National Aeronautics and Space Administration

Satellite Data for Air Quality Environmental Justice and Equity Applications

Part 2: Satellite Remote Sensing of Air Quality for Environmental Justice

Carl Malings (NASA & Morgan State University)

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Part 2 – Trainer

Carl Malings

Assistant Research Scientist

NASA, Morgan State U.

Part 2 Objectives

By the end of Part 2, participants will be able to:

- Identify remote sensing data products which are most relevant to assessing EJ related to air quality and pollutant exposure
- Articulate the benefits and limitations of using remote sensing data to assess EJ concerns related to air quality

Based on the review of environmental justice applications for remote sensing data presented in Part 1, what was the most common category for the studies discussed?

A: Light Pollution

B: Temperature and Urban Heat

C: Access to Green Space

D: Air Pollution

E: Flooding or Drought

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✓ D: Air Pollution

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Review of Prior Knowledge

- Past applications of satellite data to investigate environmental justice issues:
  - air pollution (focus of today's training)
  - green space
  - extreme temperatures (heat & cold)
  - drought, flooding, and water access
  - light at night
- Satellite remote sensing data can be combined with socio-economic information to provide evidence of disparities, inequality, and environmental injustice.
- Advantages of using satellite data to investigate environmental justice include their wide spatial coverage and long data records.
- Limitations of using satellite data to investigate environmental justice include spatial resolution, temporal frequency, and validation against ground data.

How to Ask Questions

- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.

Background on Air Quality and its Health Impacts

The Scale of the Global Air Quality Problem

- Poor air quality is the **number one environmental and occupational risk factor** for premature death globally.
- Air pollution is estimated to be responsible for about **7 million premature deaths** each year.
- Air pollution also has many negative **economic impacts** as well, for example, crop damage due to near-surface Ozone.
- Air pollution improvements can have **numerous co-benefits**, especially in greenhouse gas emission reductions.

Sources: Global Burden of Disease. *University of Washington Institute for Health Metrics and Evaluation*.
Air Pollution – silent killer. *World Health Organization*.

Air Quality Standards

		US Environmental Protection Agency National Ambient Air Quality Standards		World Health Organization 2021 Air Quality Guidelines	
	Pollutant	Time Basis	Standard	Time Basis	Standard
Aerosols	$PM_{2.5}$ (fine particulates)	annual	12 µg/m^3	annual	5 µg/m^3
		daily	35 µg/m^3	daily	15 µg/m^3
	PM_{10} (coarse particulates)			annual	15 µg/m^3
		daily	150 µg/m^3	daily	45 µg/m^3
	Pb	3-month	0.15 µg/m^3		
Trace Gases	NO_2	annual	53 ppb	annual	10 µg/m^3
		hourly	100 ppb	daily	25 µg/m^3
	SO_2	3-hour	500 ppb	daily	40 µg/m^3
		hourly	75 ppb		
	O_3	8-hour	70 ppb	8-hour	100 µg/m^3
				peak season	60 µg/m^3
	CO	8-hour	9 ppm	daily	4 mg/m^3
		hourly	35 ppm		

Sources: NAAQS Table. *US Environmental Protection Agency*.
What are the WHO air quality guidelines? *World Health Organization*.

The Air Quality Index and Pollutant Concentrations

- An Air Quality Index is used to **convey air quality information to the public.**
- Different countries use different indices.
- US EPA AQI is **calculated separately** for each criteria pollutant.
- The **highest AQI across all criteria pollutants** is the reported AQI.
- **Measured AQI** are based on the previous day's measurements, and only for the pollutants measured by each station.
- **Nowcast AQI** covers Ozone and $PM_{2.5}$, using the most recent hourly data.
- **Forecast AQI** usually also covers Ozone and $PM_{2.5}$, based on multiple data sources and forecaster judgement.
- AQI is **informational but not regulatory.**

AQI	Description	Range $PM_{2.5}$, daily [$\mu g/m^3$]	Range O_3, 8-hour [ppb]	…
0 – 50	Good	0 – 12	0 – 54	…
51 – 100	Moderate	12.1 – 35.4	55 – 70	…
101 – 150	Unhealthy for Sensitive Groups	35.5 – 55.4	71 – 85	…
151 – 200	Unhealthy	55.5 – 150.4	86 – 105	…
201 – 300	Very Unhealthy	150.5 – 250.4	106 – 200	…
301 +	Hazardous	250.5 +	201 +	…

