National Aeronautics and Space Administration

Introduction to ARSET program

Pawan Gupta

Satellite Remote Sensing of Air Quality, 18-19 November 2018

NASA's Applied Remote Sensing Training Program (ARSET)

http://arset.gsfc.nasa.gov/

- Empowering the global community through remote sensing training
- Part of NASA's Applied Sciences Capacity Building Program
- Goal: increase the use of Earth Science in decision-making through training for:
  - policy makers
  - environmental managers
  - other professionals in the public and private sector
- Trainings offered focusing on applications in:

Disasters
9 Trainings

Eco
12 Trainings

Health & Air Quality
55 Trainings

Water Resources
20 Trainings

ARSET Training Levels

Advanced Training, *Level 2*
- Online and in-person
- Requires Level 1 training or equivalent knowledge
- More in-depth or focused topics

Beginning Training, *Level 1*
- Online and in-person
- Requires Level 0 training or equivalent knowledge
- Specific applications

Fundamentals Training, *Level 0*
- Online only
- Assumes no prior knowledge of remote sensing

ARSET Training Impacts: Health & Air Quality (2008-2017)

Total ARSET Participants (2009-2017): 13,042

Health & Air Quality Participants 2,978

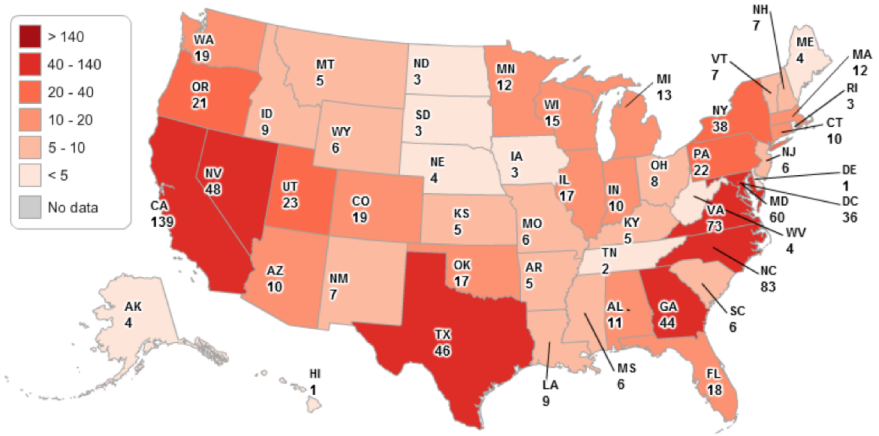
17 online trainings

75 countries

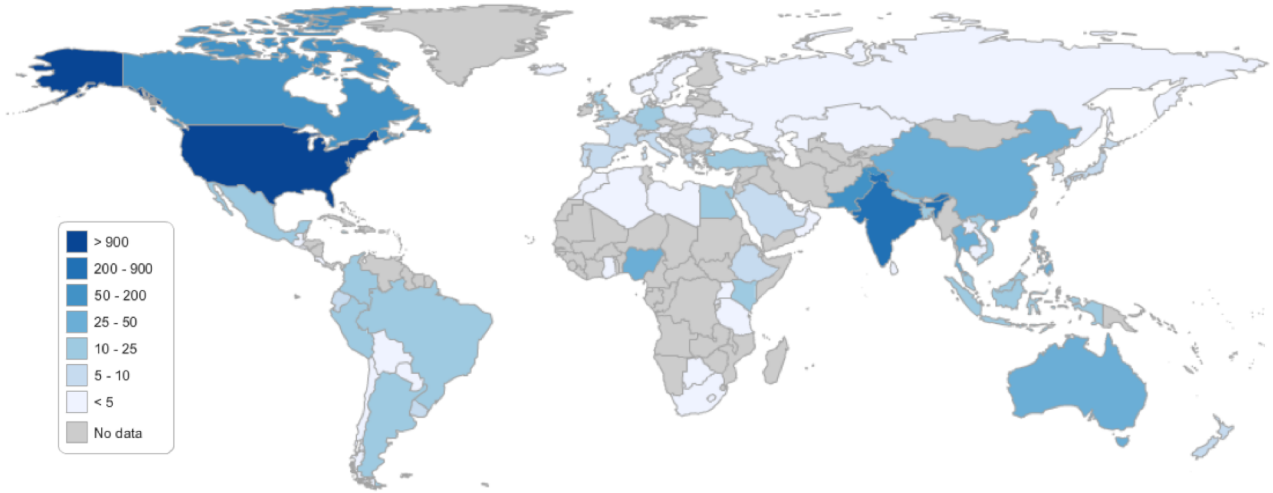
38 in-person trainings

836 organizations

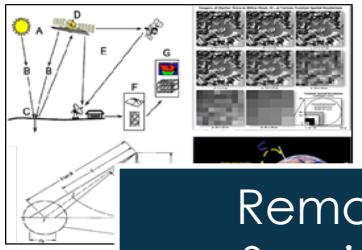
US Health & Air Quality Participants



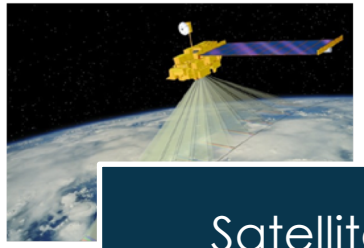
Global Health & Air Quality Participants



ARSET Air Quality Trainings

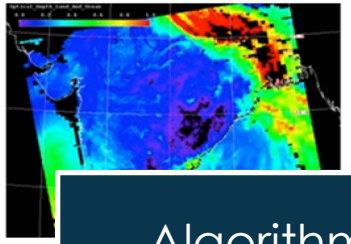


Remote Sensing

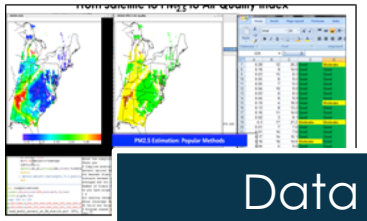


Satellites

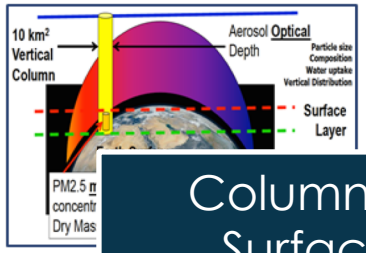
Imagery



Algorithms

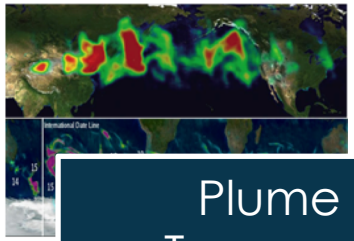


Data & Tools

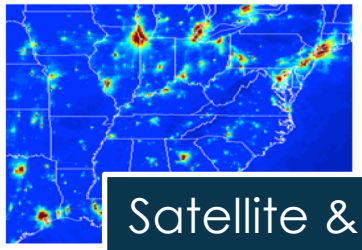


Column to Surface

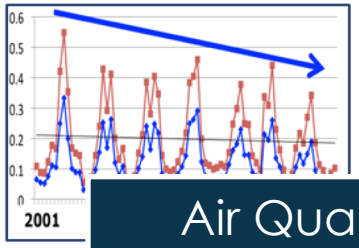
Dust & Smoke



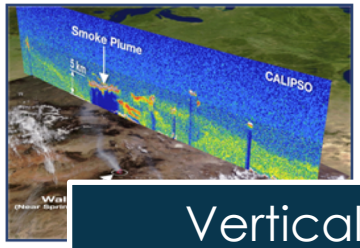
Plume Transport



Satellite & Model Comparison



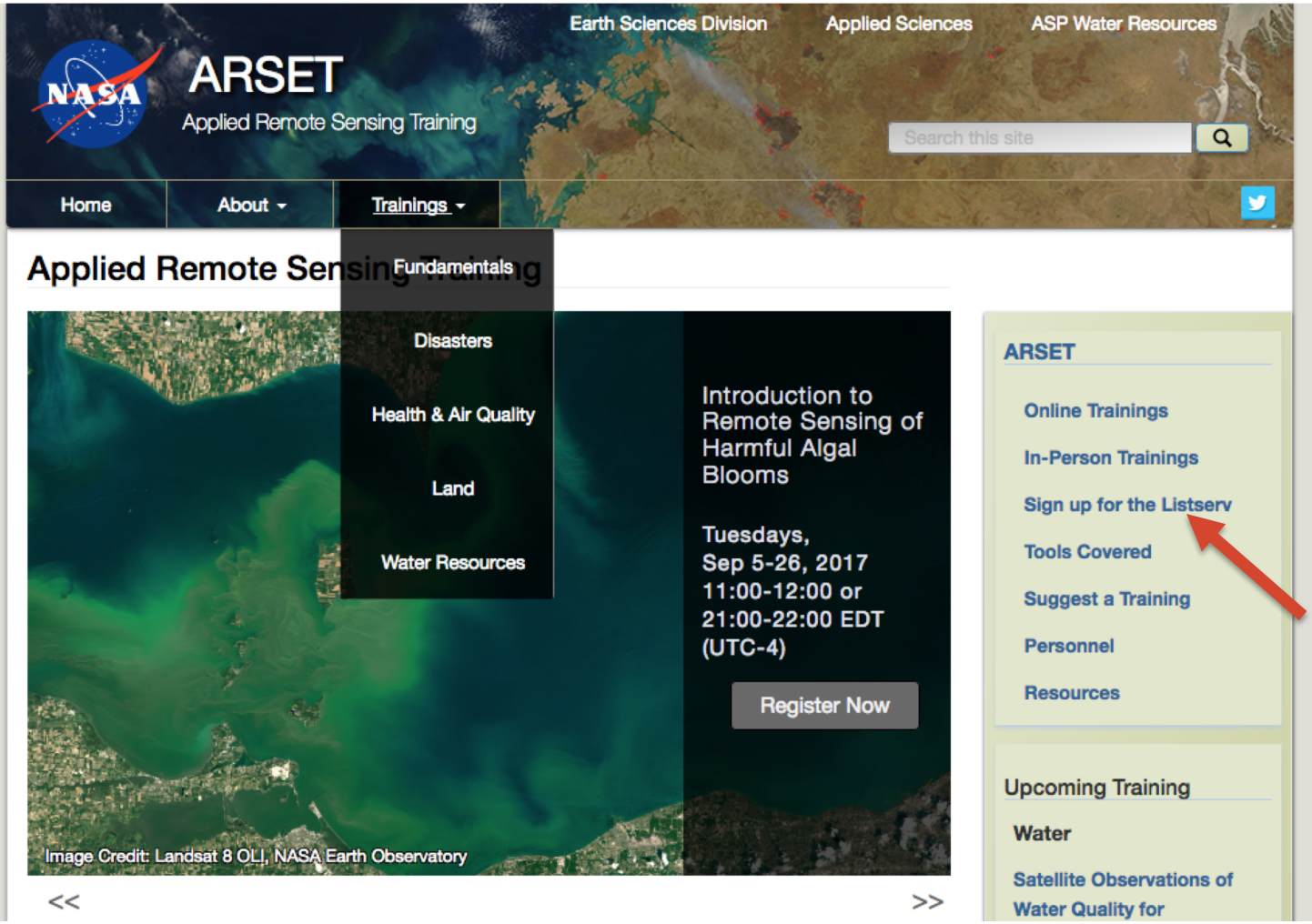
Air Quality Trends



Vertical Profiles

Learn More About ARSET

http://arset.gsfc.nasa.gov/



National Aeronautics and Space Administration

Introduction to Satellite Remote Sensing of Air Quality: An Overview

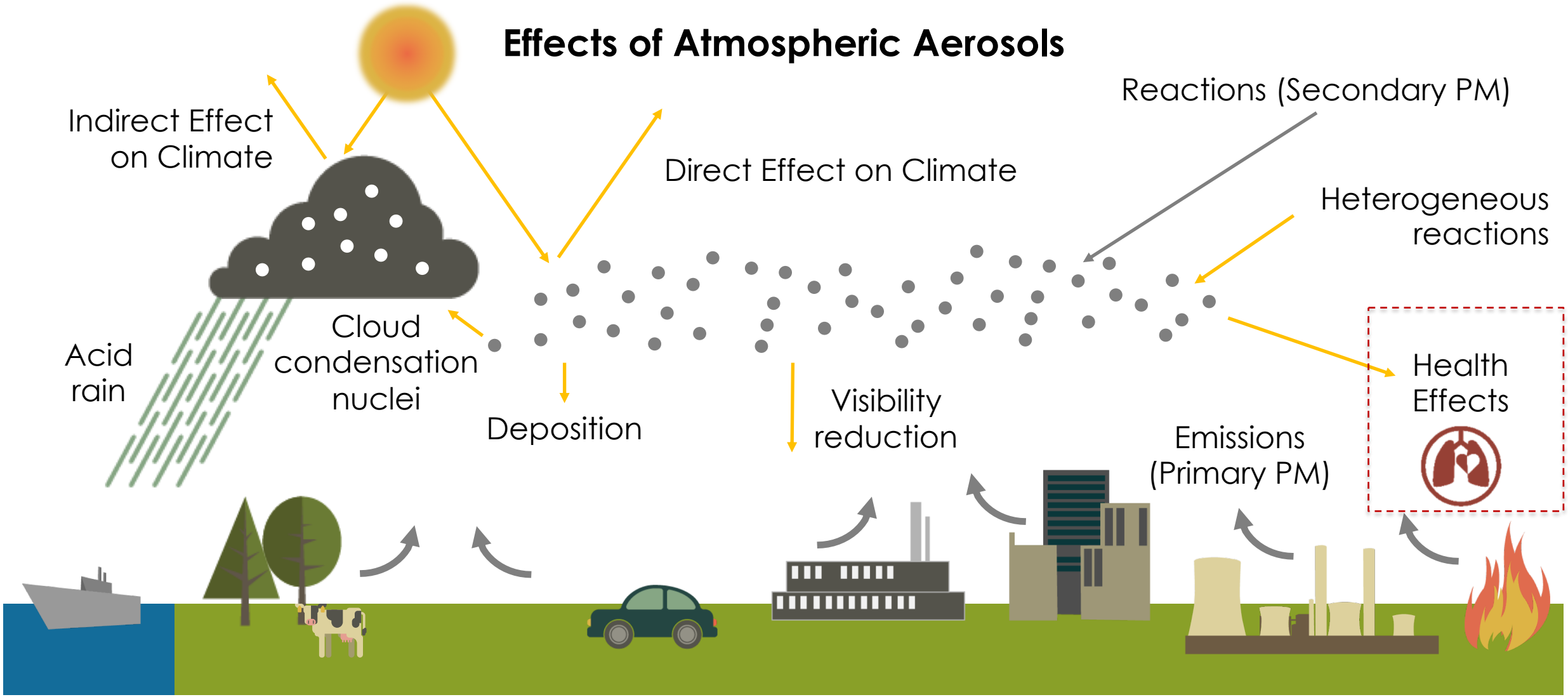
Pawan Gupta

Satellite Remote Sensing of Air Quality, 18-19 November 2018

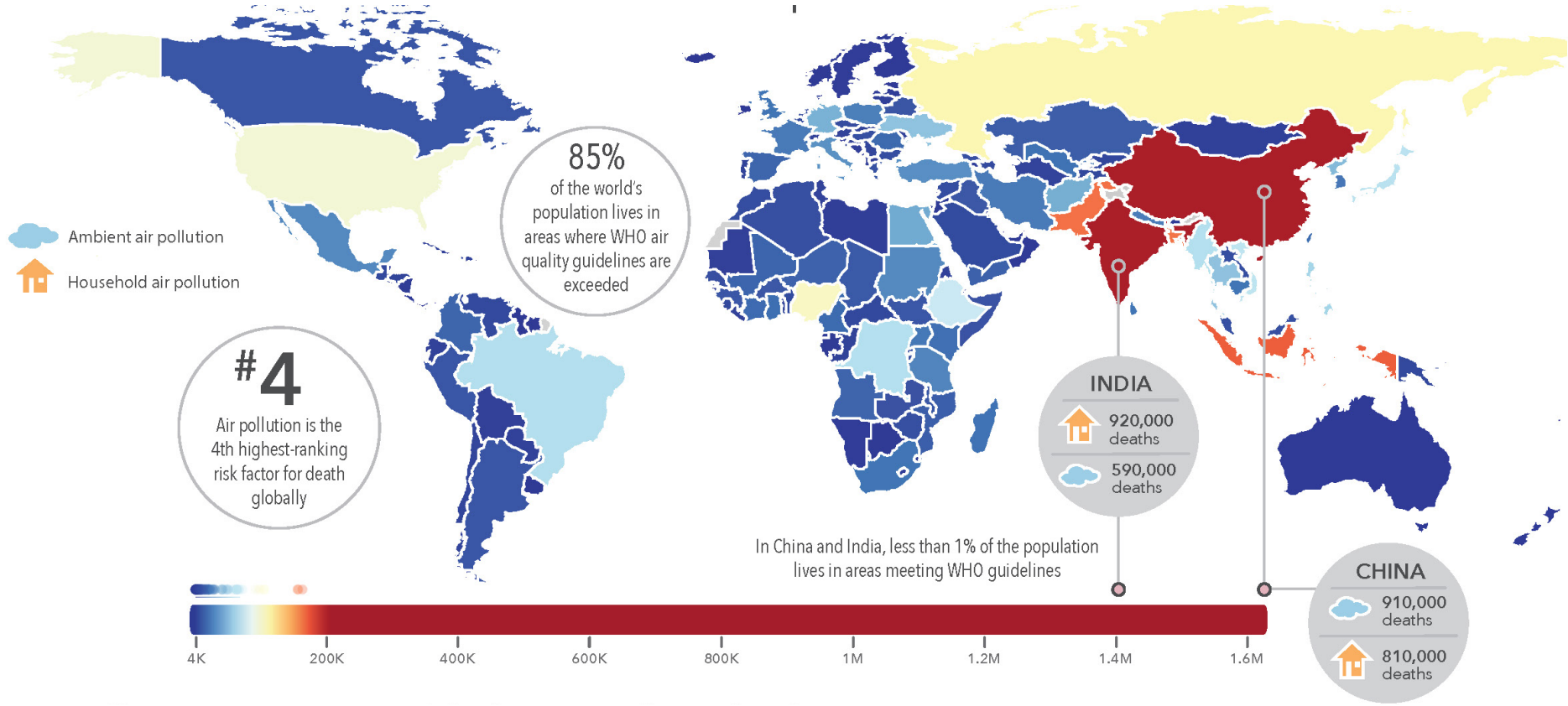
Learning Objectives

- By the end of this presentation, you will be able to:
  - describe existing satellite capabilities for global air quality monitoring
  - identify upcoming and future satellite missions for air quality monitoring

Motivation: Tiny, but Potent



Global Burden of Air Pollution



- Air pollution was responsible for 5.5 million deaths in 2013
- Satellite data can help quantify the impact on human health

Image Credit: http://thelancet.com/gbd/2013

UN Sustainable Development Goals (SDGs)

