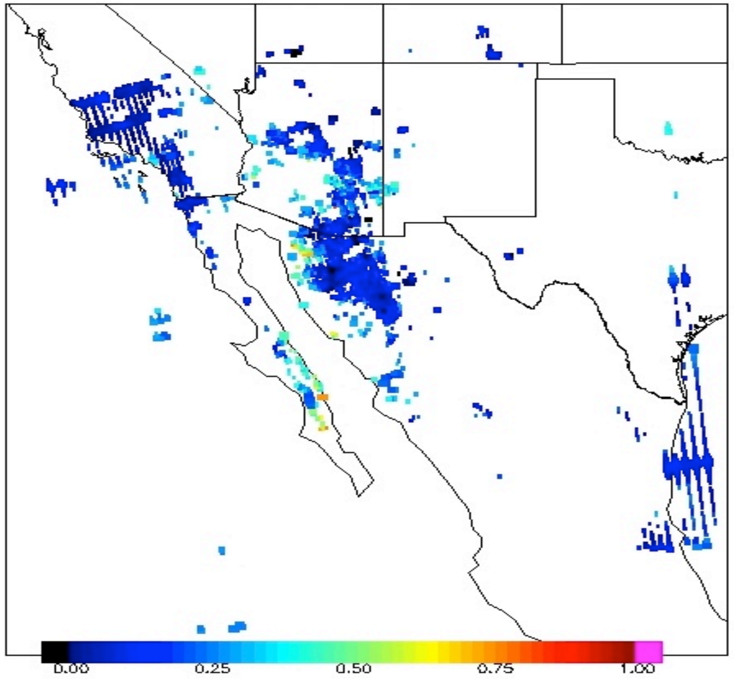
- The dark target and deep blue products are separate and when both are available, the user must select which to use
- In collection 6 (and 6.1), there is a joint product that uses an automated procedure to select the appropriate product