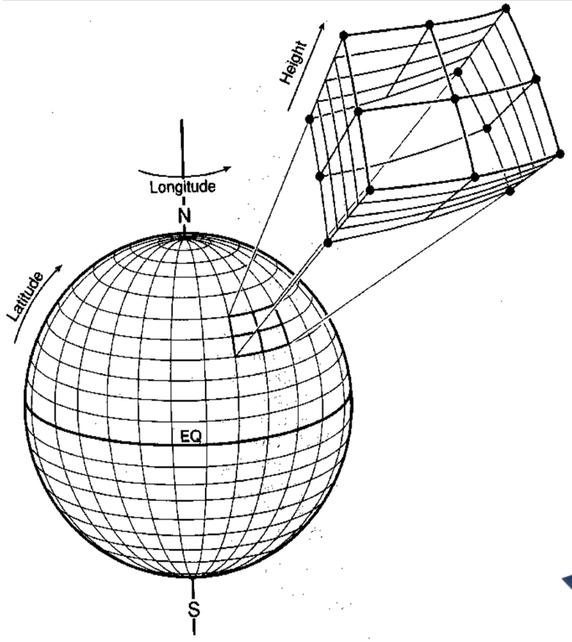
Source: Technical Assistance Document for the Reporting of Daily Air Quality. *US Environmental Protection Agency.*