Transforming Our World: The 2030 Agenda for Sustainable Development

- A plan of action for people, planet, and prosperity
- All countries and all stakeholders, acting in collaborative partnership, will implement this plan
- 17 SDGs and 169 targets under this agenda
- Balance the three dimensions of sustainable development:
  – economic, social, and **environmental**

Text adapted from "Transforming our world: the 2030 Agenda for Sustainable Development"

Traditional Air Quality Monitoring

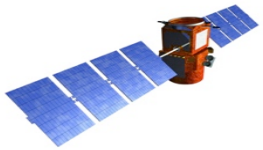
www.aqicn.org

Air Pollution Monitoring

Ground Measurements

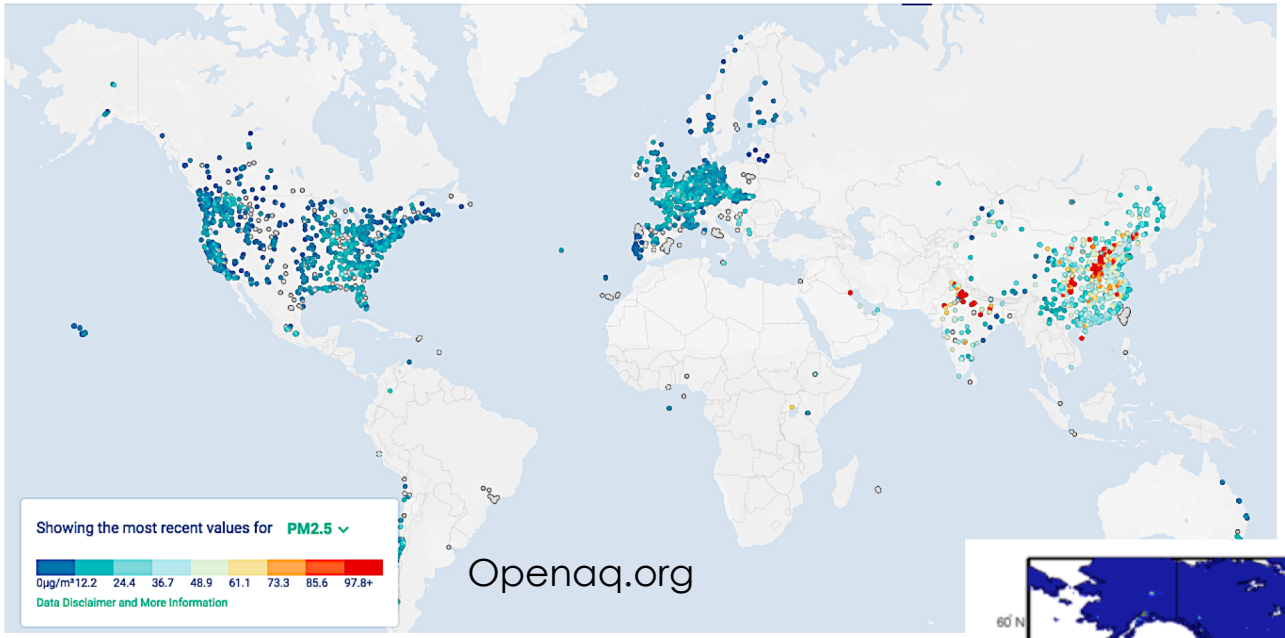
Air & Space Observations

Models



Why use satellite data?

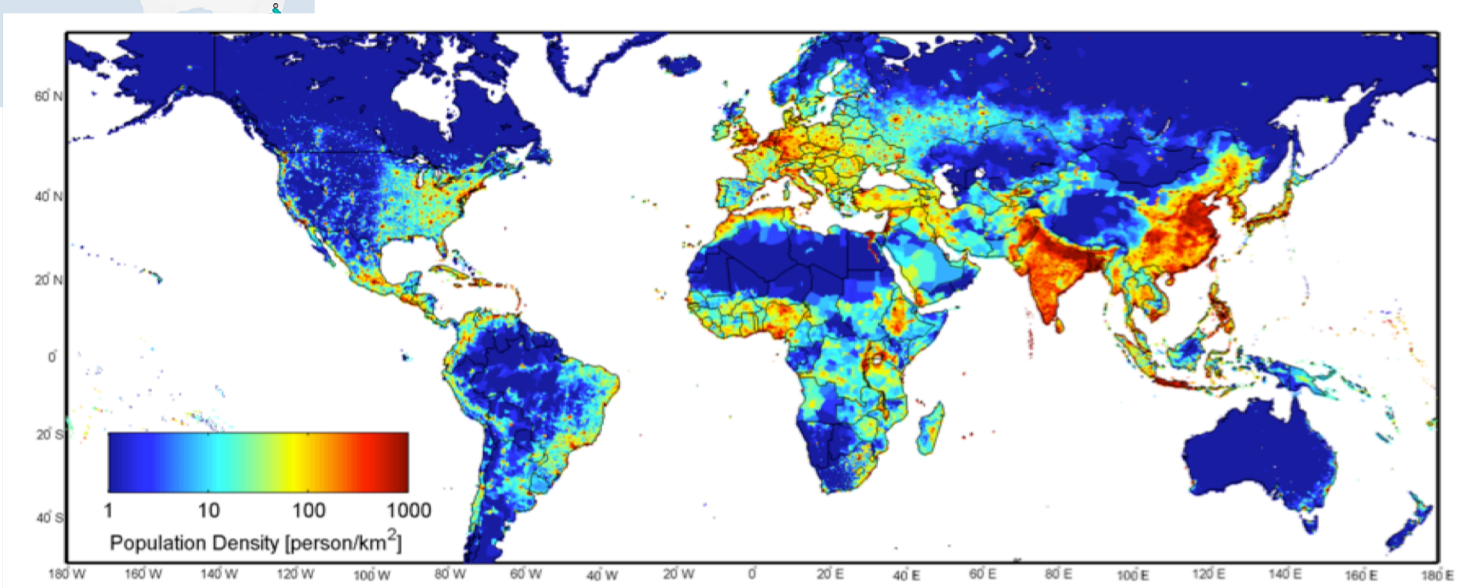
Global Status of $PM_{2.5}$ Monitoring



Openaq.org

Ground Sensor Network

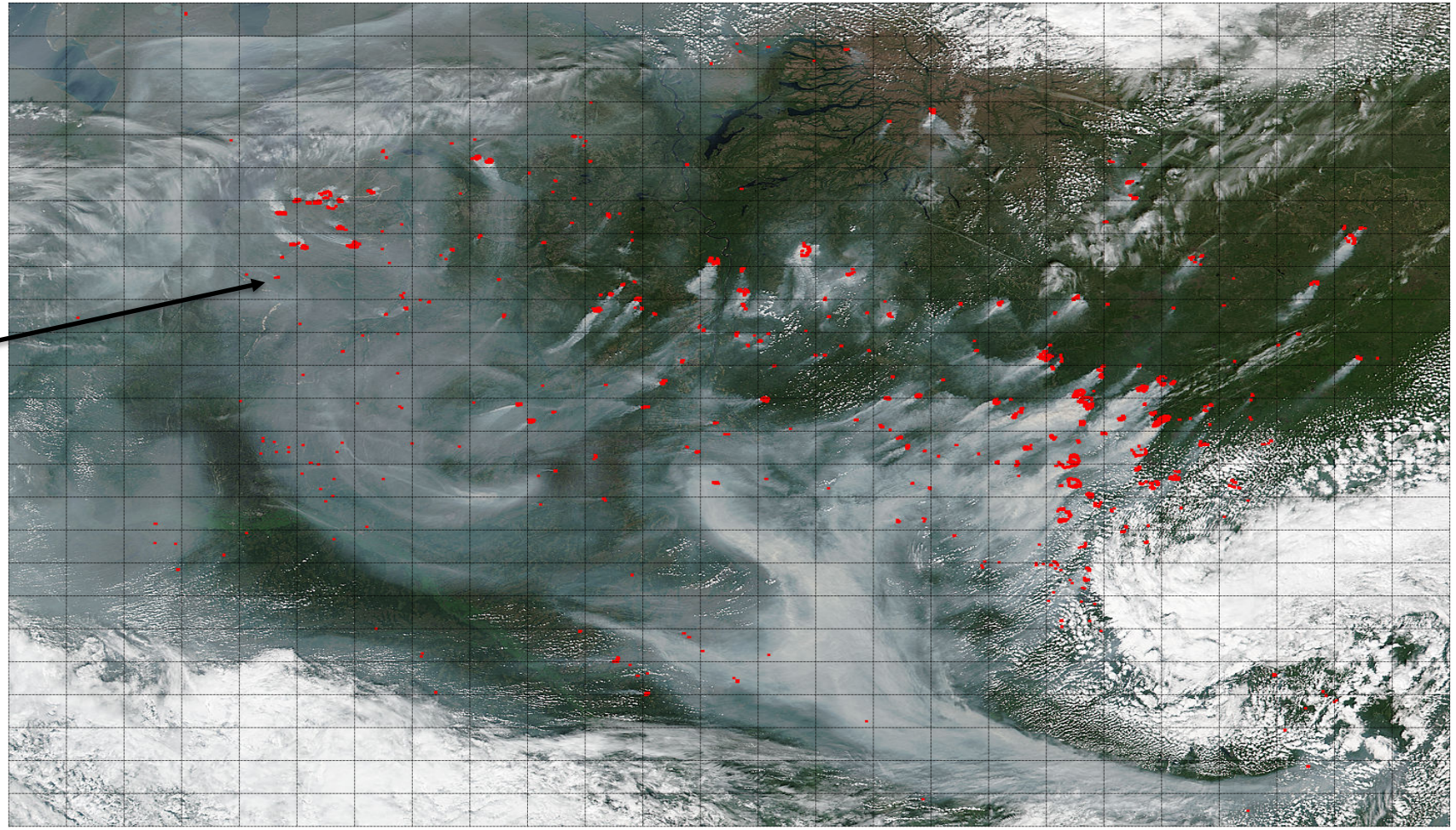
Population Density



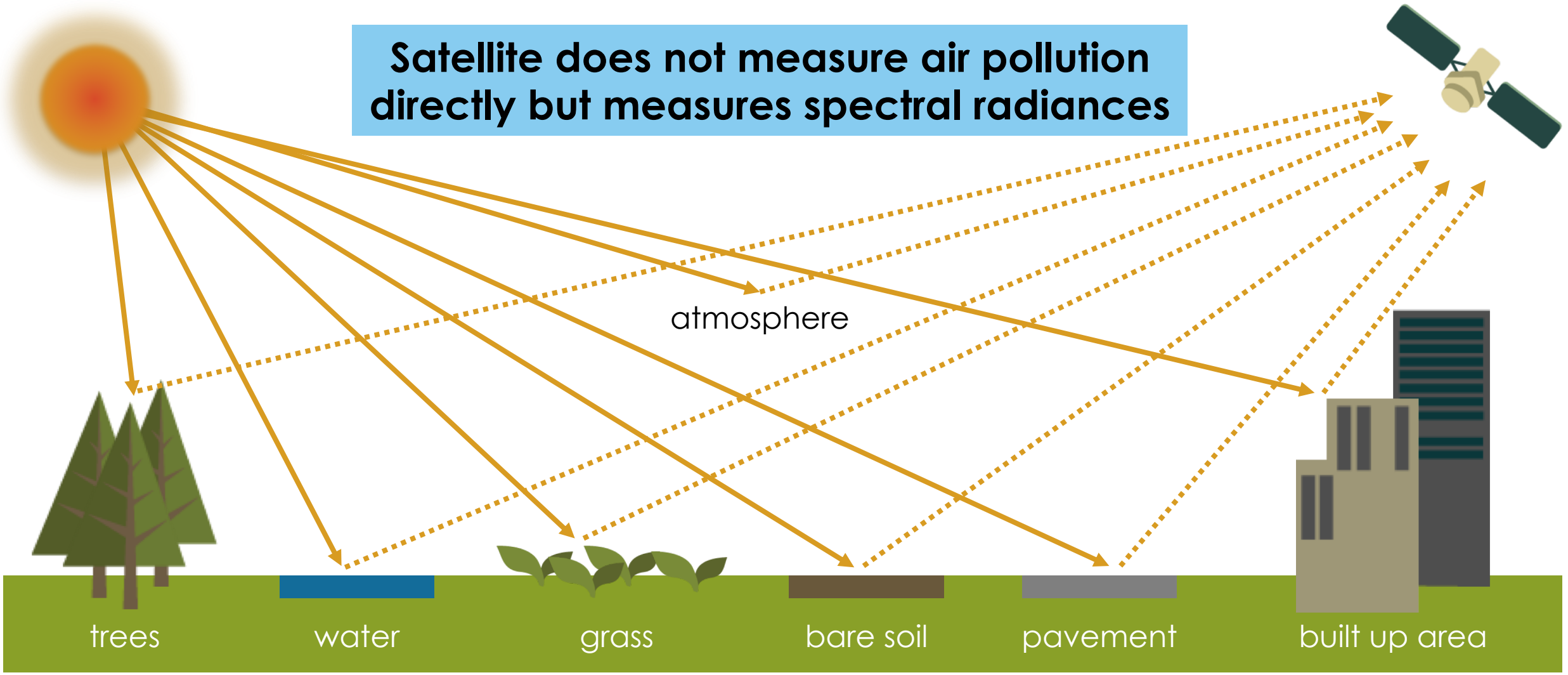
“A Picture is Worth a Thousand Words”

A satellite picture is worth ~~a~~ **millions of data points**

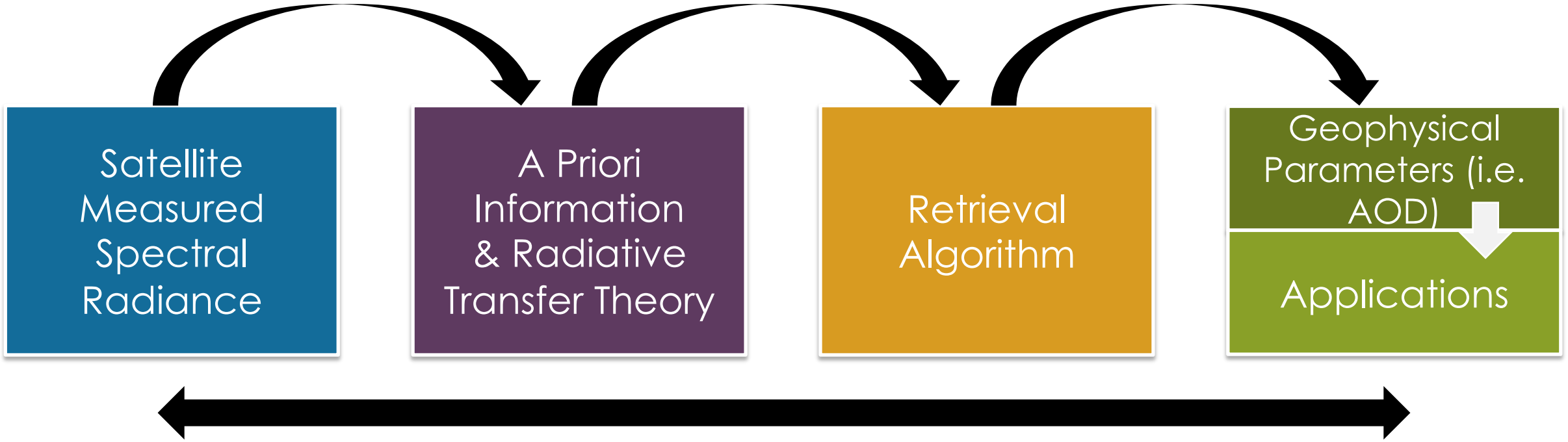
A geo-physical number



What do satellites measure ?