MODIS Aerosol Products

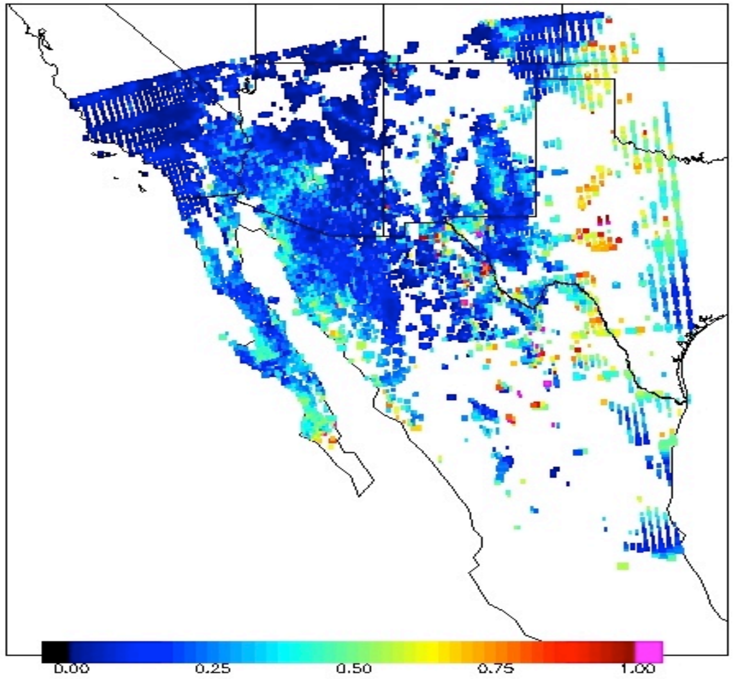
Two Algorithms



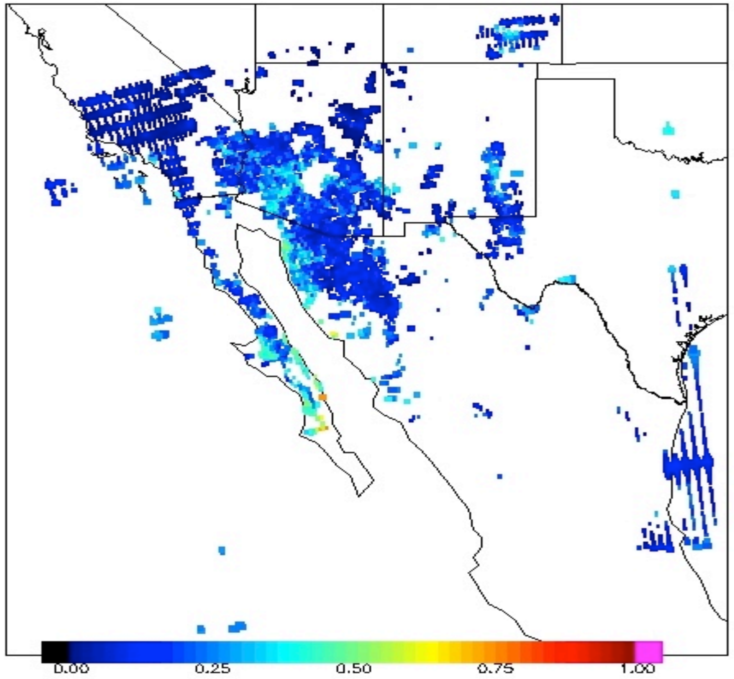
Dark Target



Deep Blue

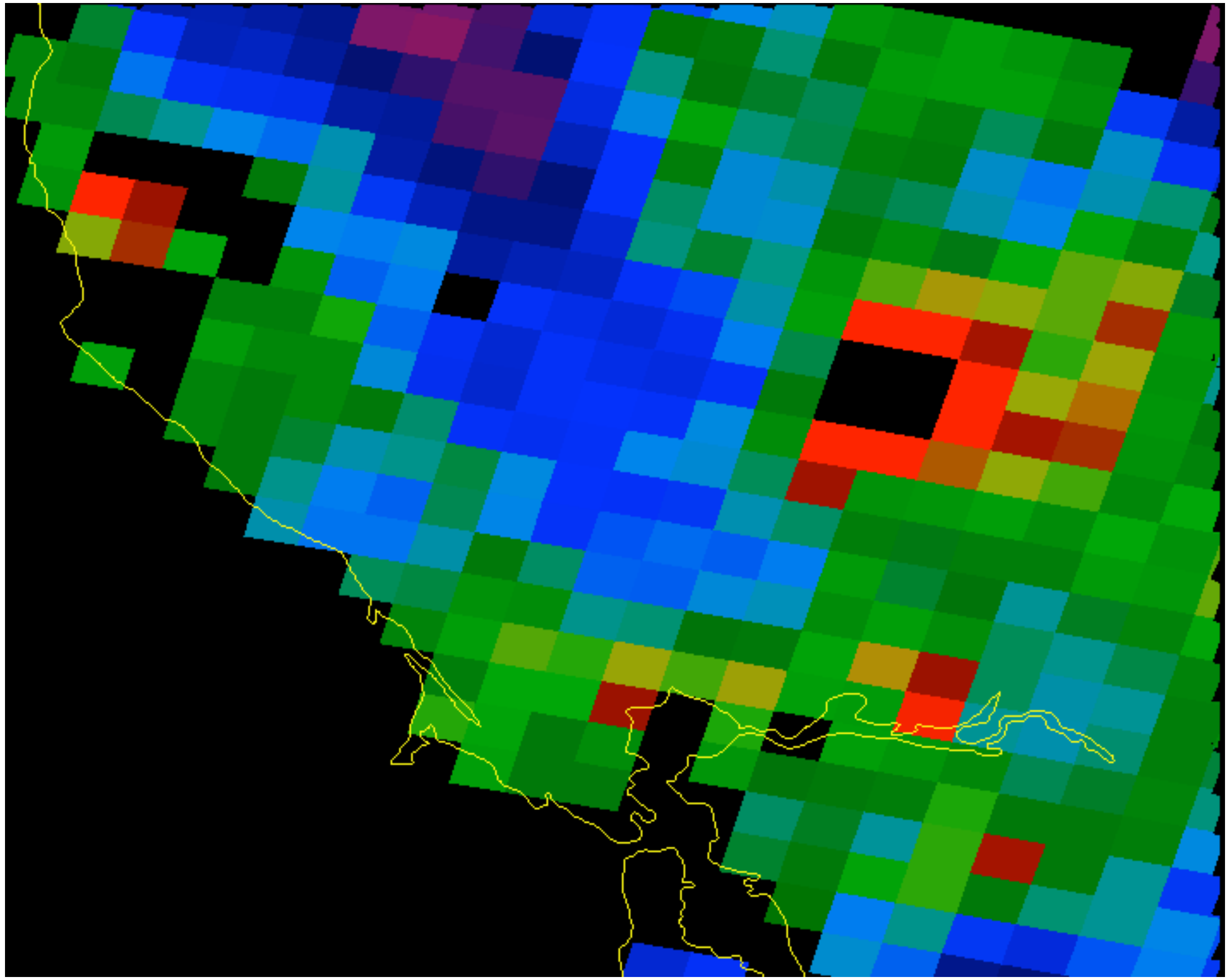


Deep_Dark_Combined

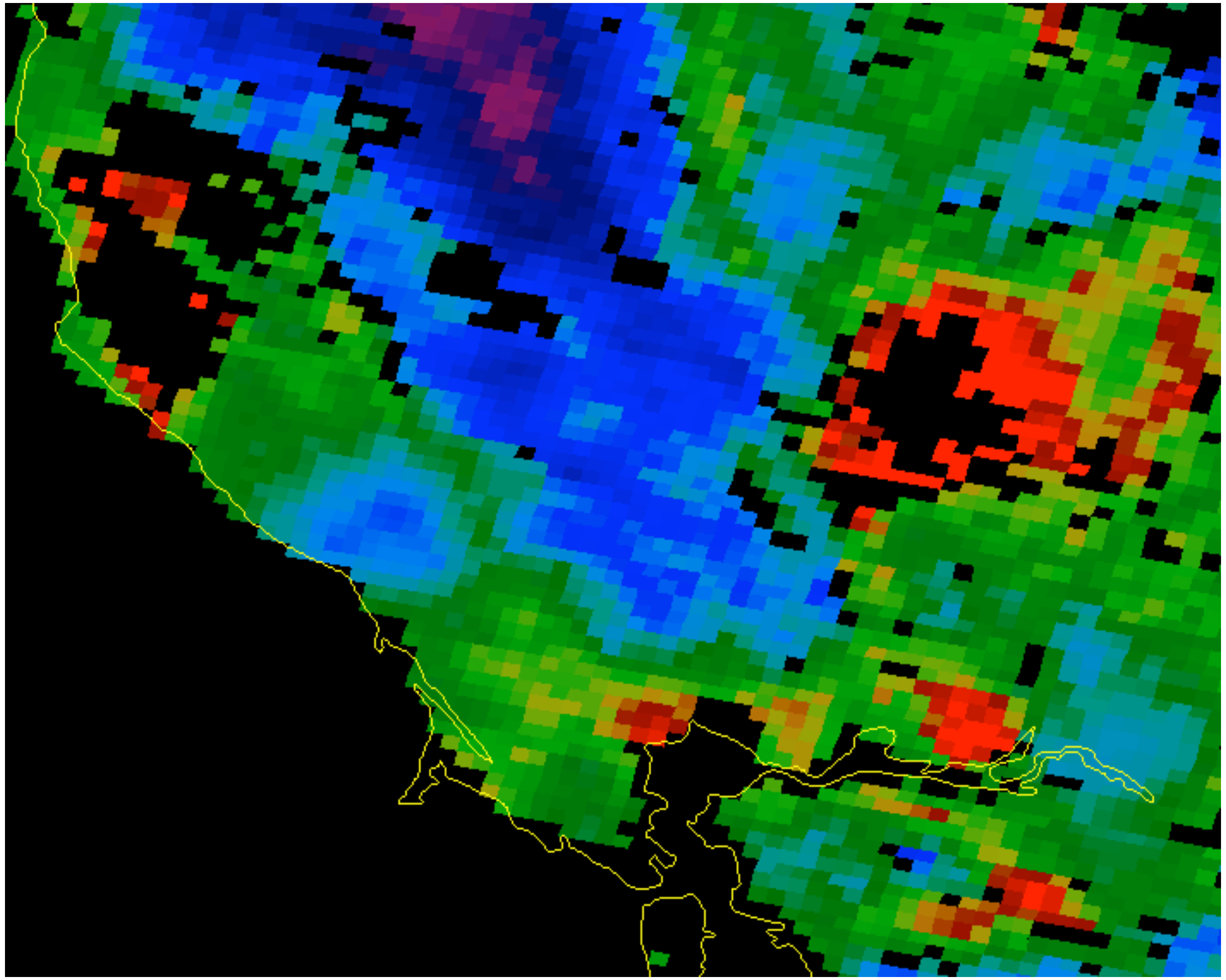


MODIS 10 km vs. 3k m Products

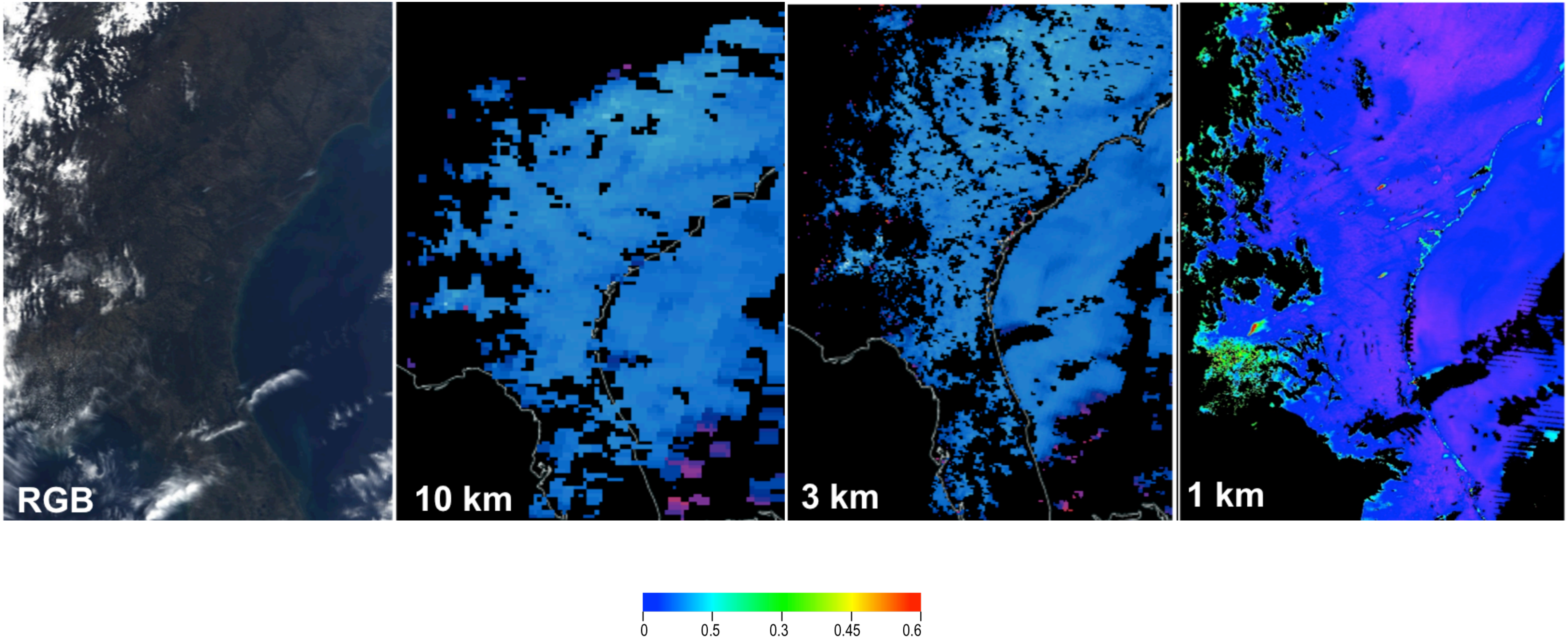
10km



3 km

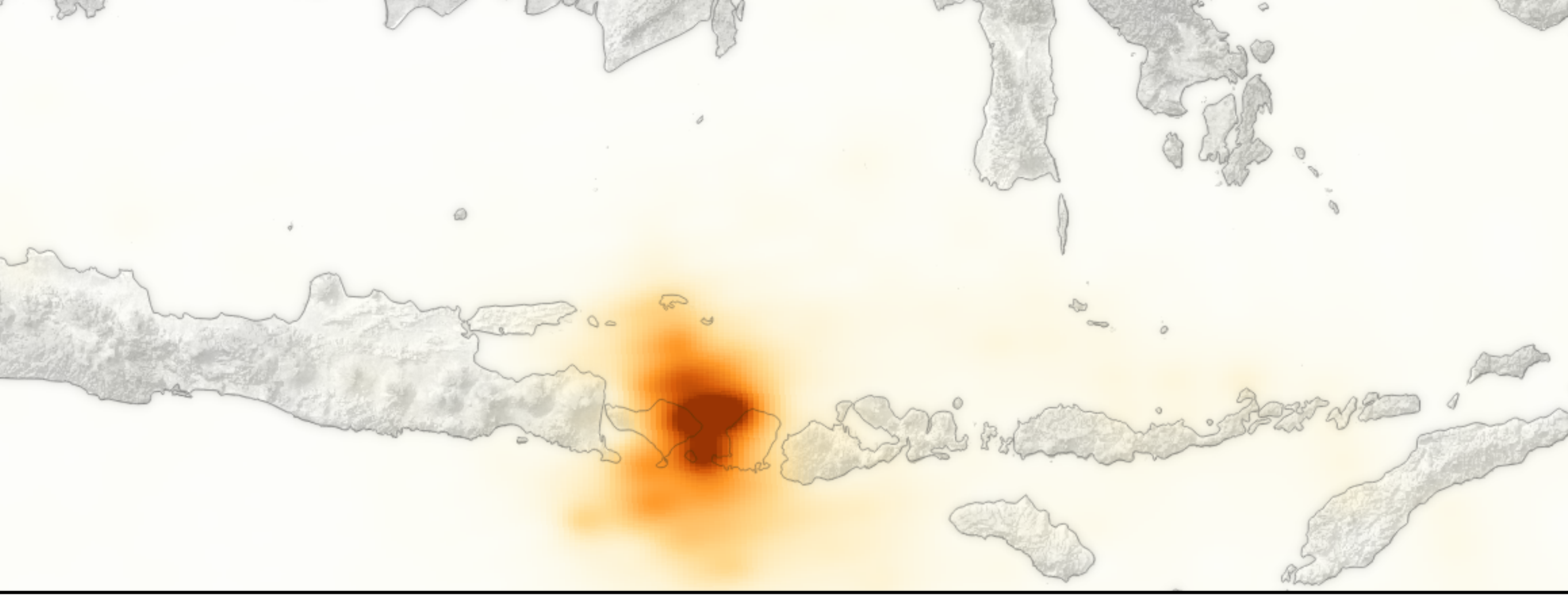


High Resolution Aerosol Product



Satellite Aerosol Products