Characterizing Air Pollution Exposure

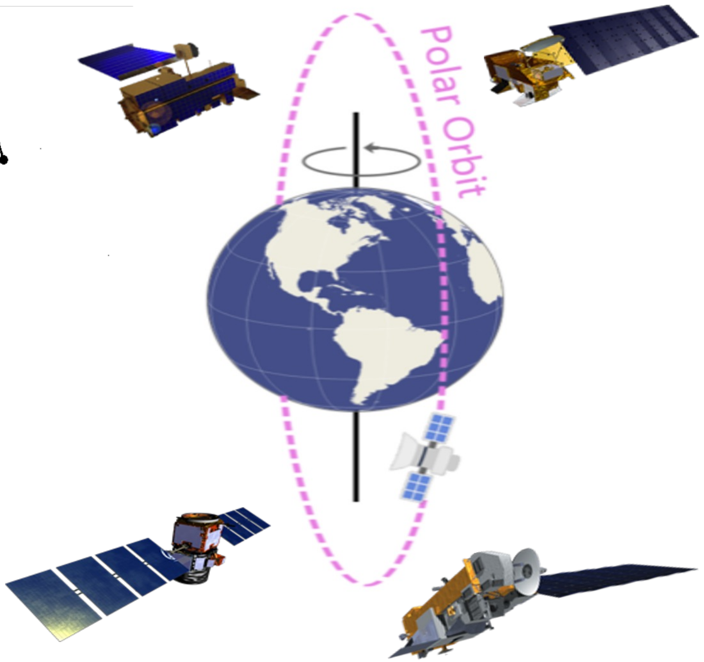
Ground-based monitors

Sensor networks

Models – statistical and physical

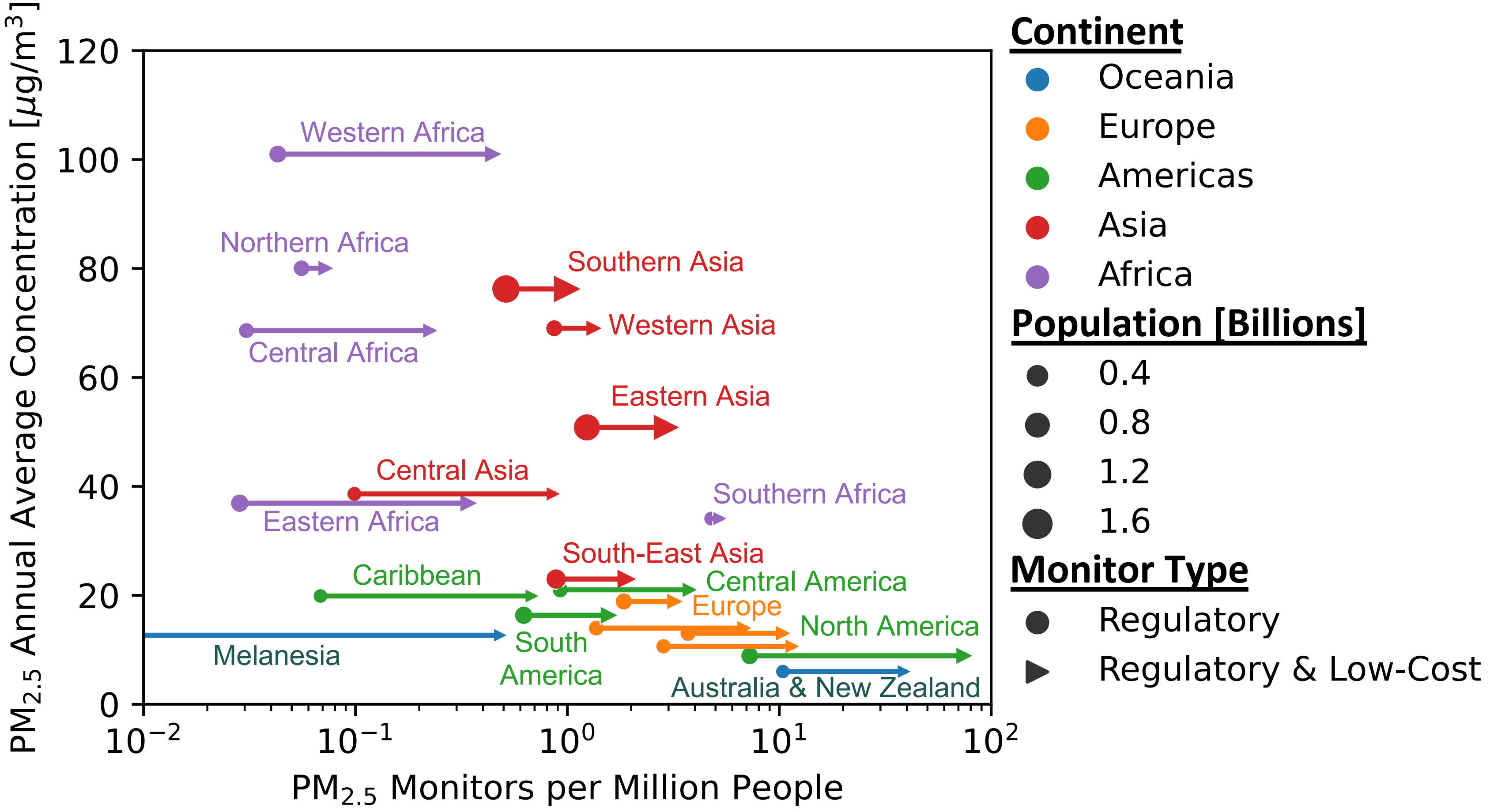


Satellite remote sensing



The Global Air Quality Data Gap

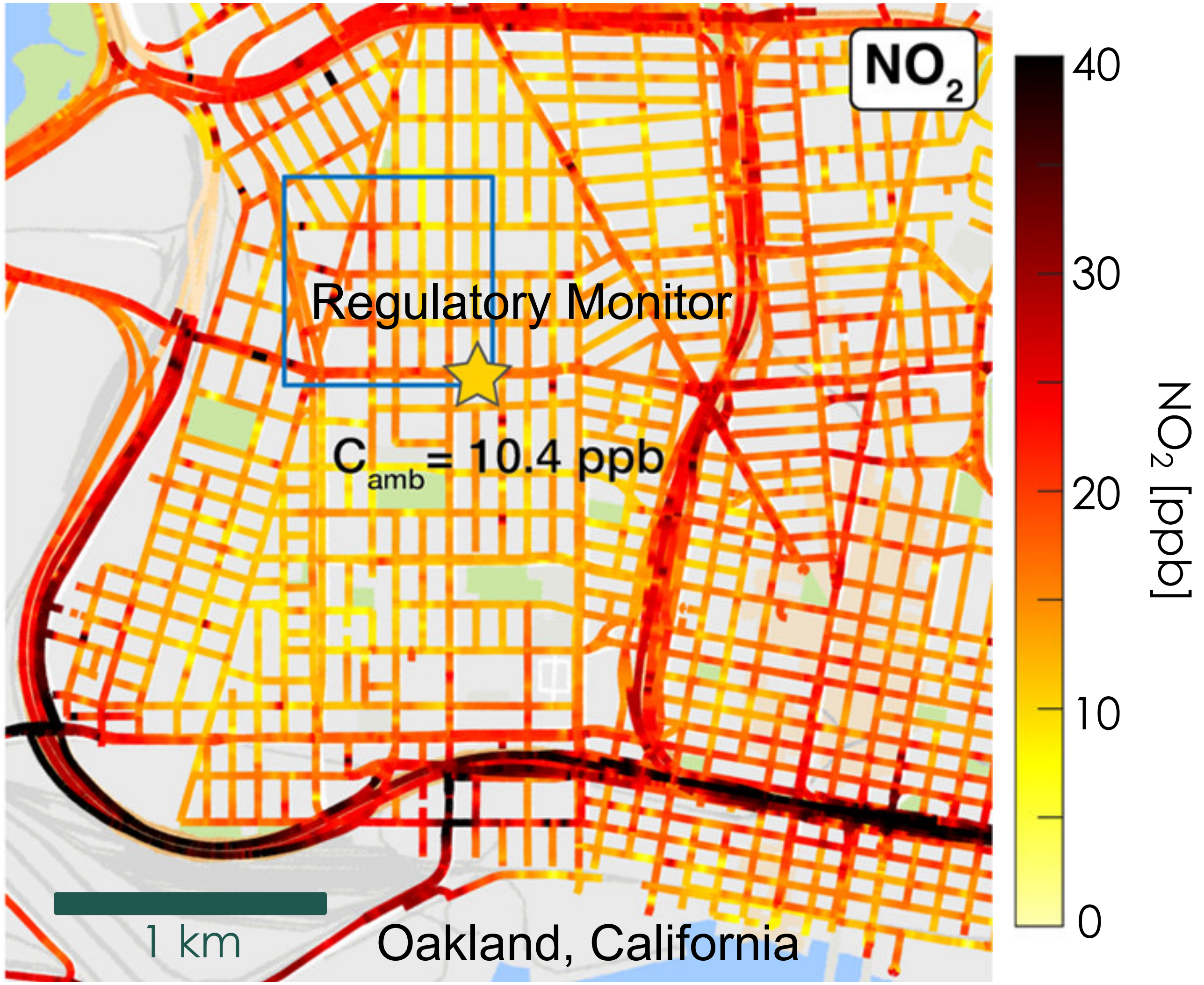
- Most regions have **fewer than 10 regulatory air quality monitors per million people** for $PM_{2.5}$ (and generally fewer for other pollutants).
- Densities vary greatly regionally; regions with higher concentrations tend to be less well monitored.
- Low-cost sensors increase monitor density by up to ten times in some regions.
- This may still be insufficient in areas with highly variable pollution.