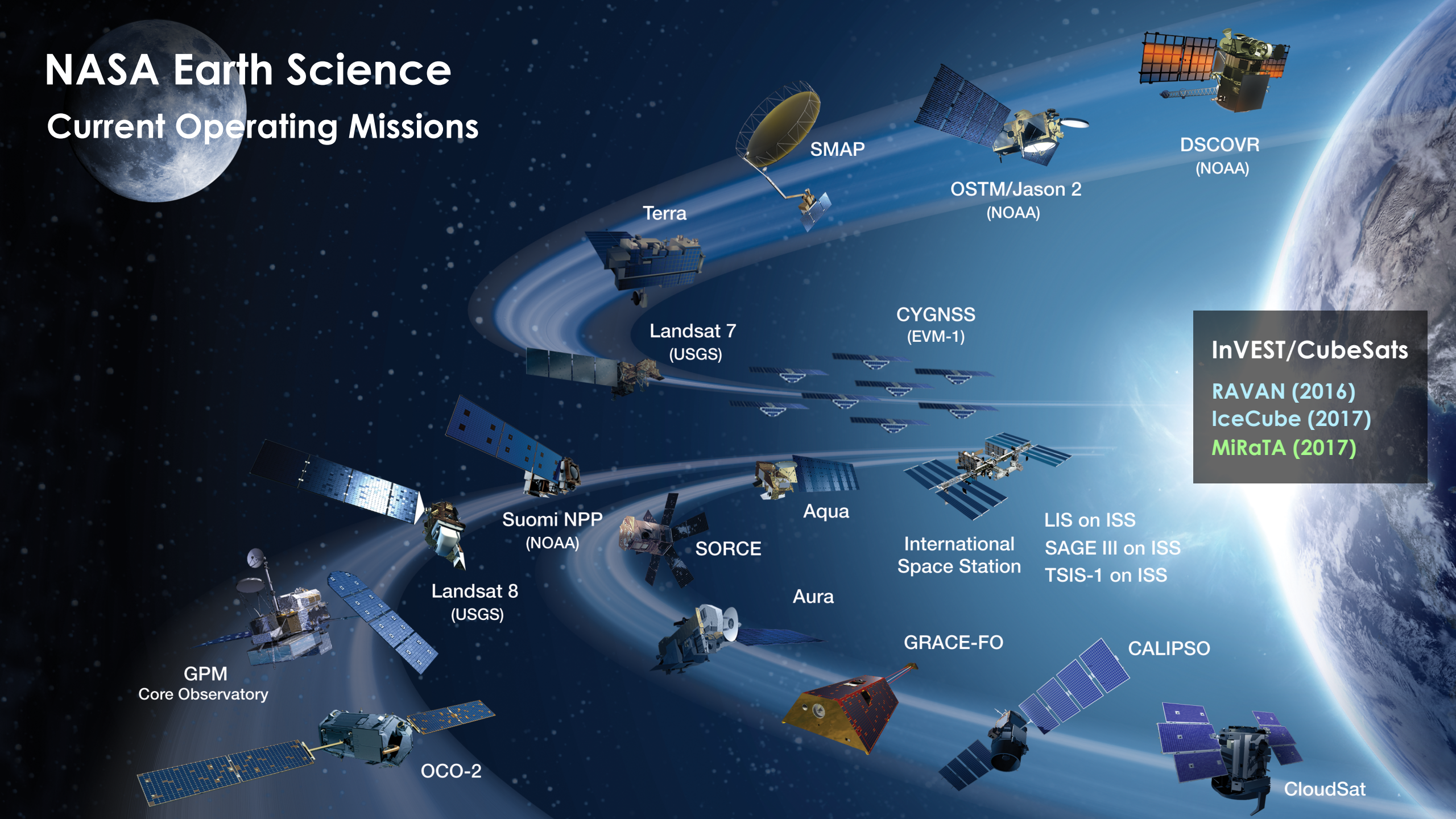


The Remote Sensing Process



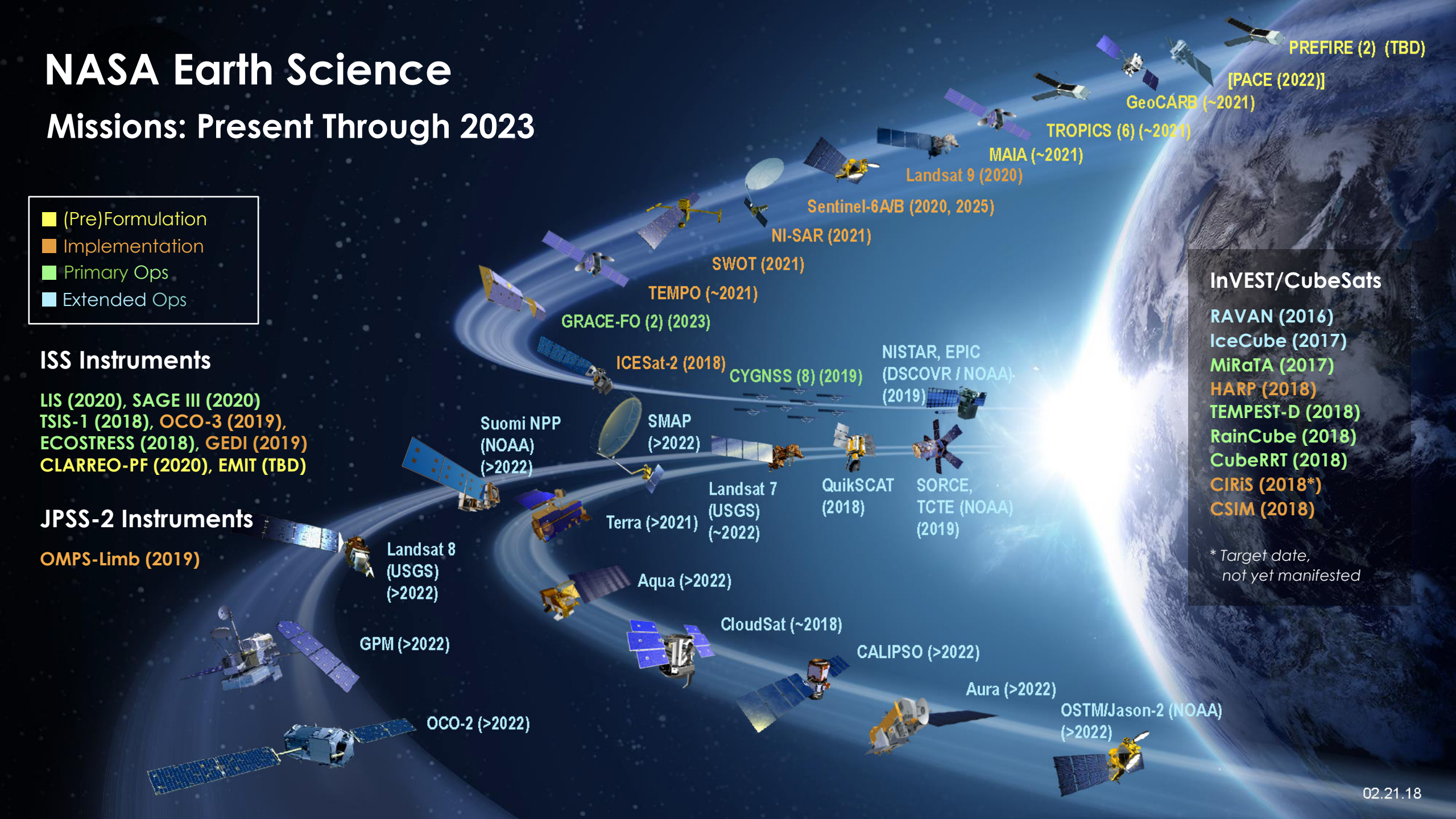
NASA Earth Science

Current Operating Missions



NASA Earth Science

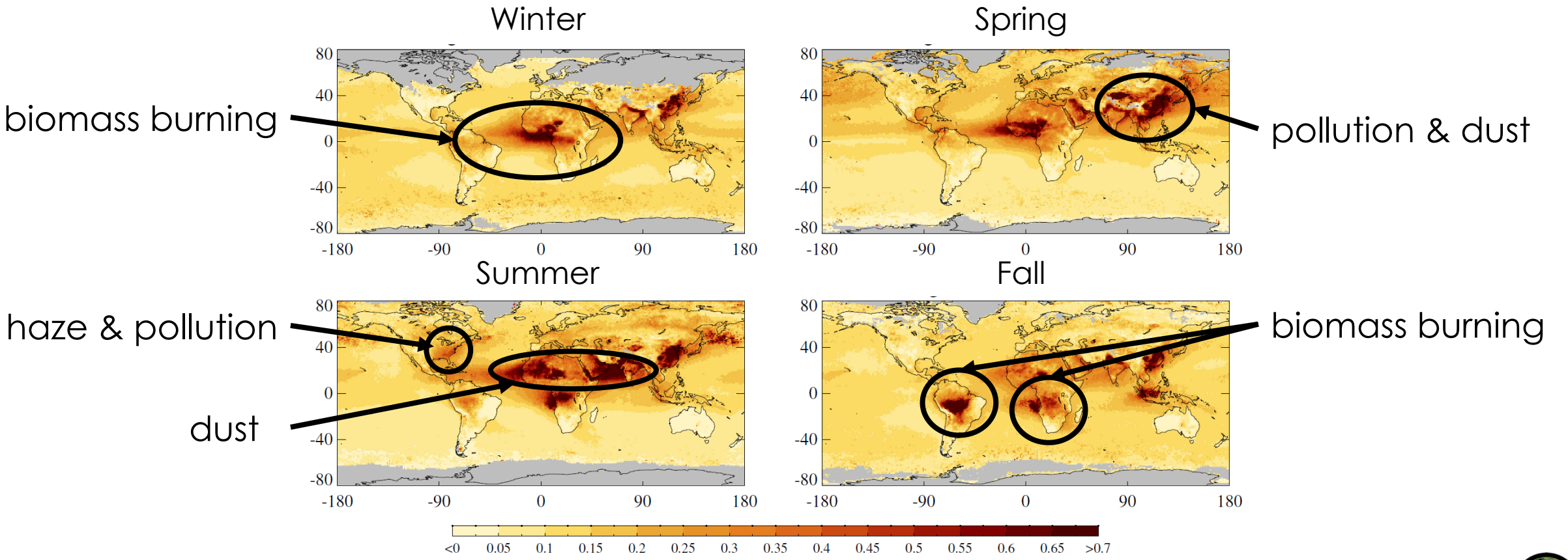
Missions: Present Through 2023



Aerosols from Satellites

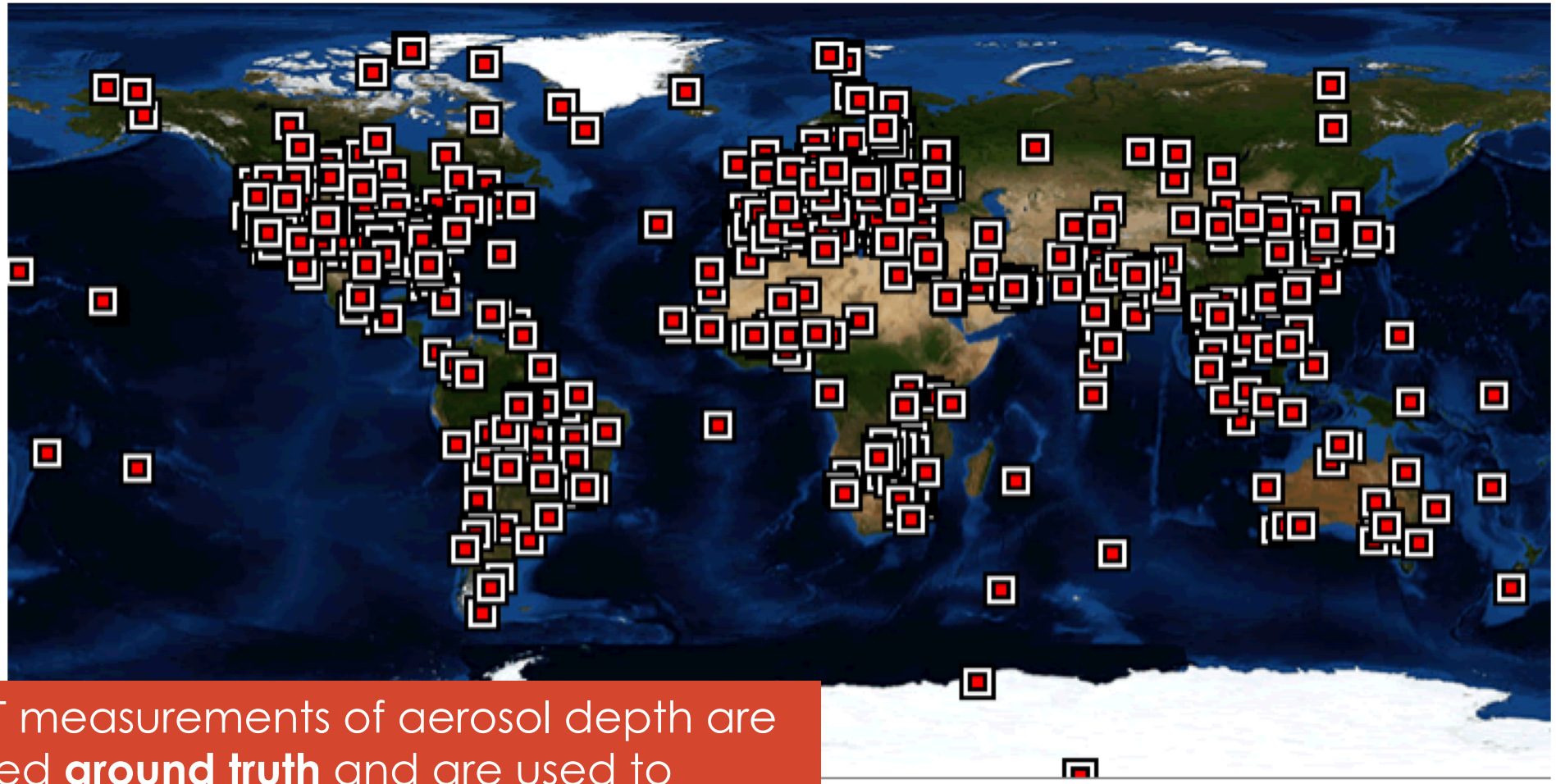
- Several satellites provide state-of-the-art aerosol measurements globally, on a daily basis

Aerosol Optical Thickness (Aqua MODIS)



AERONET

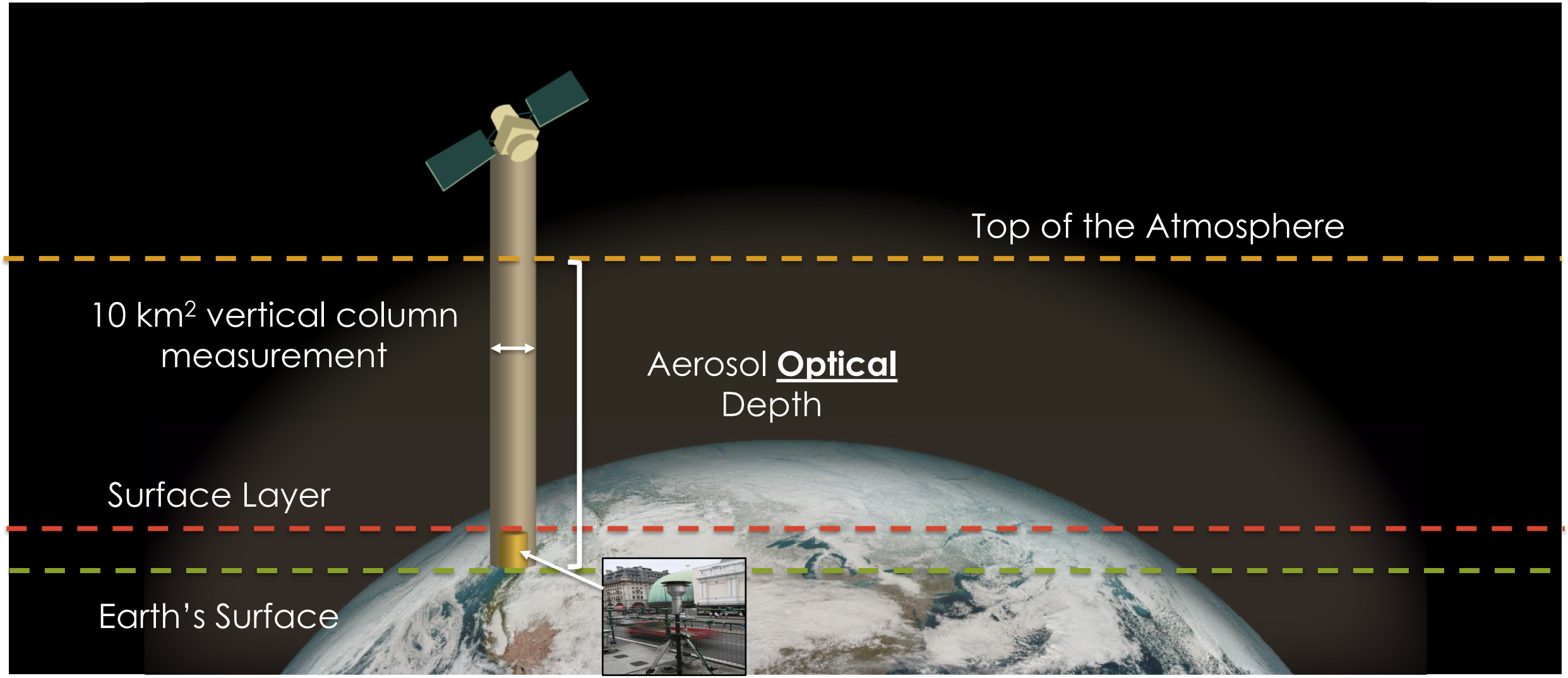
http://aeronet.gsfc.nasa.gov/



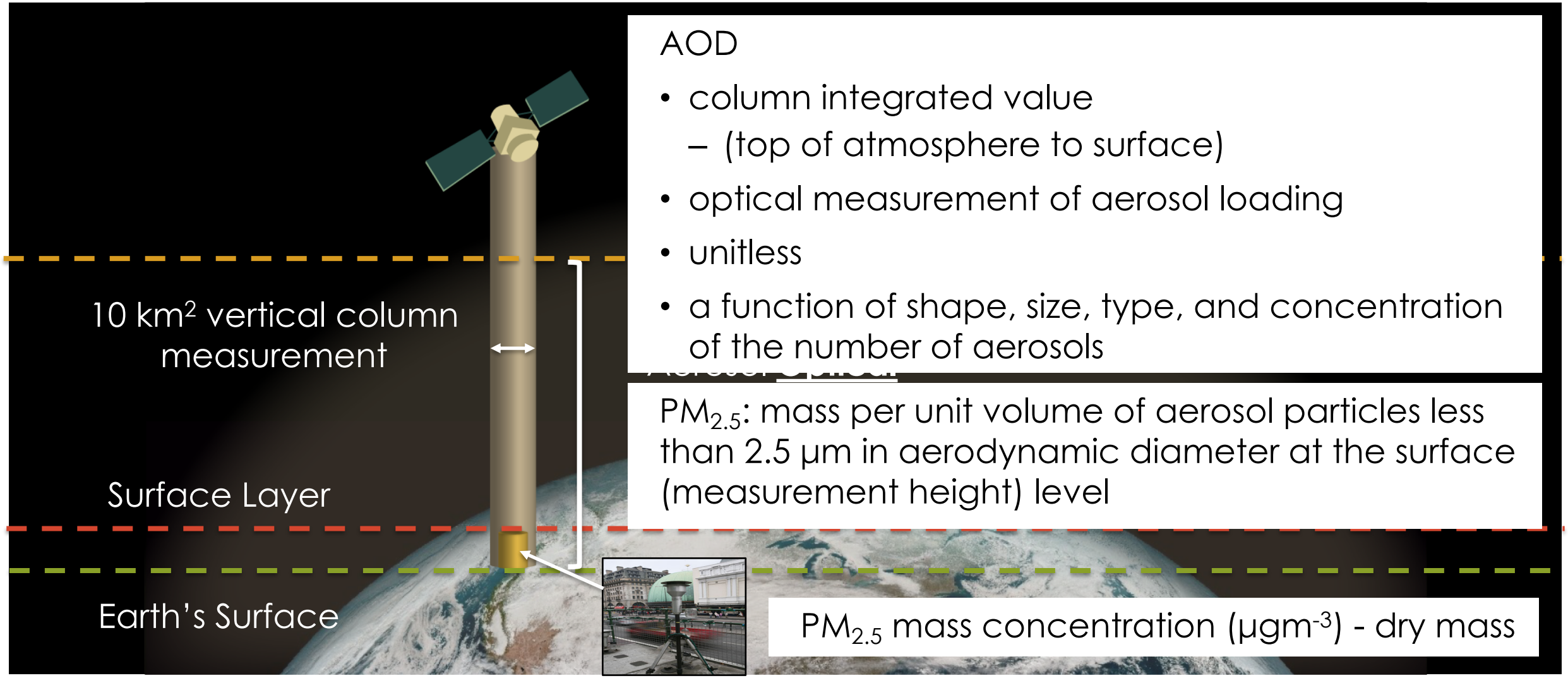
AERONET measurements of aerosol depth are considered **ground truth** and are used to validate satellite aerosol retrievals