	MODIS	MISR	OMI	VIIRS
Strengths	• Coverage • Resolution • Calibration • Accuracy	• Calibration • Accuracy • Particle Shape • Aerosol height for thick layer or plume	• Indication of absorbing or scattering particles	• Coverage • Resolution • Calibration • Smaller bow-tie effect
Weaknesses	• Bright surfaces • Ocean glint • Non-spherical particles	• Coverage	• Resolution • Cloud contamination	• Bright surfaces* • Ocean glint
Main Products	• AOD • Ocean-5 wavelengths • Land-3 wavelengths • Fine Fraction (Ocean only)	• AOD • 4 wavelengths • Spherical/Non-Spherical Ratio • Particle Size (3 bins)	• AOD • AAOD • Aerosol Index	• AOD • Aerosol Type
Product Resolution	• 10 km • 3 km	• 17.6 km	• 13 x 24 km	• 0.75 km • 6 km
Global L3 Aggregates	• Daily • 8 day • 30 day	• Monthly • 3 month • Annual	• Daily • Monthly	• Daily • Monthly



OMI

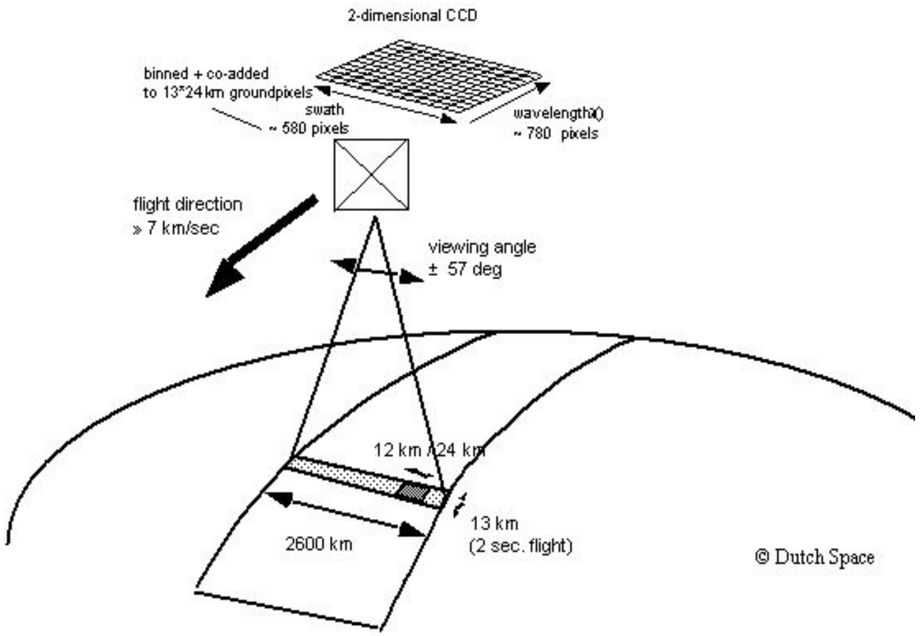
Ozone Monitoring Instrument (OMI)