Applications

Satellite vs. Ground Observation



Satellite vs. Ground Observation



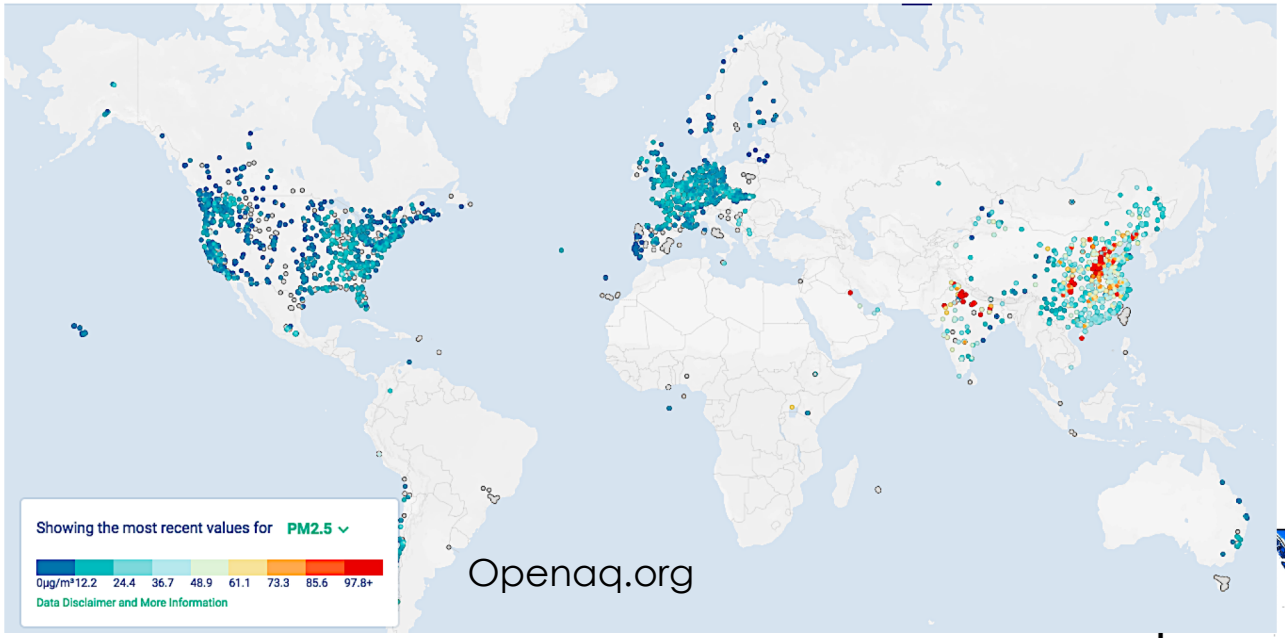
AOD

- column integrated value
  - (top of atmosphere to surface)
- optical measurement of aerosol loading
- unitless
- a function of shape, size, type, and concentration of the number of aerosols

$PM_{2.5}$: mass per unit volume of aerosol particles less than 2.5 μm in aerodynamic diameter at the surface (measurement height) level

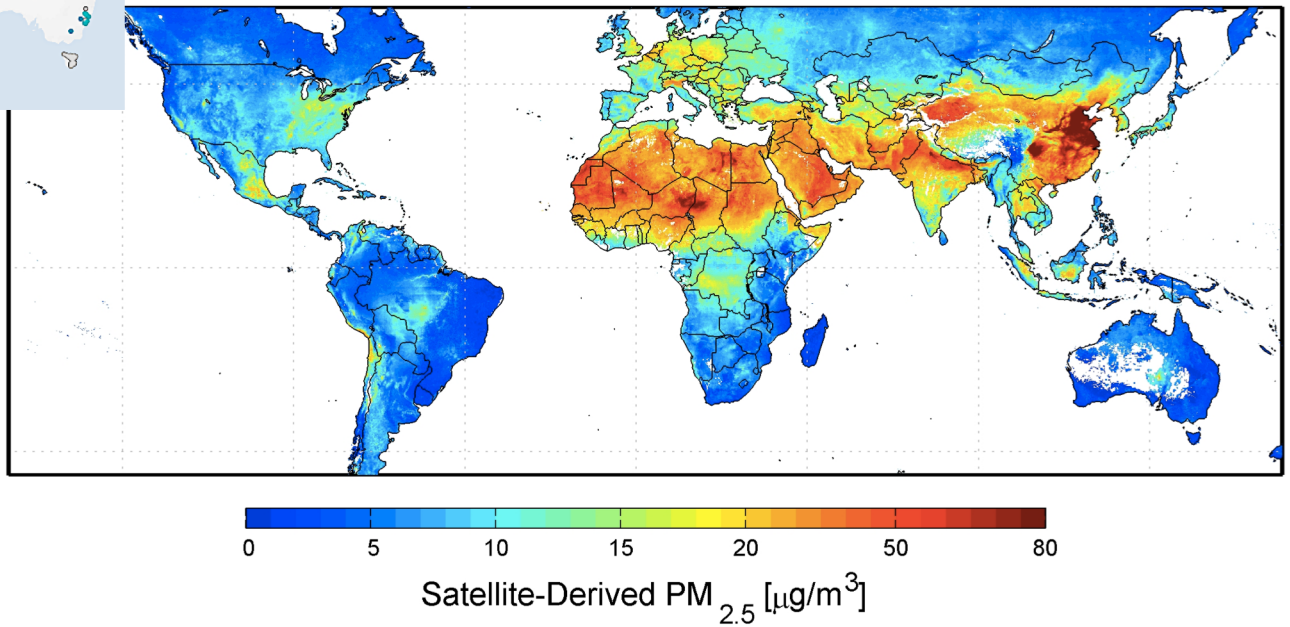
$PM_{2.5}$ mass concentration (μgm^{-3}) - dry mass