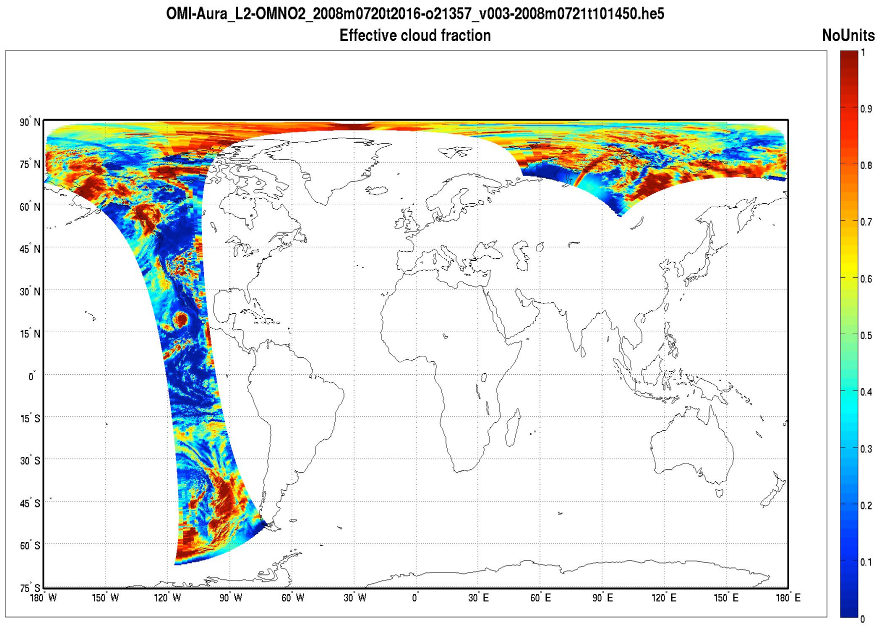
- Launched July 15, 2004
- NASA EOS Aura Satellite
- Nadir-viewing UV/Visible
  - 270 – 310 nm at 0.6 nm
  - 310 – 500 nm at 0.45 nm
- 1:45 p.m. equatorial crossing time
- 13x24 km2 at nadir
- Daily global coverage

- Products
  - Total Column O_3
  - Tropospheric Column O_3
  - Aerosol optical depth (in UV)
  - Total Column Formaldehyde
  - Total Column NO_2
  - Tropospheric column NO_2
  - Total Column SO_2

Data Granule

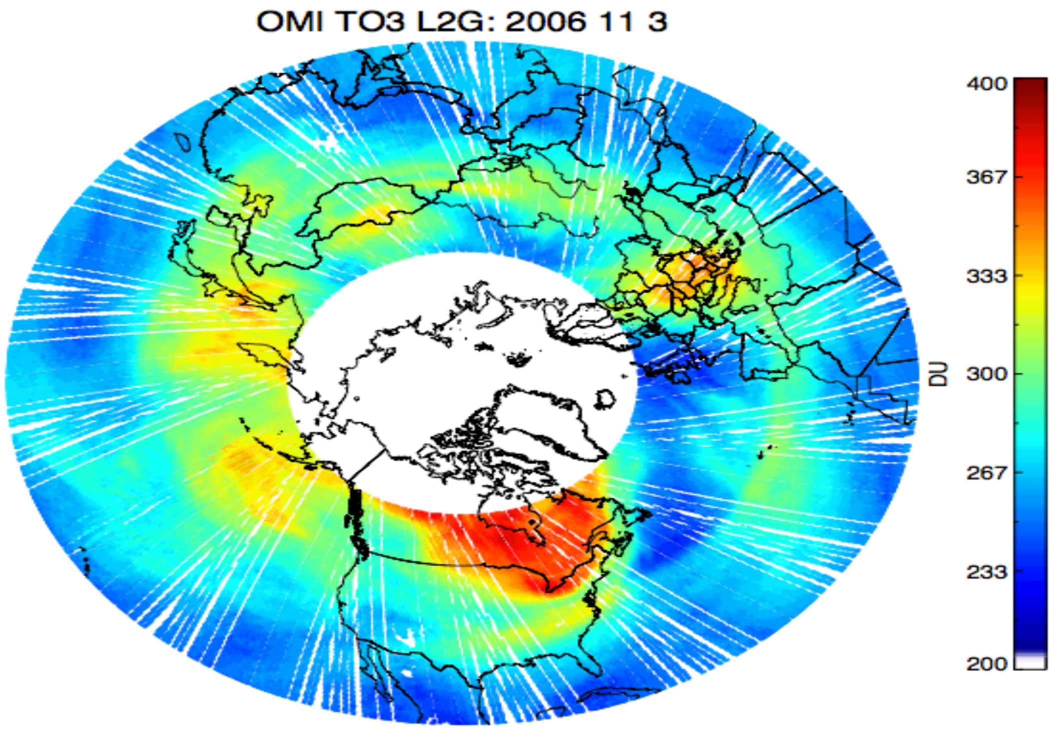
- Product File
  - covers sunlit portion of the orbit with an approx. 2,600 km wide swath
  - contains 60 binned pixels or scenes per viewing line
- 14 or 15 granules are produced daily, providing fully contiguous coverage of the globe