Global Status of $PM_{2.5}$ Monitoring



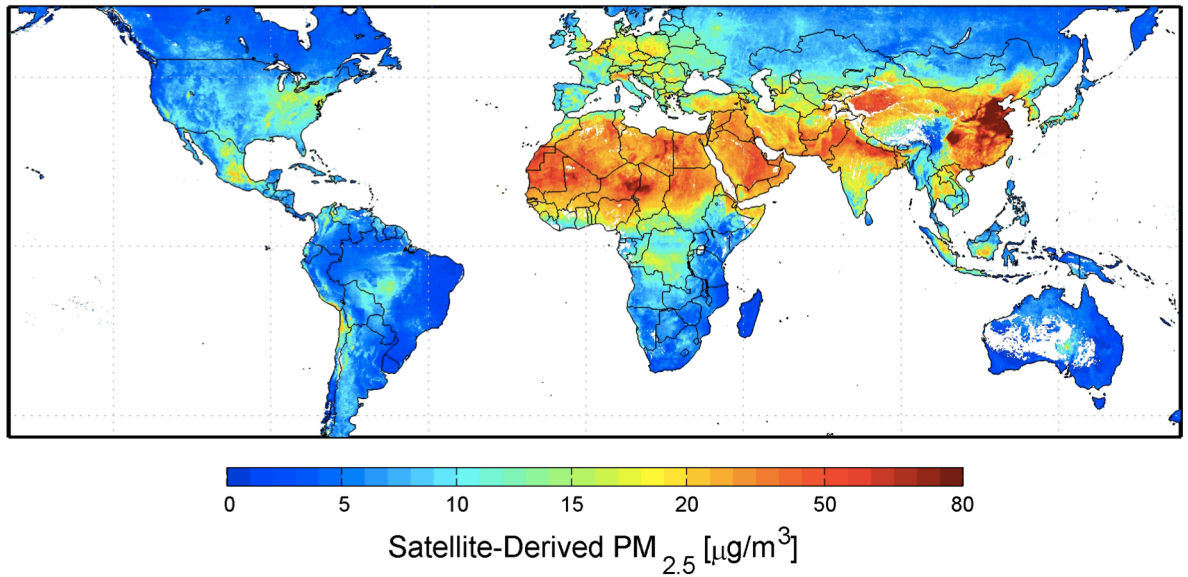
Ground Sensor Network

Satellite Estimated $PM_{2.5}$



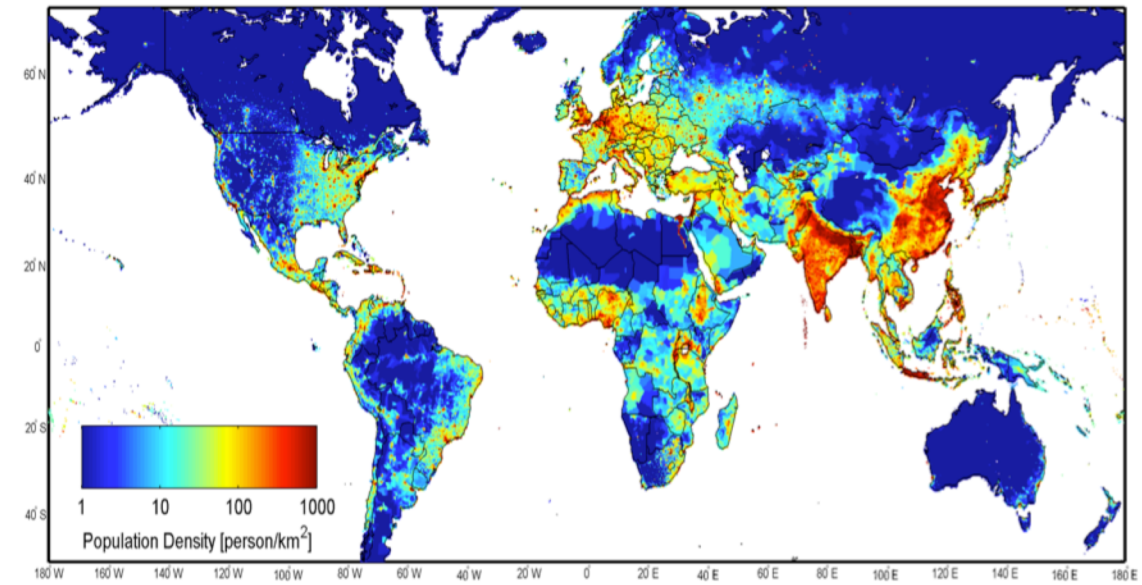
Credit: van Donkelaar et al., 2010

Global Status of $PM_{2.5}$ Monitoring: Future View



Satellite Estimated $PM_{2.5}$

Population Density

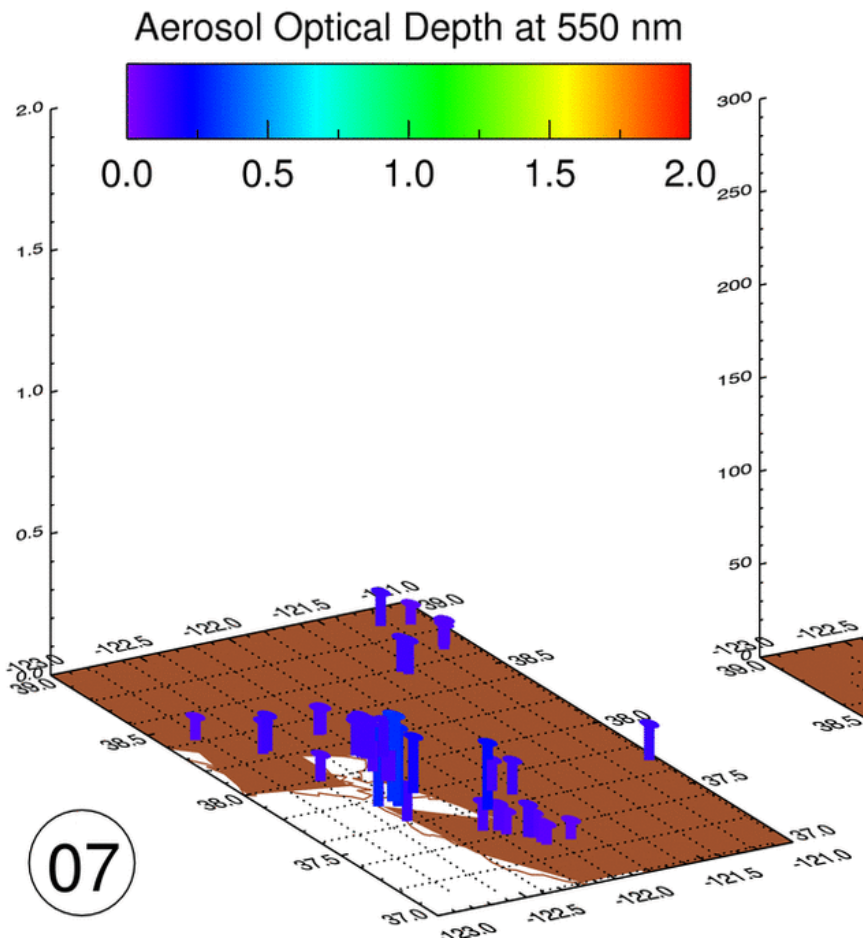


Credit: van Donkelaar et al., 2010

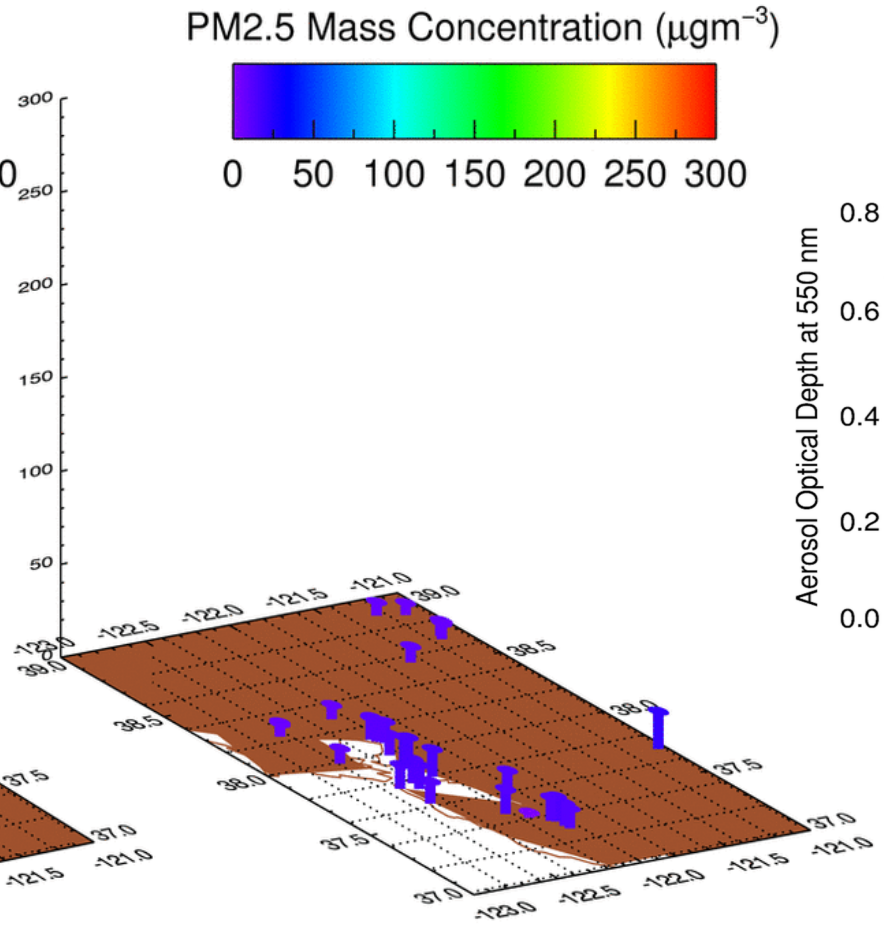
Application of Satellite Observations

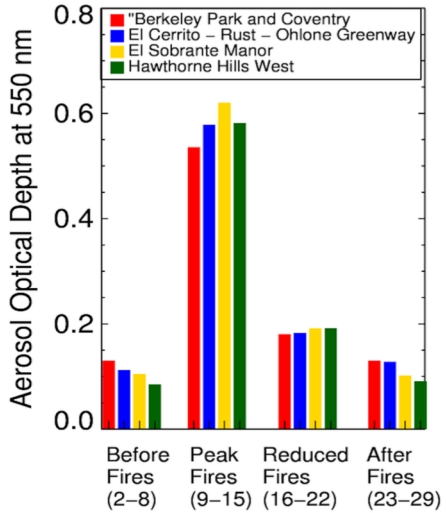
Fires in CA, USA

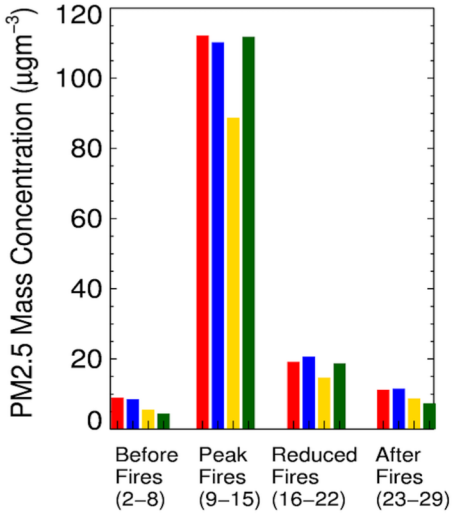
Satellite



Surface



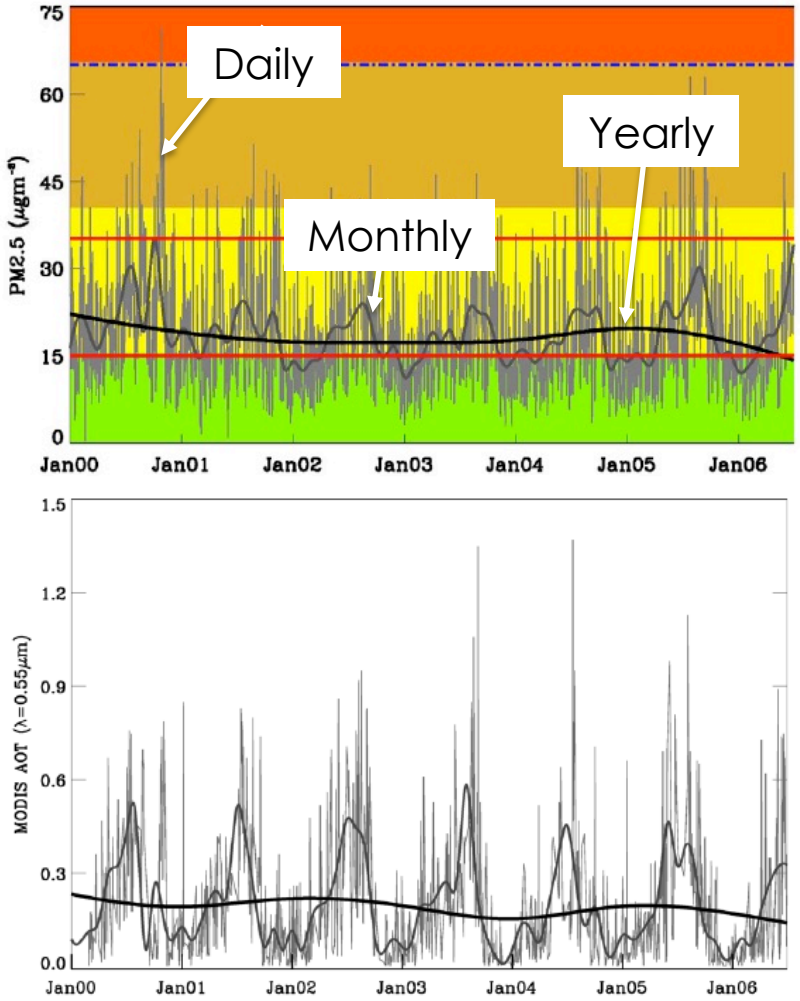




Credit: Gupta et al., 2018

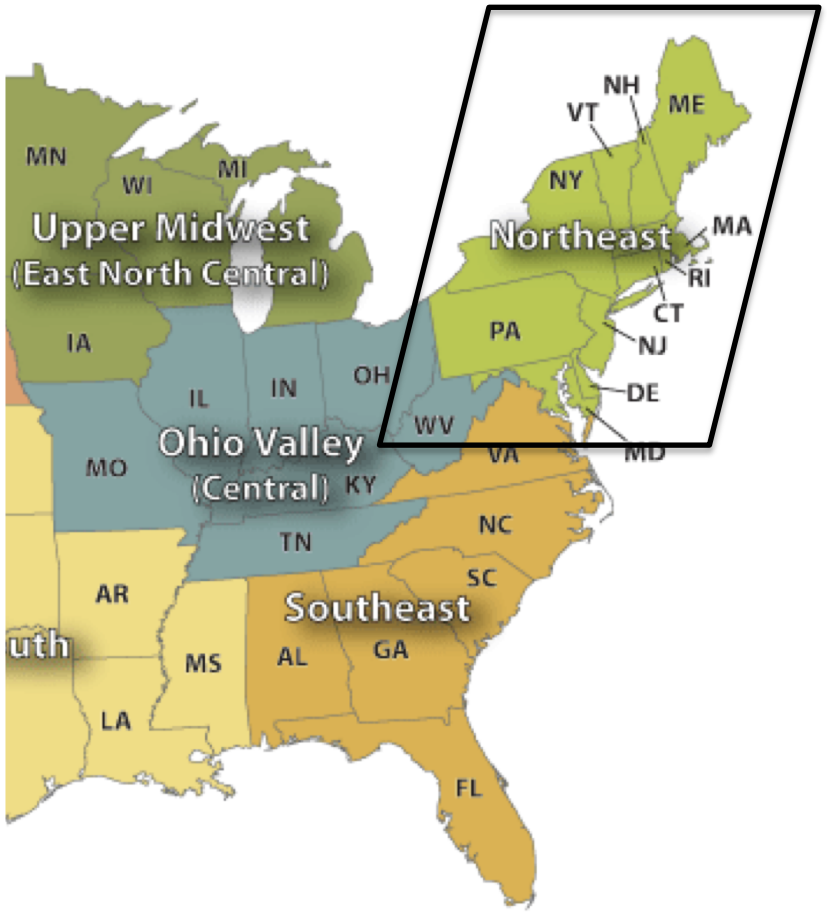
Air Quality Trends

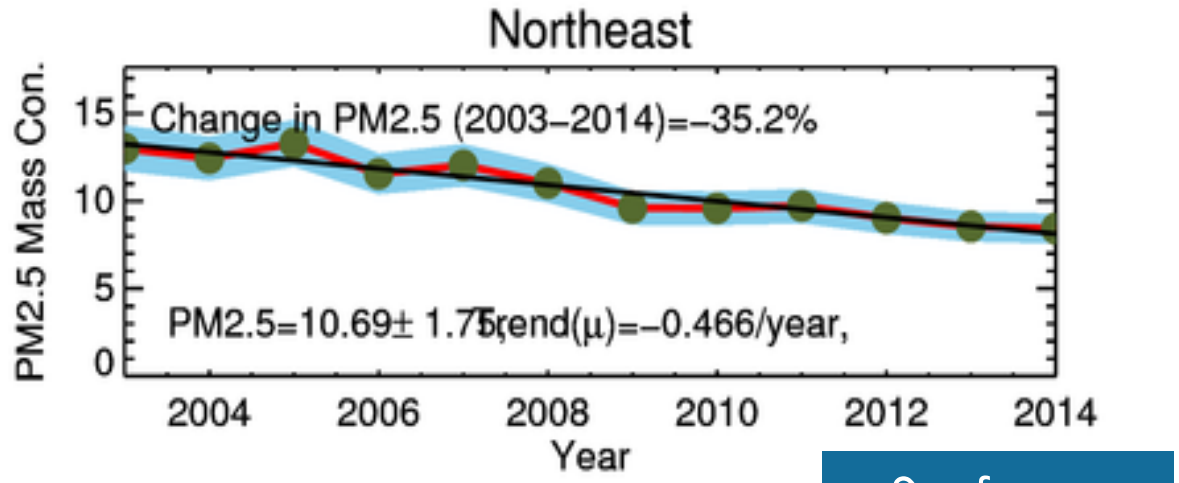
Birmingham, Alabama



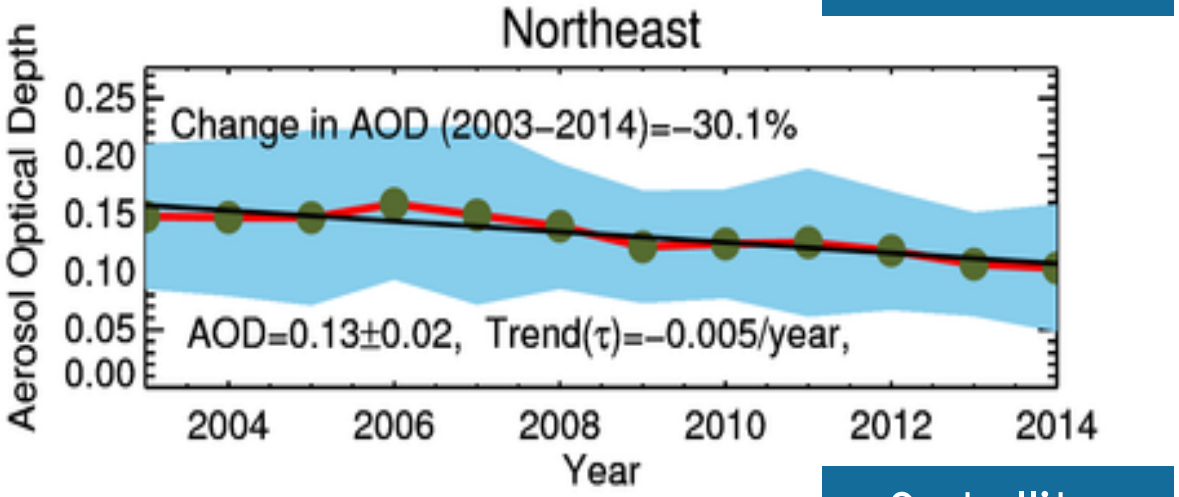
- A decreasing trend in annual $PM_{2.5}$ was noted with the almost 22% reduction in $PM_{2.5}$ mass concentration observed in 2006 compared to 2002
- MODIS-Terra Collection 5, Level 2, 10 km^2 AOTs for 2000-2006

Measurements: Surface vs. Satellite





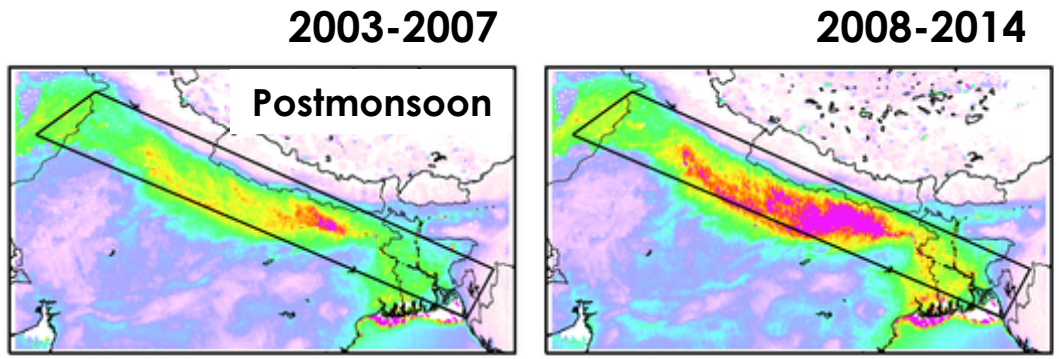
Surface

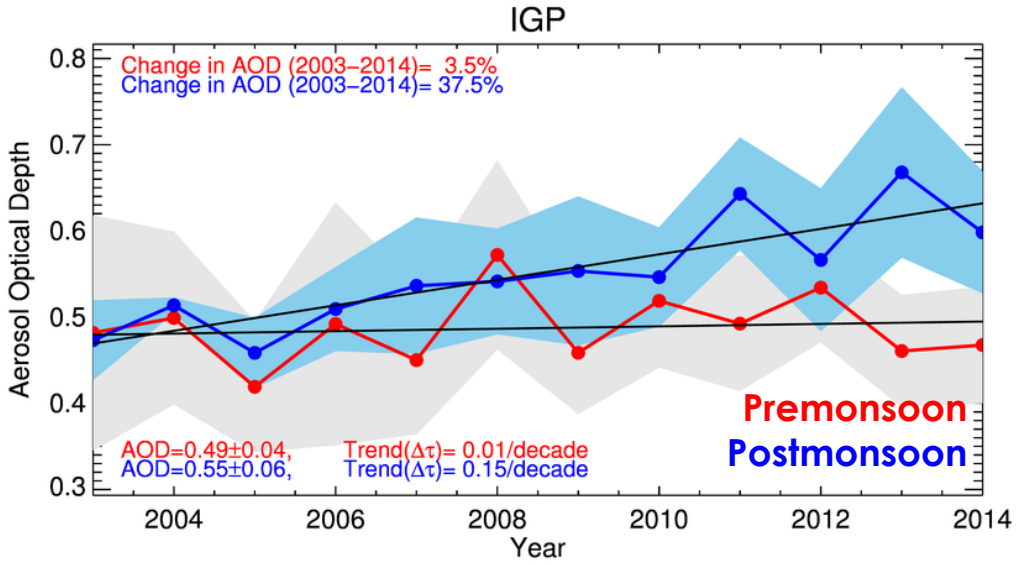


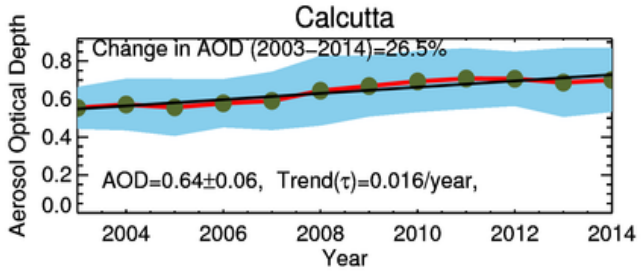
Satellite

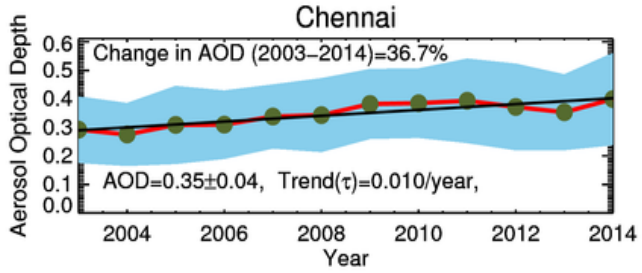
Map Credit: U.S. Climate Regions, NOAA; Time Series Credit: Gupta

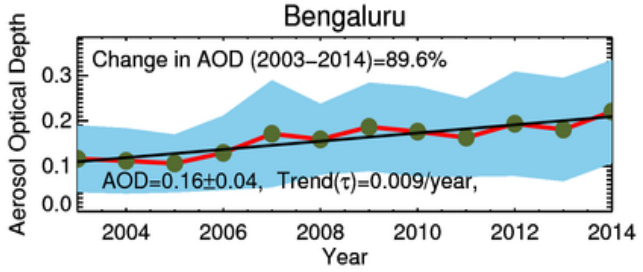
Aerosol Trends over India

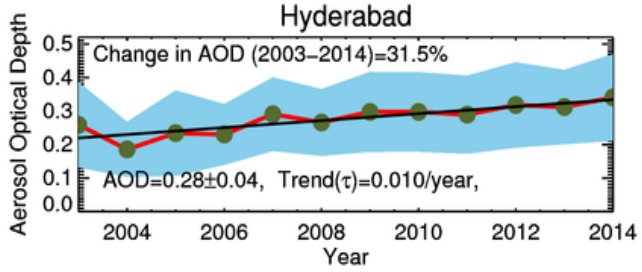


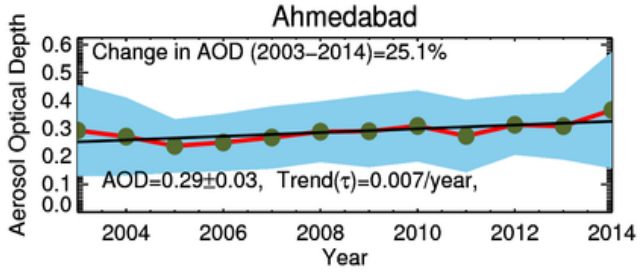


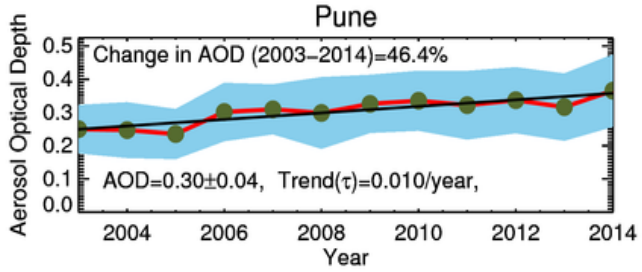


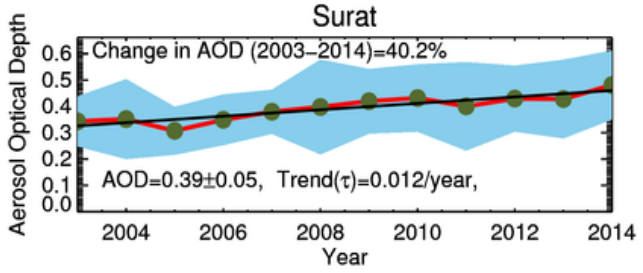






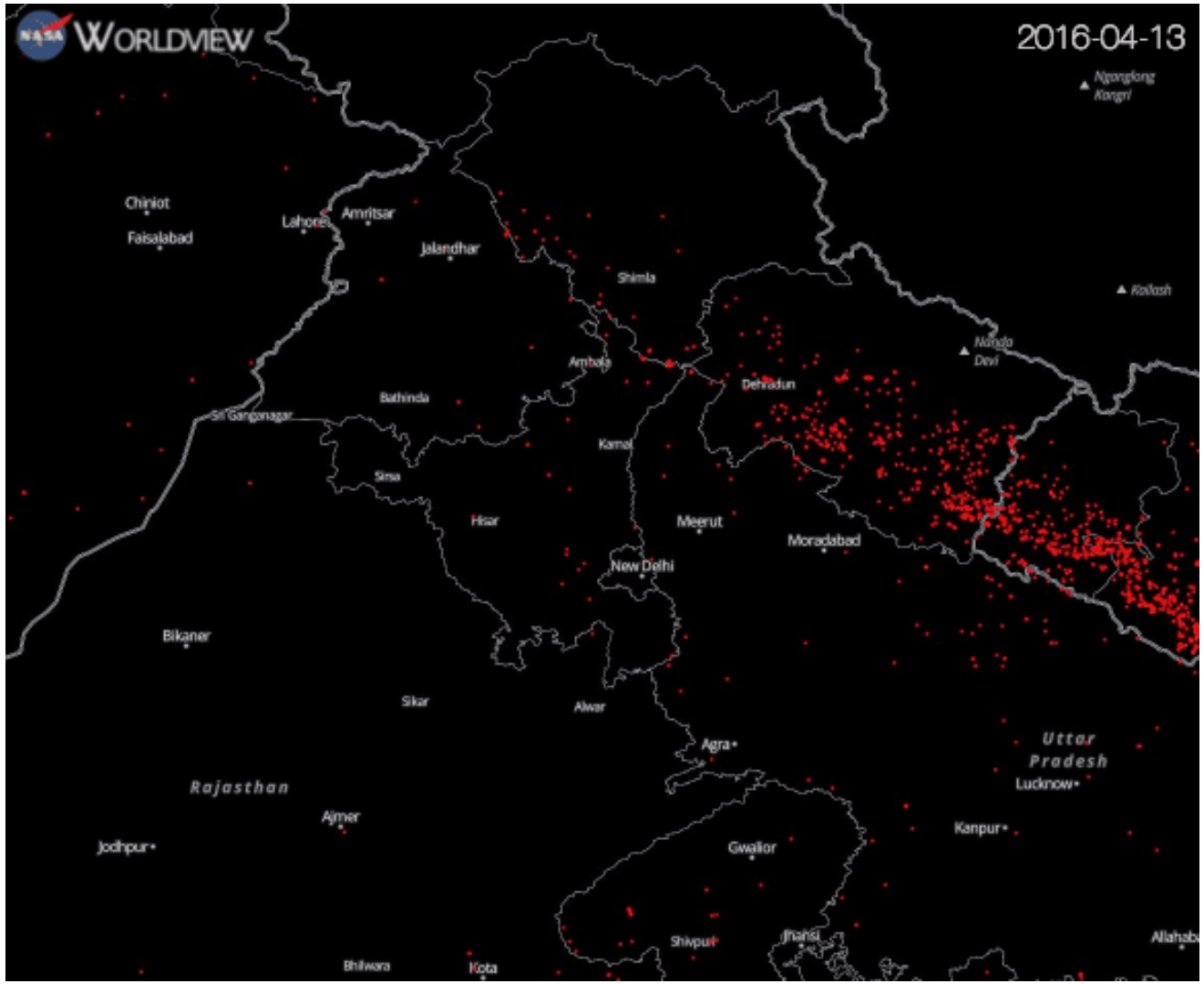






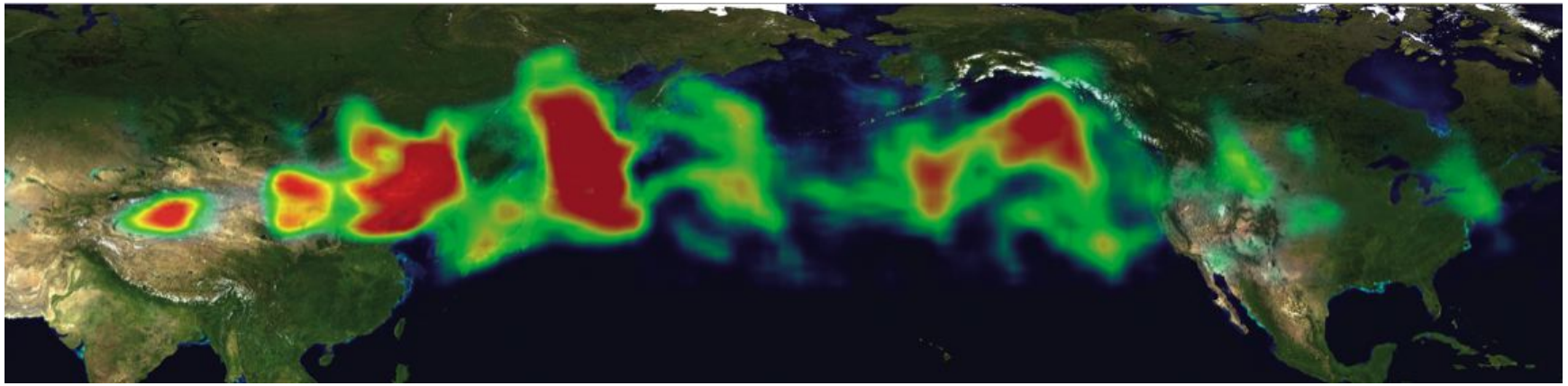
Gupta et al.,

Fire Detection and Monitoring

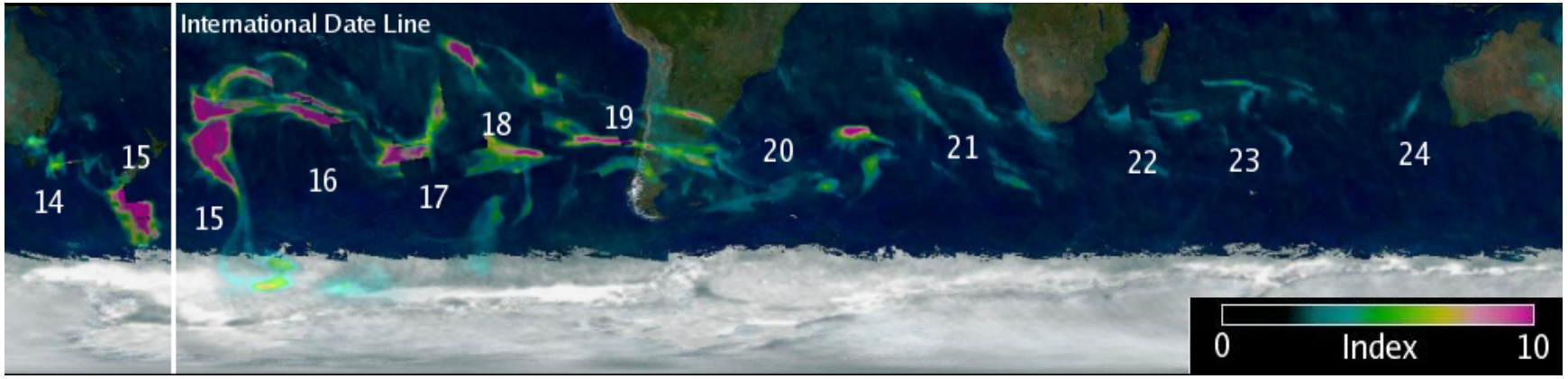


Long Range Transport

Dust from Mongolian Deserts Reaches the U.S.