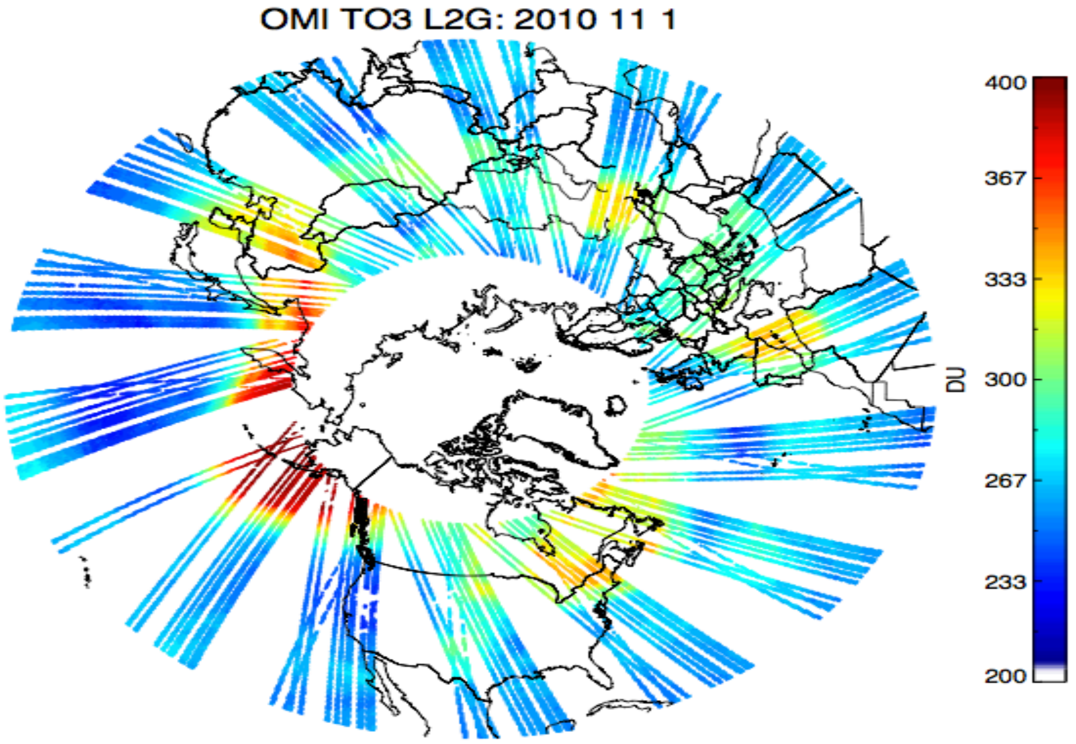




Important Information Regarding OMI

- Almost 50% data loss since 2008 (row anomaly effect)
- Affects all OMI products





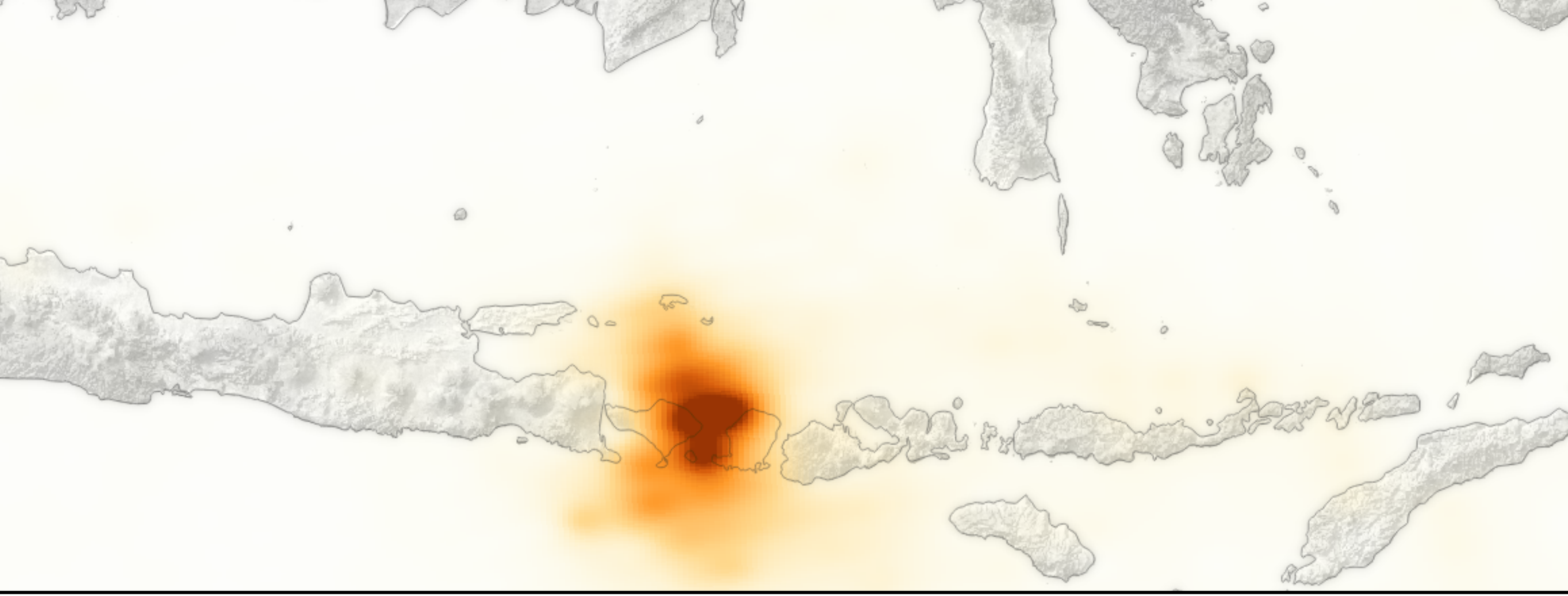
Quantification of Gas Abundances - Units

Satellite Tracer	Units
OMI O_3, SO_2	Dobson Units (DU)
OMI NO_2	Molecules/cm^2

$$1\ DU = 2.69 \times 10^{16}\ molec/cm^2$$

References & Links

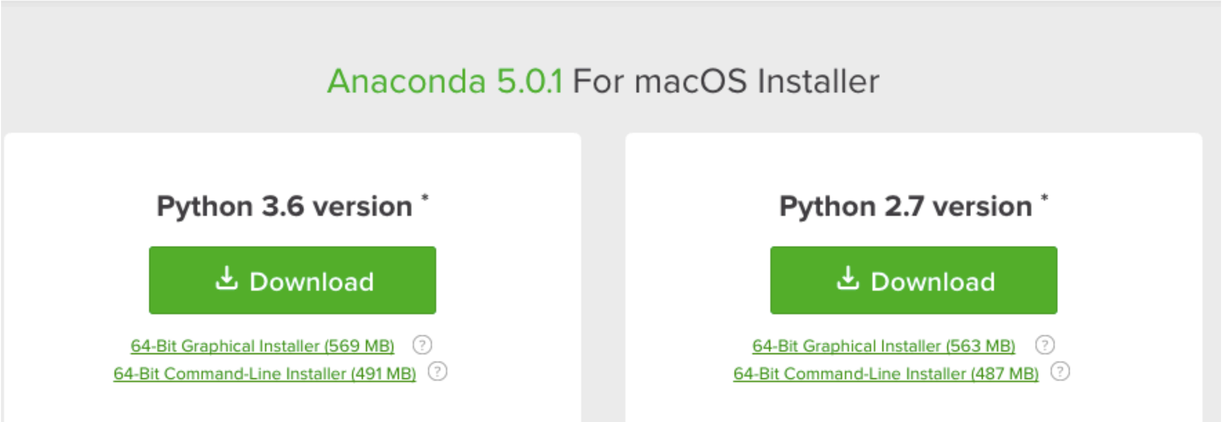
- ARSET air quality page
  - http://arset.gsfc.nasa.gov/airquality
- NASA air quality
  - http://airquality.gsfc.nasa.gov
- MODIS Atmos
  - http://modis-atmos.gsfc.nasa.gov/
- OMI data
  - http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI



Things to do for Session 2

Computer Requirements

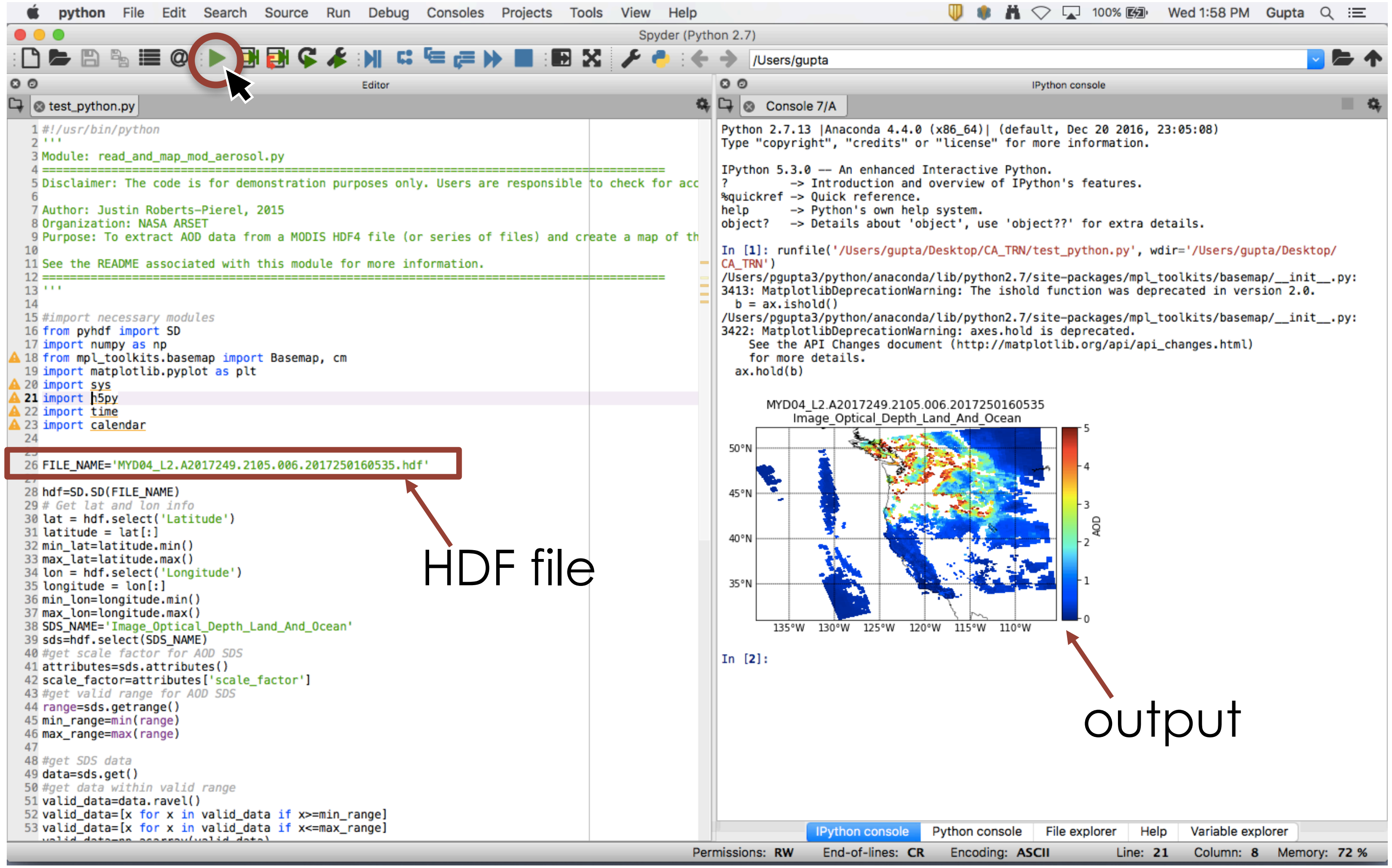
- Install Python 2.7 using [Anaconda]
- Install all required python packages
  - Package List (right)
- Test python and package installations using following python test code
  - test_python.py
- Download MODIS Data and Python Codes on the training website
  - https://arset.gsfc.nasa.gov/airquality/webinars/2018-hiresdatasets
- For more detail on the code, visit: https://arset.gsfc.nasa.gov/airquality/python-scripts-aerosol-data-sets-merra-modis-and-omi