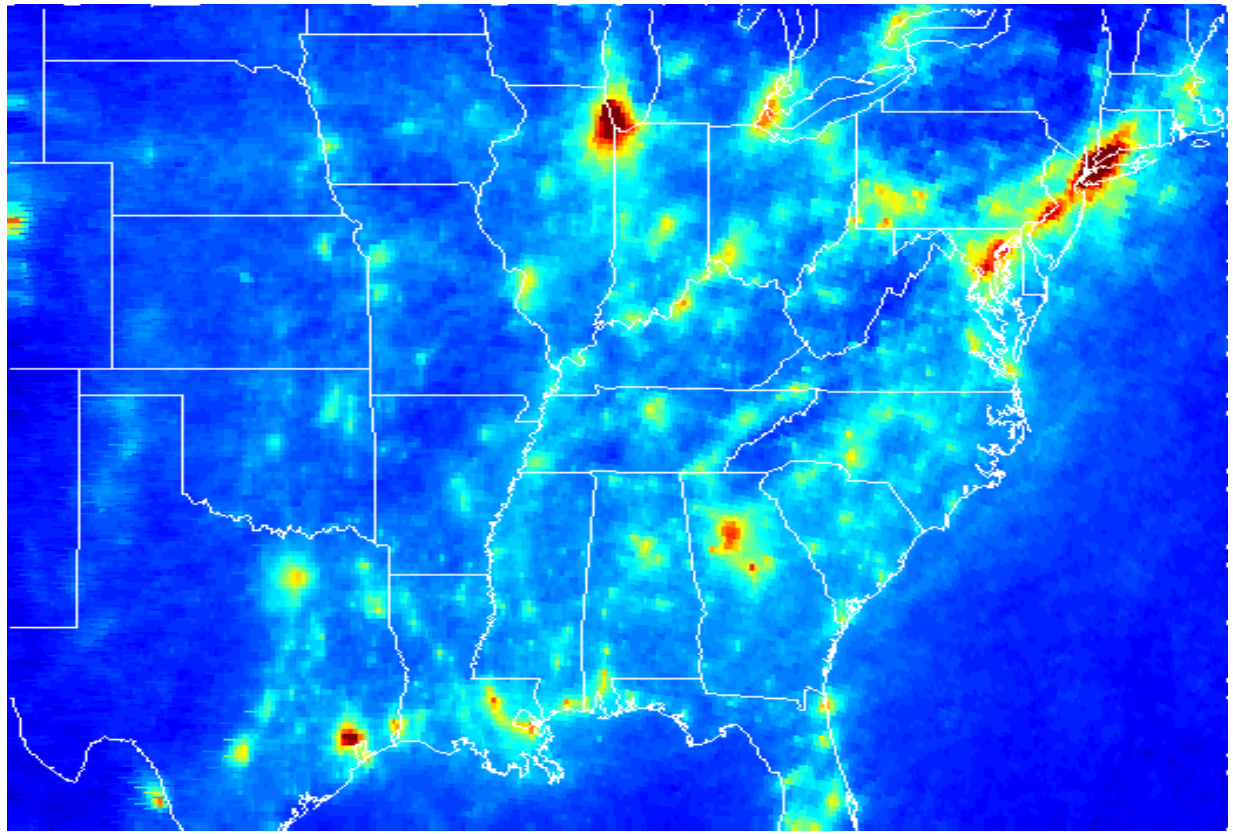


Smoke Travels Around the World in 11 Days

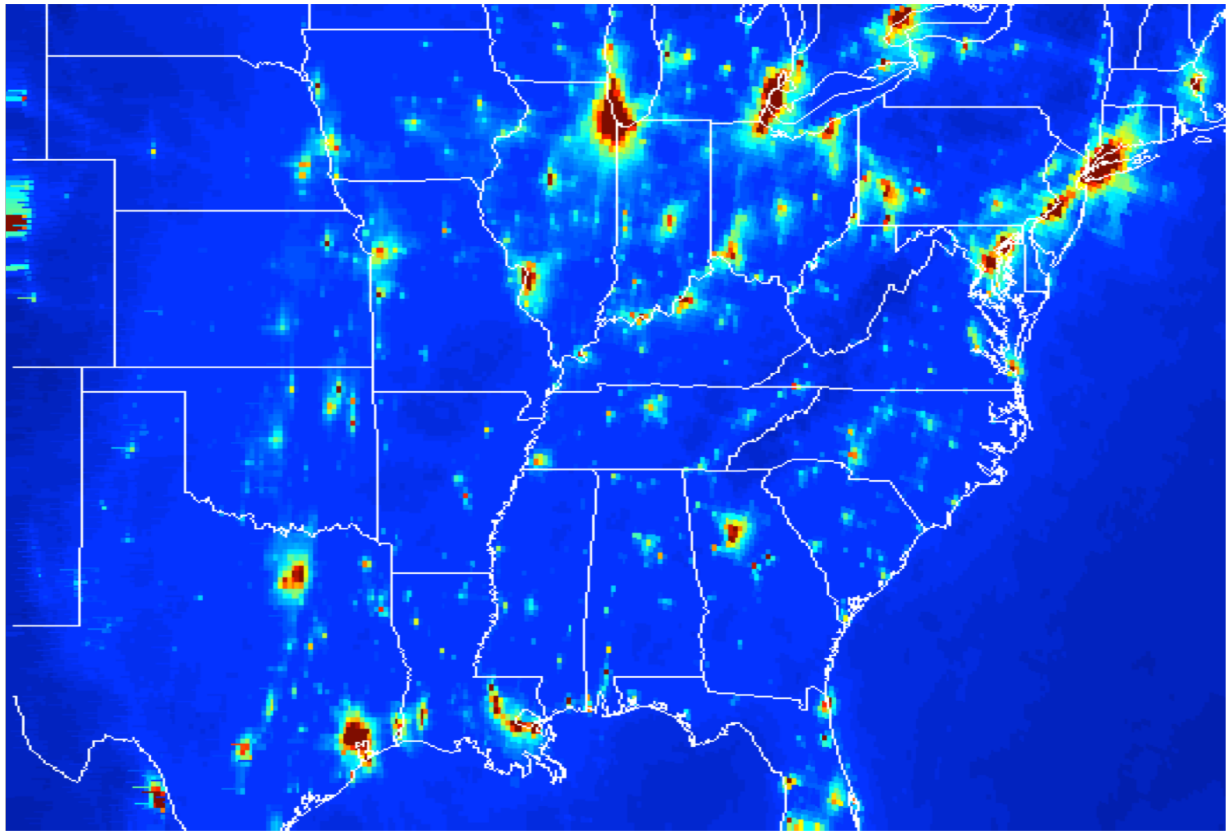


Model-Satellite Inter-Comparison

CMAQ Model NO_2

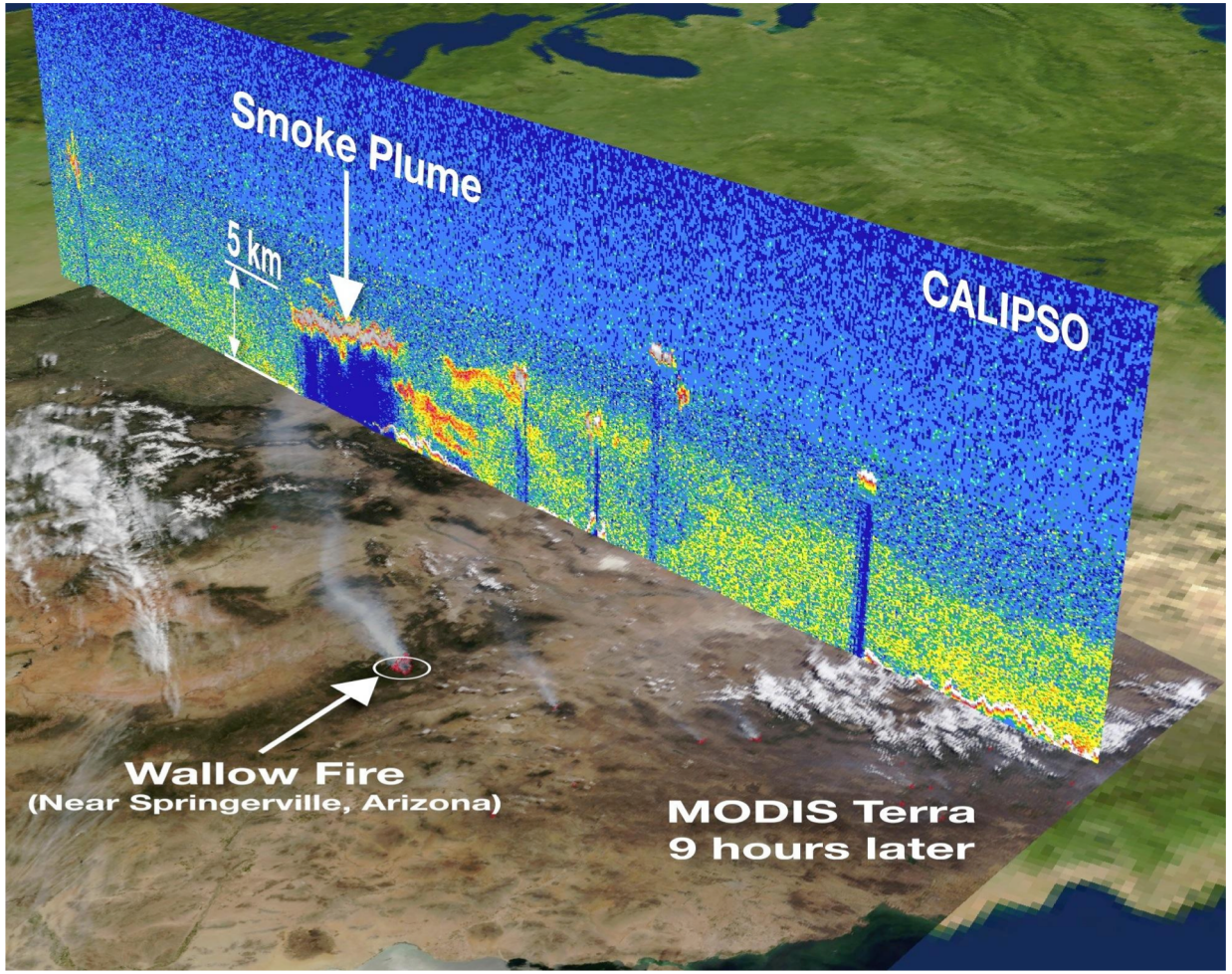


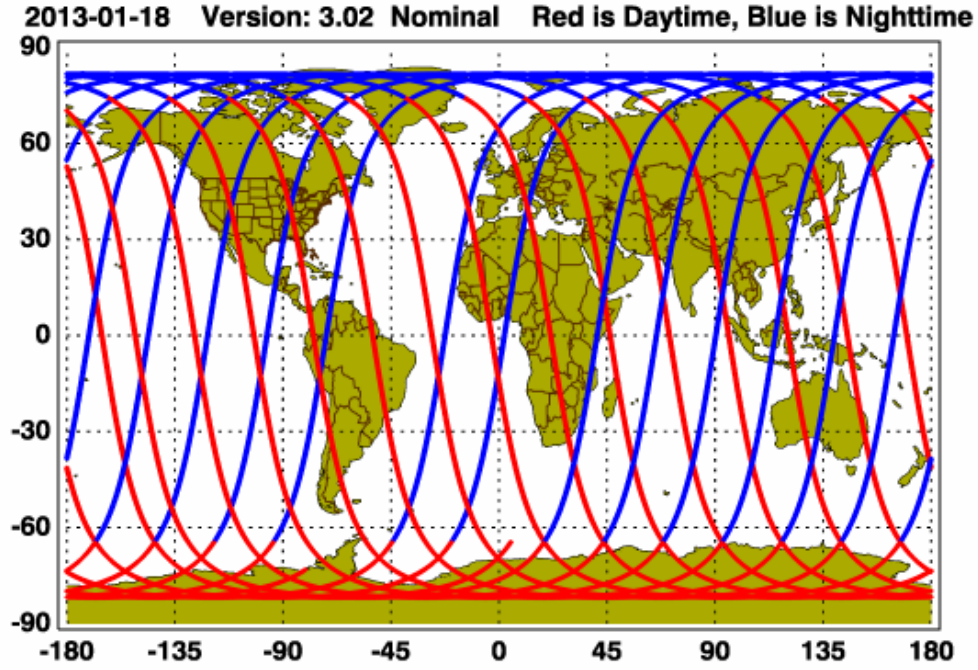
OMI NO_2



Vertical Profiles of Aerosols

CALIPSO: Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations

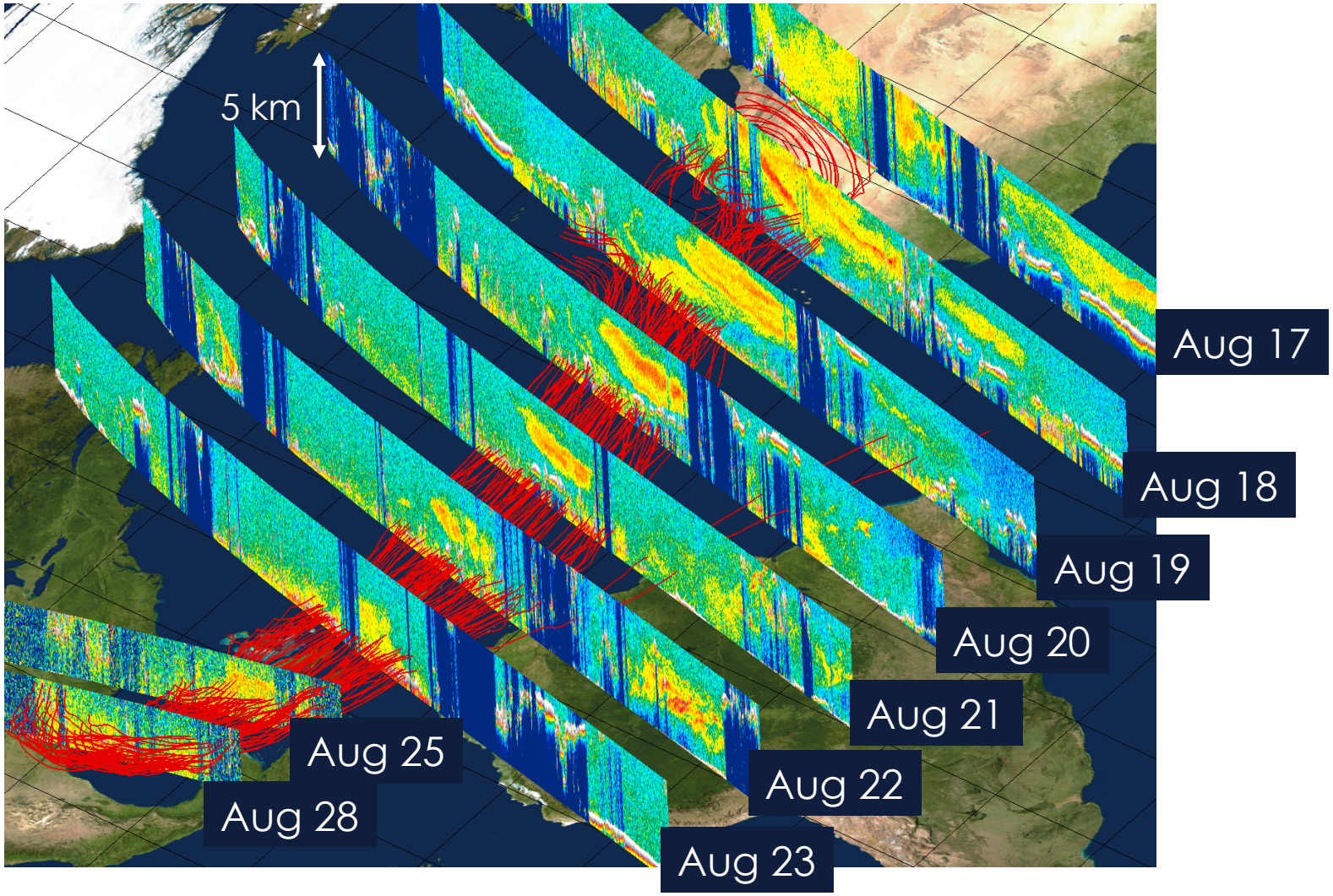




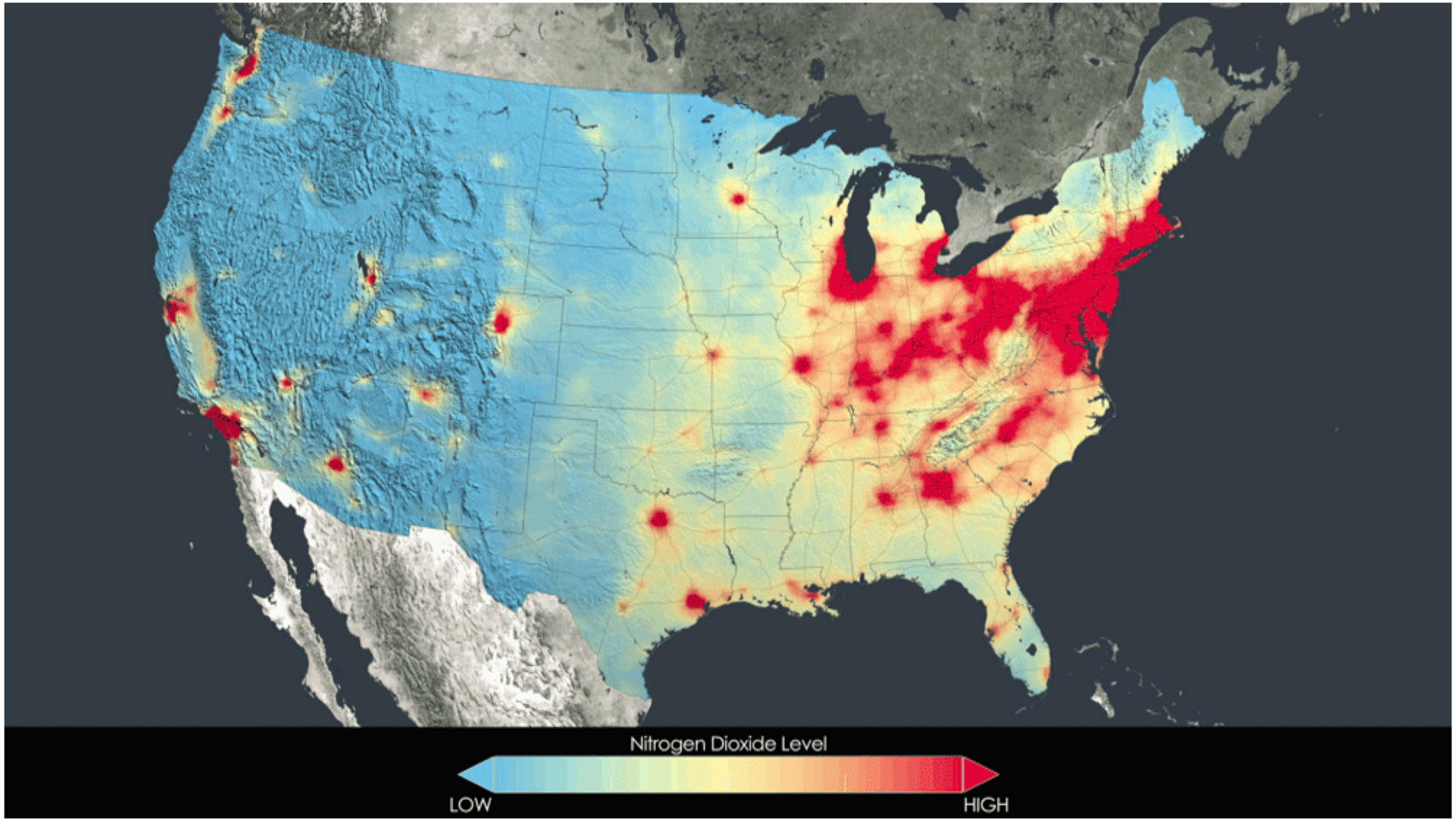
CALIPSO Browse Images: https://www-calipso.larc.nasa.gov/products/lidar/browse_images/production/

Example of CALIPSO Data

Major Saharan Dust Transport Event: Aug 17-28, 2007

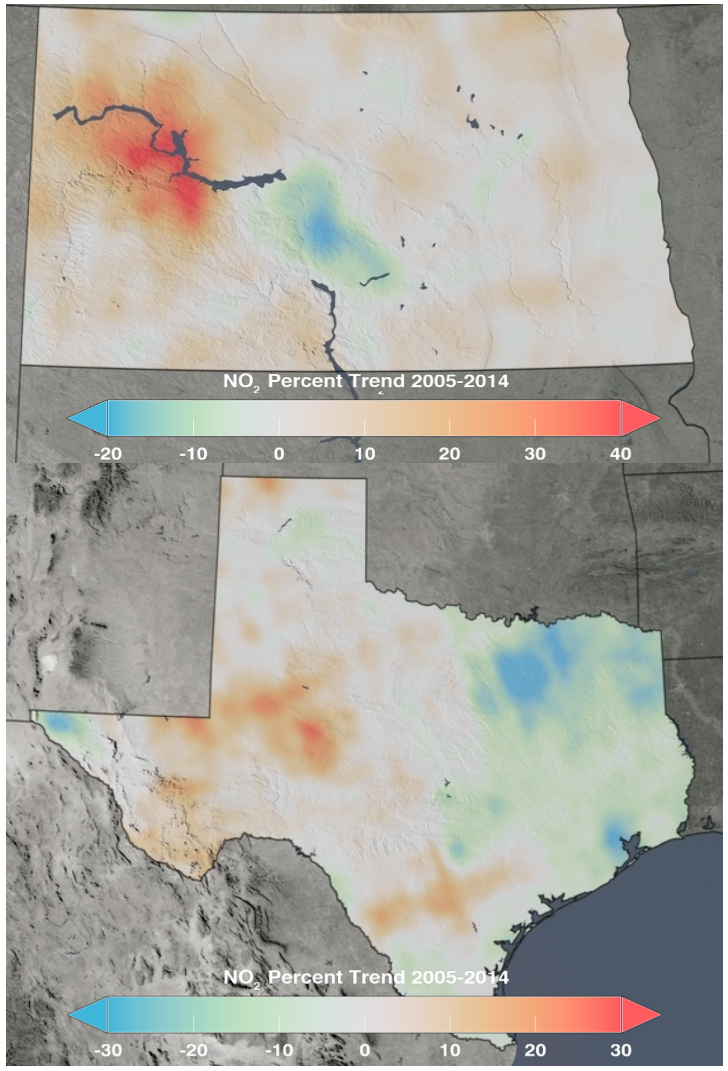


NO_2 Trends Over the United States