- Python package list:
  - pyhdf
  - numpy
  - sys
  - mpl_toolkits.basemap
  - matplotlib
  - linearSegmentedColormap
  - h5py
  - time
  - calendar

Python Test

- Open the spyder editor inside Anaconda
- Open **test_python.py**
- Make sure the directory has the python code and HDF file
- Open the **ipython** console in the spider
- Run the code using the **green arrow** on the top
- Output should be an image as shown

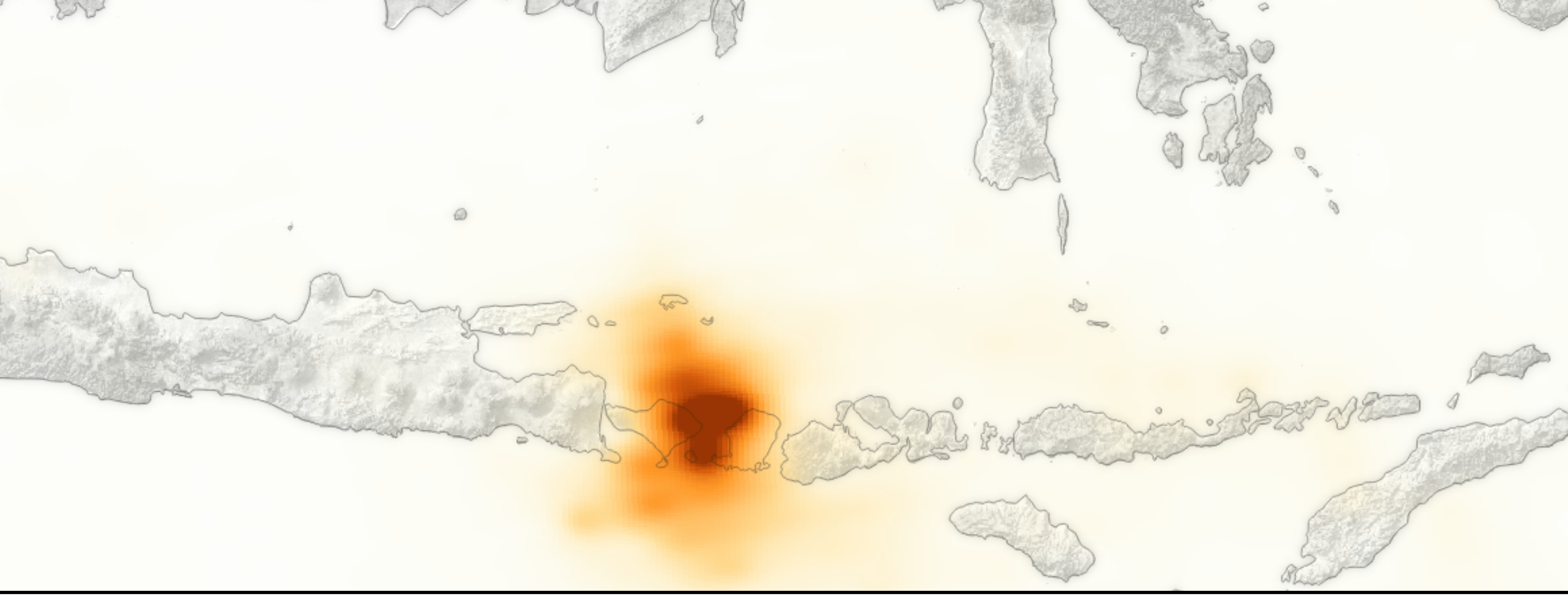


Data Download

- MODIS 10 km, 3 km Aerosol Parameters
- Laadsweb – Earth Data Login
- Select and download data for suggested case studies: https://arset.gsfc.nasa.gov/sites/default/files/airquality/webinars/18-hires/week2_code_data.zip

Suggest Case MODIS Aerosol Data

- Follow the instructions as outlined in the exercise available on the training webpage: https://arset.gsfc.nasa.gov/airquality/webinars/2018-hiresdatasets
- Data Details:
  - Satellite: MODIS- Aqua
  - Product Names: MYD04_L2 and MYD04_3K
  - Date: 2017/10/08 to 2017/10/09
  - Region of interest: -123 E to -121 E & 36 N to 39 N



Questions & Discussion