OMI Detects NO_2 Increases from ONG Activities

2005 - 2014



North Dakota

Suomi NPP VIIRS Lights at Night

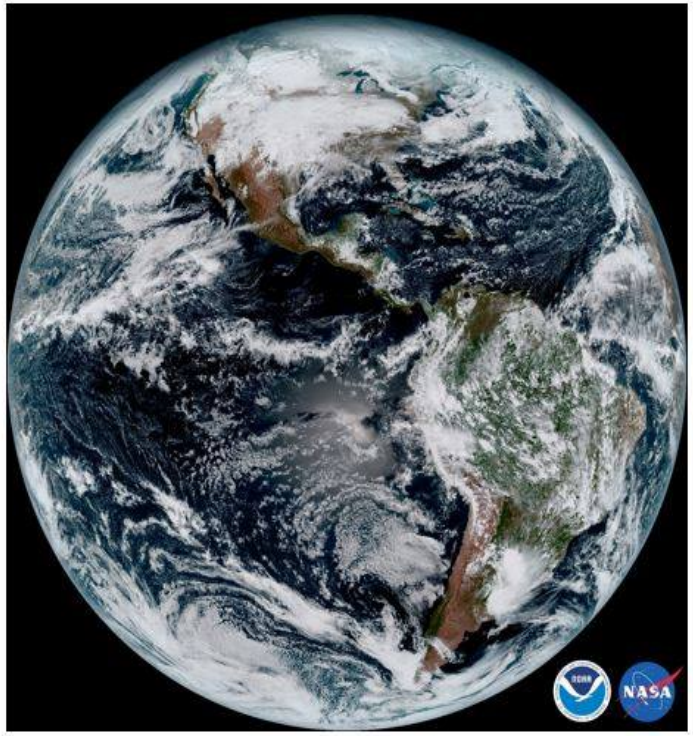
Texas

Courtesy of: Bryan Duncan

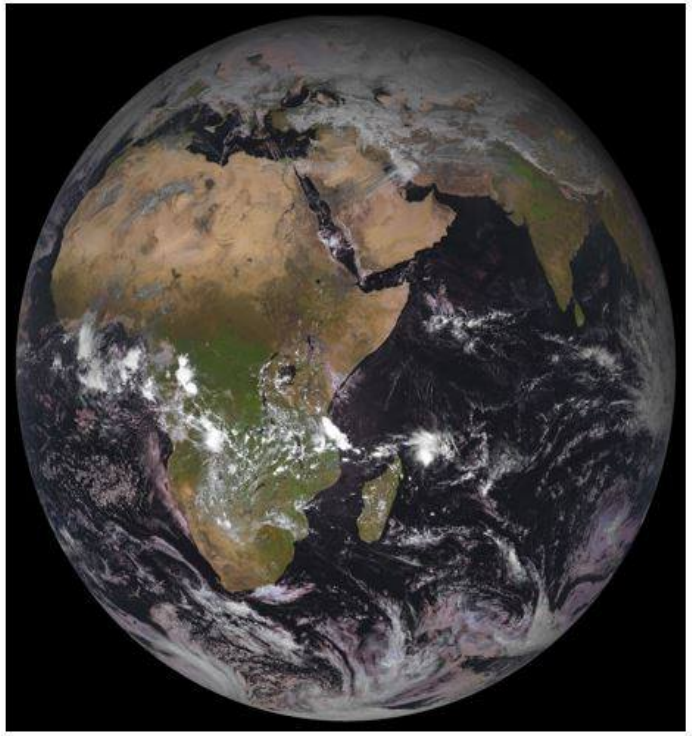
Future Satellite Capabilities for Air Quality Applications

Breaking the Temporal Barrier

The beginning of a new era in satellite remote sensing of air quality



GOES-16



METEOSAT-8

HIMAWARI-9

Source: NOAA NESDIS

GOES-16 Loop: Dust Storm in Southern California

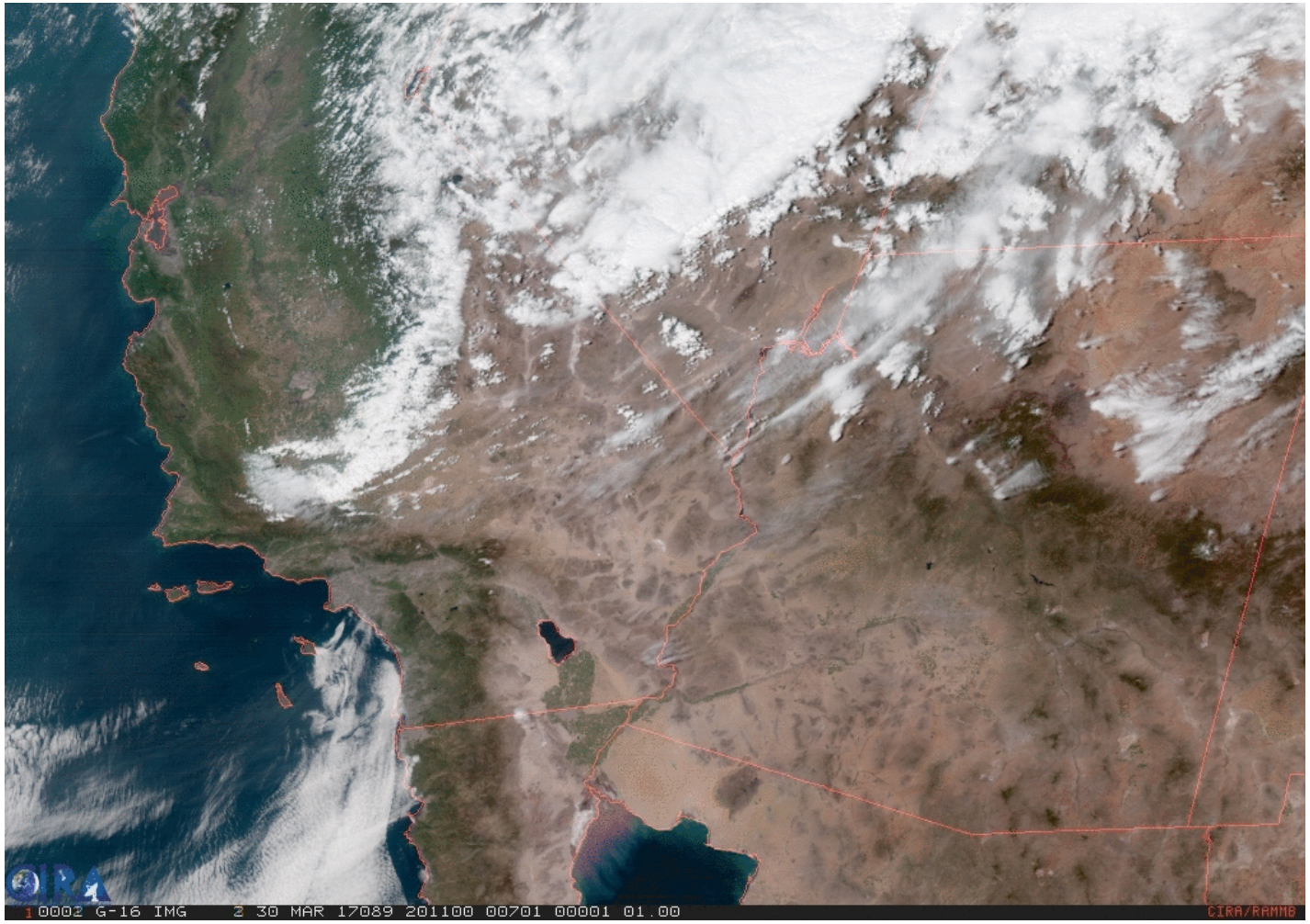


Image Credit: NOAA CoRP, STAR: http://rammb.cira.colostate.edu/ramsdis/online/loop_of_the_day/

Himawari-8 Loop: Fog and Smog Over India

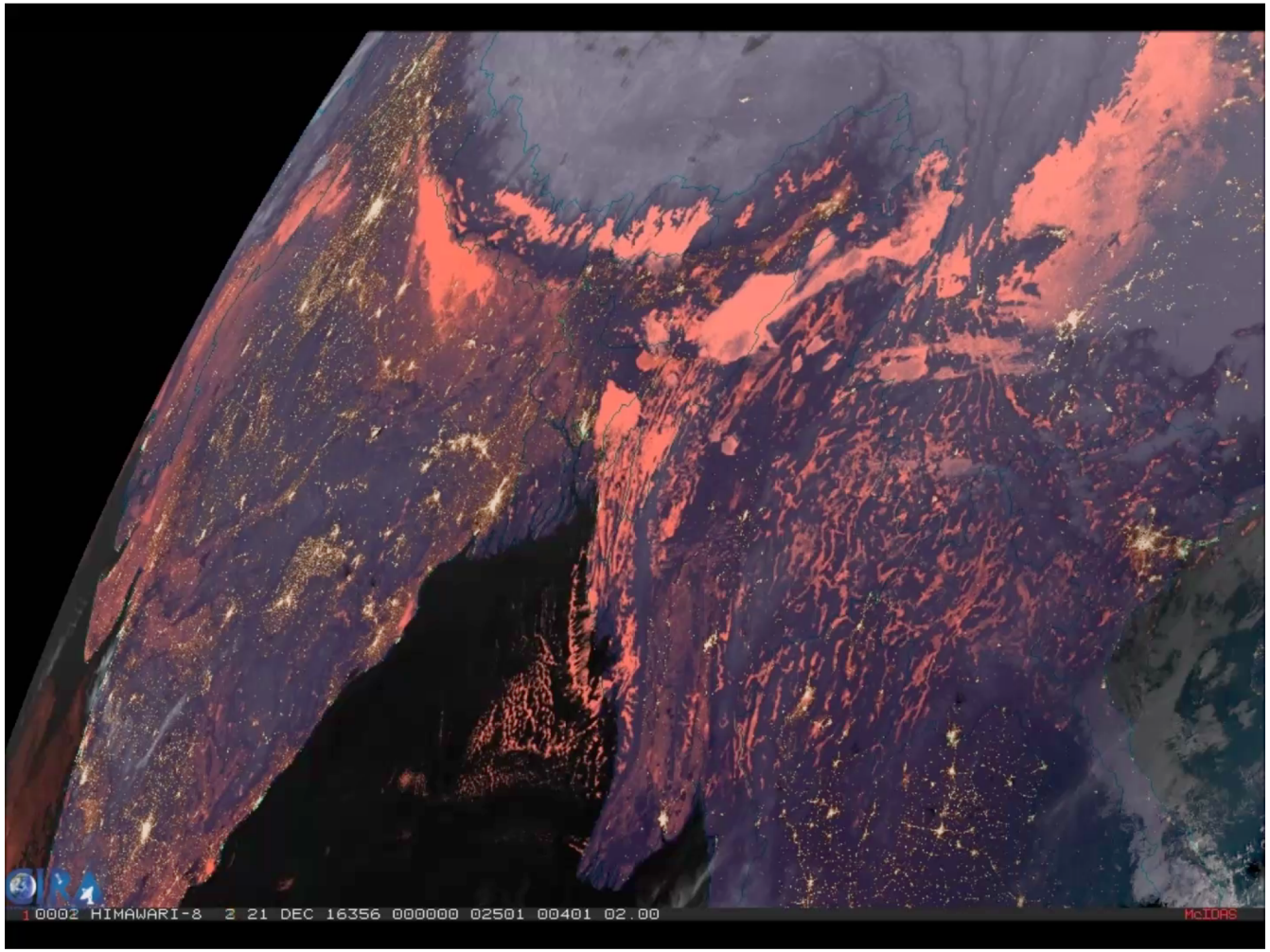
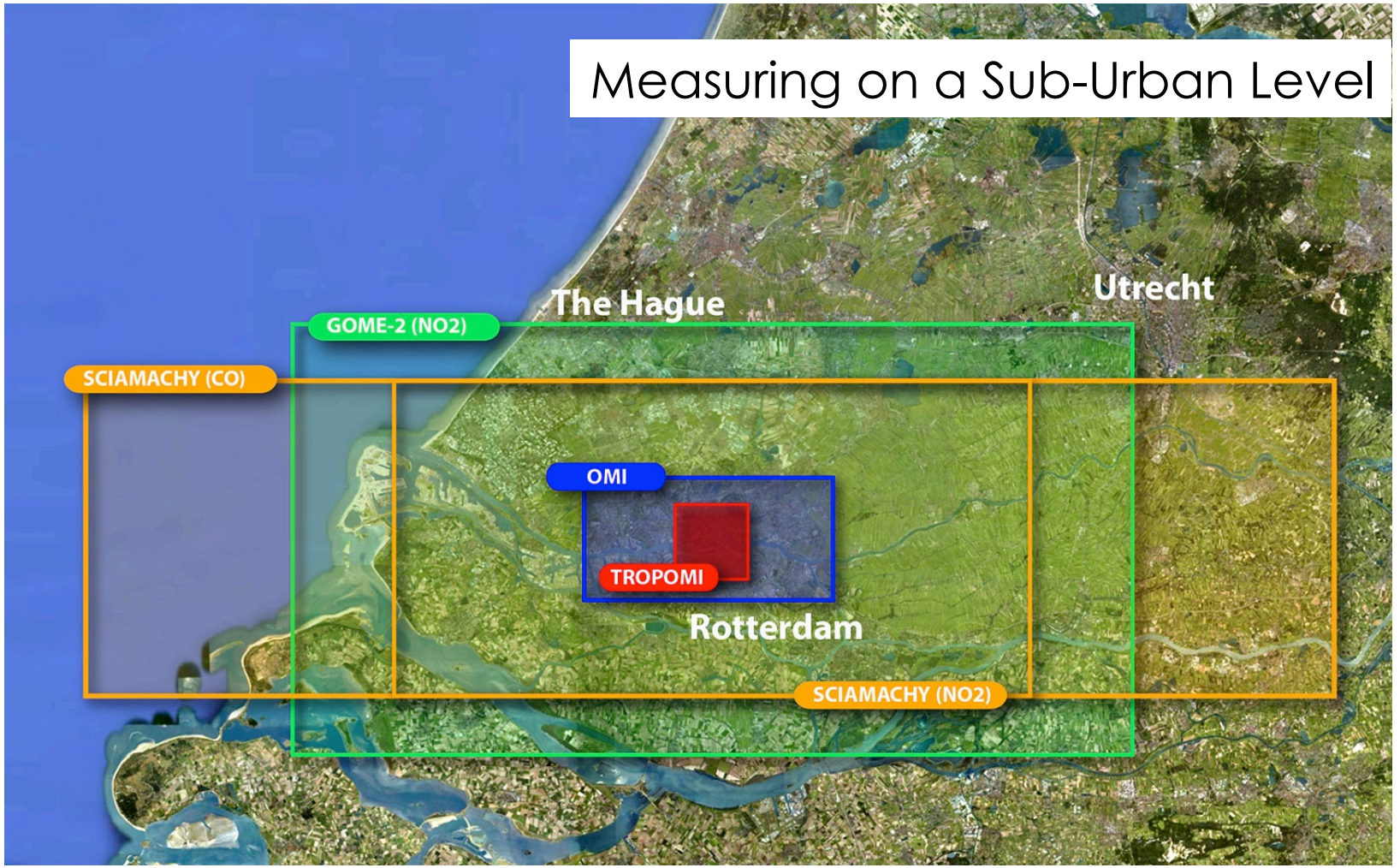


Image: NOAA CoRP, STAR: http://rammb.cira.colostate.edu/ramsdis/online/loop_of_the_day/

Upcoming Instruments: European Space Agency TROPOMI

TROPOMI Highlights

- Launched 2017
- Observes the whole globe
- Sub-urban spatial resolution (7 km x 7 km)
- 1x/day: NO_2, ozone (0-2 km vertical), aerosol, clouds, formaldehyde, glyoxal, SO_2, CO, methane

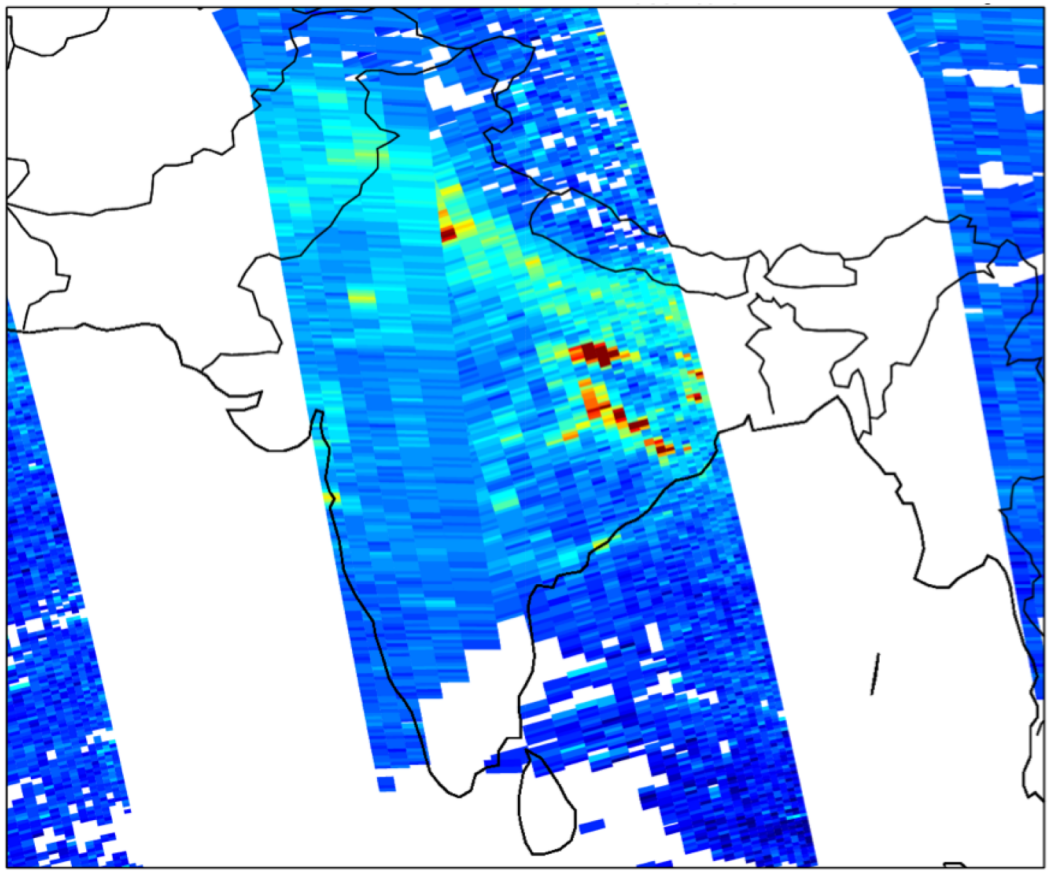


Slide Courtesy: Bryan Duncan

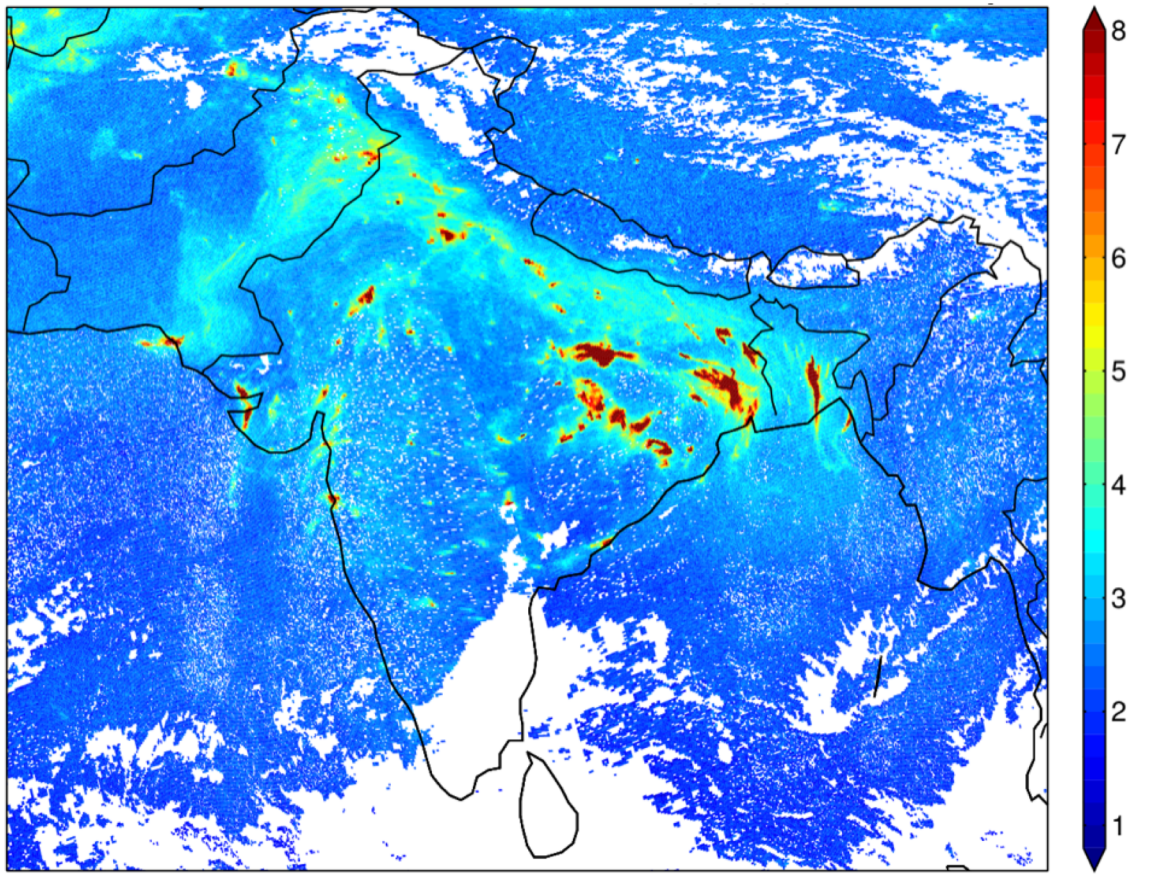
TROPOMI: Impact of Resolution

November 28, 2017

OMI NO_2 (Real Data)



TROPOMI NO_2 (Real Data)



Spatial Resolution = 3.5 x 7.0 km^2

Global pollution monitoring constellation (2018-2020)

Policy-relevant science and environmental services enabled by common observations

- Improved emissions, at common confidence levels, over industrialized Northern Hemisphere
- Improved air quality forecasts and assimilation systems
- Improved assessment, e.g., observations to support the United Nations Convention on Long Range

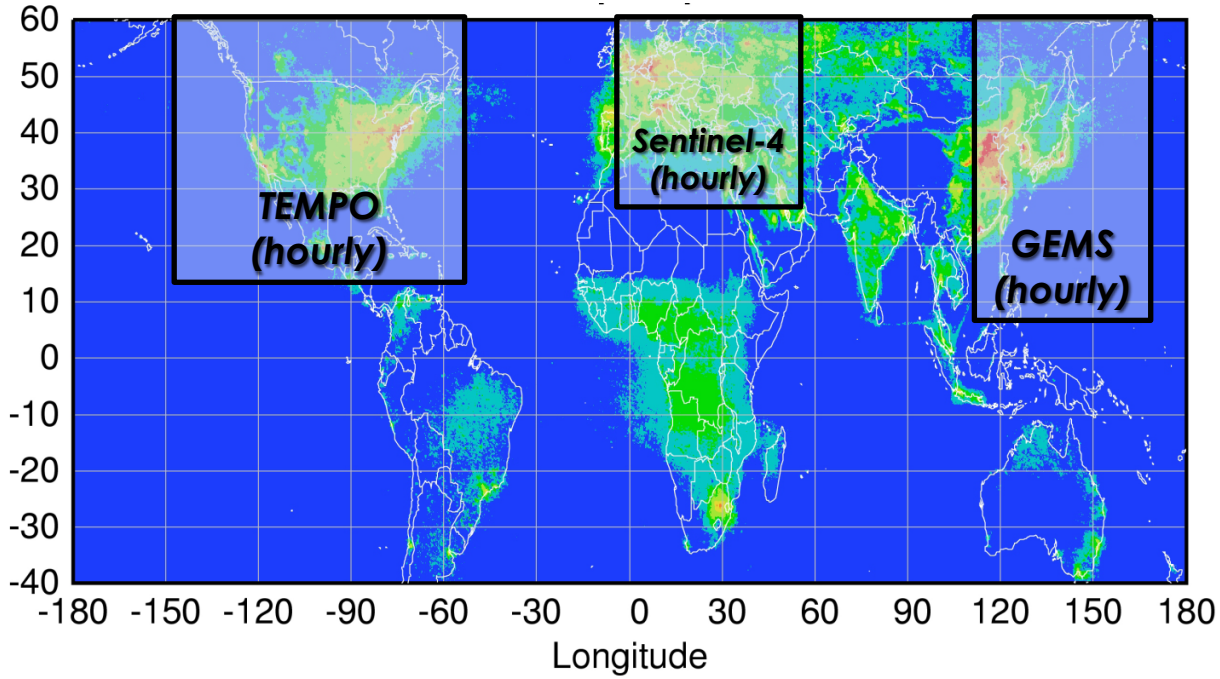
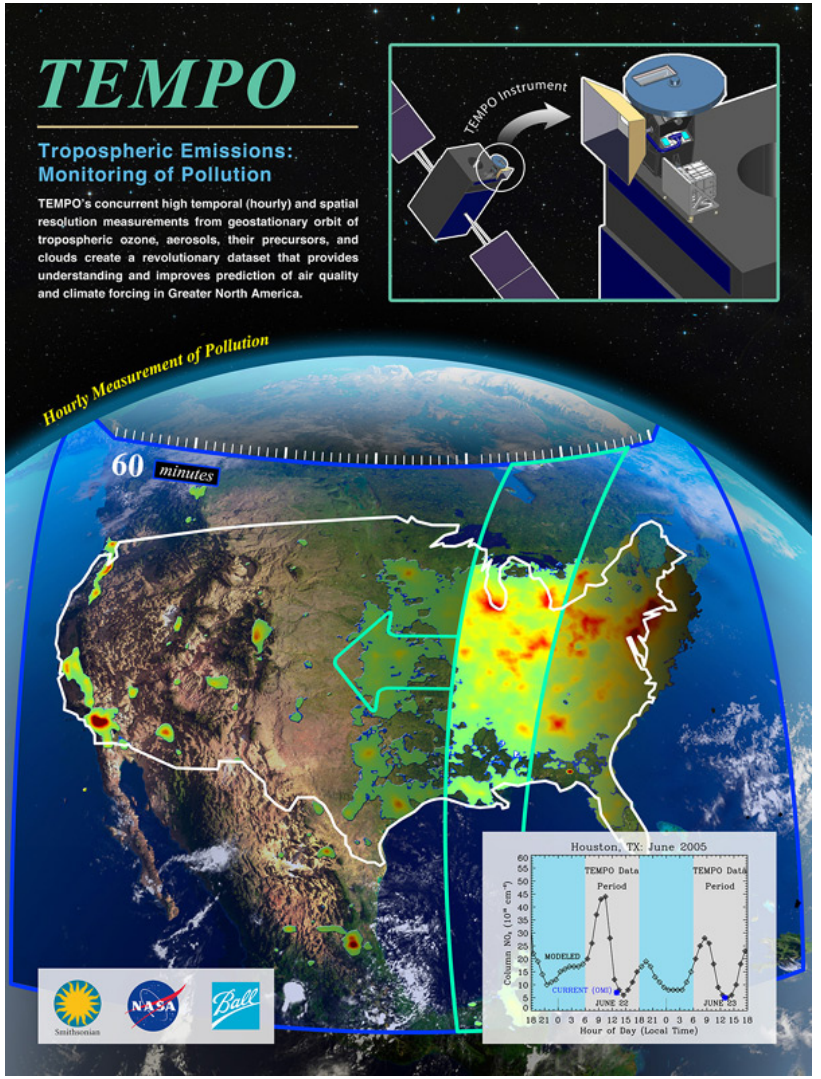


Image Credit: Courtesy Jhoon Kim, Andreas Richter

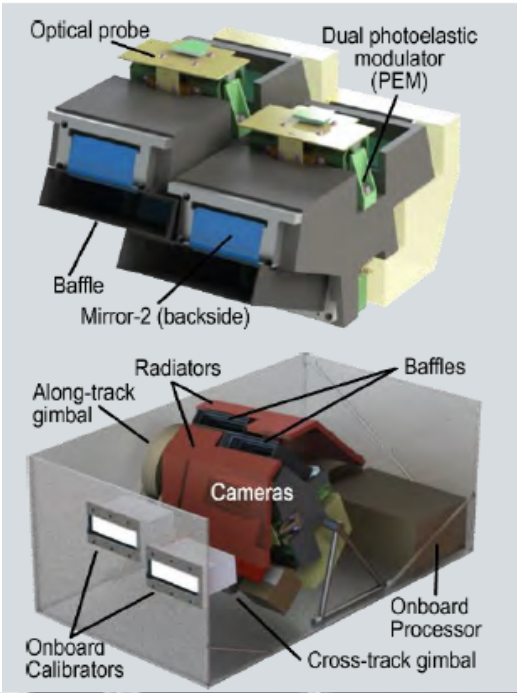
TEMPO

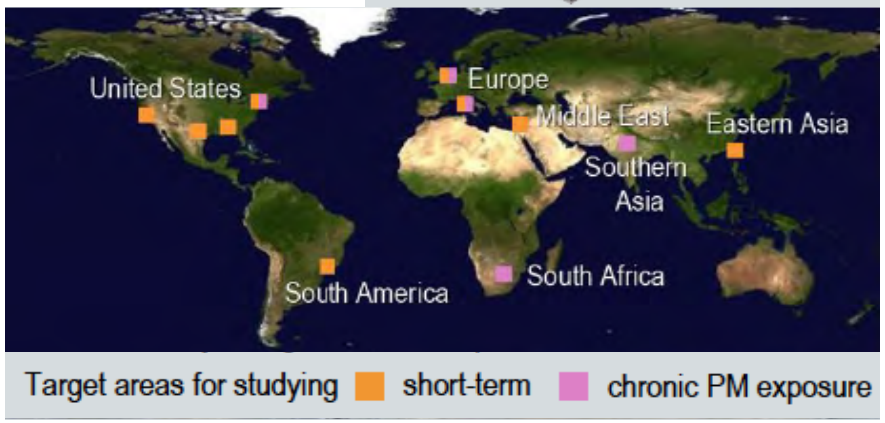
- Geostationary over North America
- High Temporal Resolution
  - 1 hr
- High Spatial Resolution
  - 2.2 x 4.7 km
- Spectral Range
  - 290-740nm
- Data Products:
  - O_3, NO_2, $C_2H_2O_2$, aerosols, cloud parameters, & UVB radiation
- Expected Launch: 2021



Multi-Angle Imager for Aerosols (MAIA)

- Mission Goal: Assess linkages between different airborne particulate matter types and adverse birth outcomes, cardiovascular and respiratory disease, and premature deaths
- Sun synchronous orbit
- Spatial Resolution: 230 m
- Large Swath Width: 600 km
- Expected Launch: 2021





Questions & Discussion

- Can satellites help fill some of the data gaps?

- What are the advantages of polar orbiting satellites compared to geostationary satellites?