Source: Malings et al. (2022) Forecasting with the GEOS-CF System and Other NASA Resources to Support Air Quality Management. *Proceedings of the International Conference on Air Quality in Africa*.

Local Data Gaps and Spatial Variability

- Only about a third of US counties have regulatory air quality monitors.
- Only 60% of census urban areas have regulatory air quality monitors.
- Pollutants may vary on small spatial scales due to their sources and atmospheric lifetimes.
- Pollutants with longer lifetimes will be more spatially uniform and temporally consistent.



Sources: [Do you have outdoor air monitoring data for all counties in the U.S.?](#) *US Environmental Protection Agency*.
Apte et al. (2017) [High-Resolution Air Pollution Mapping with Google Street View Cars: Exploiting Big Data](#). *Env. Sci. & Tech*.

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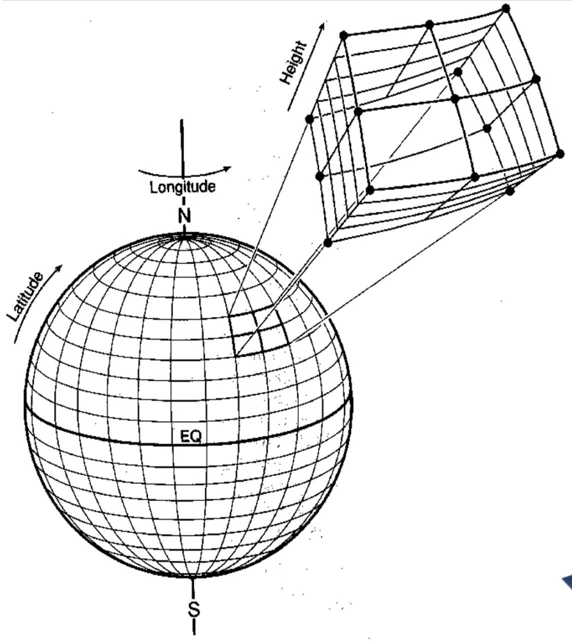
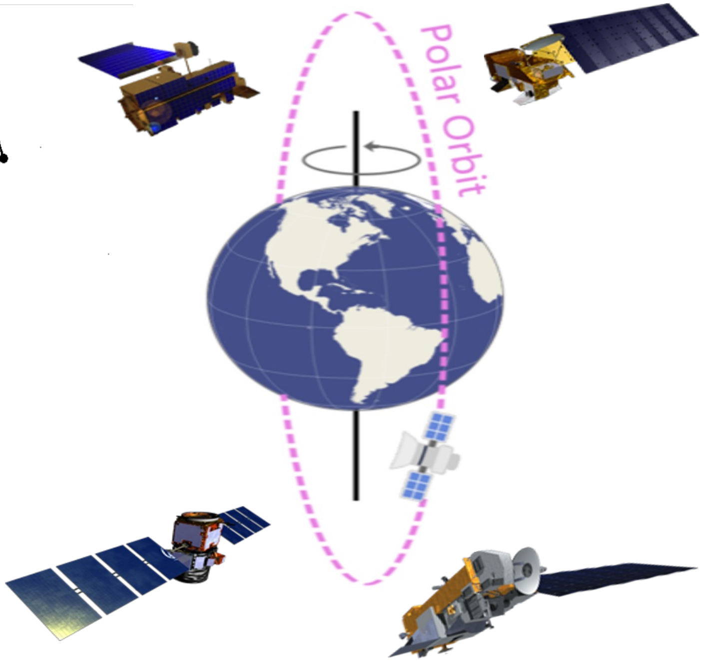
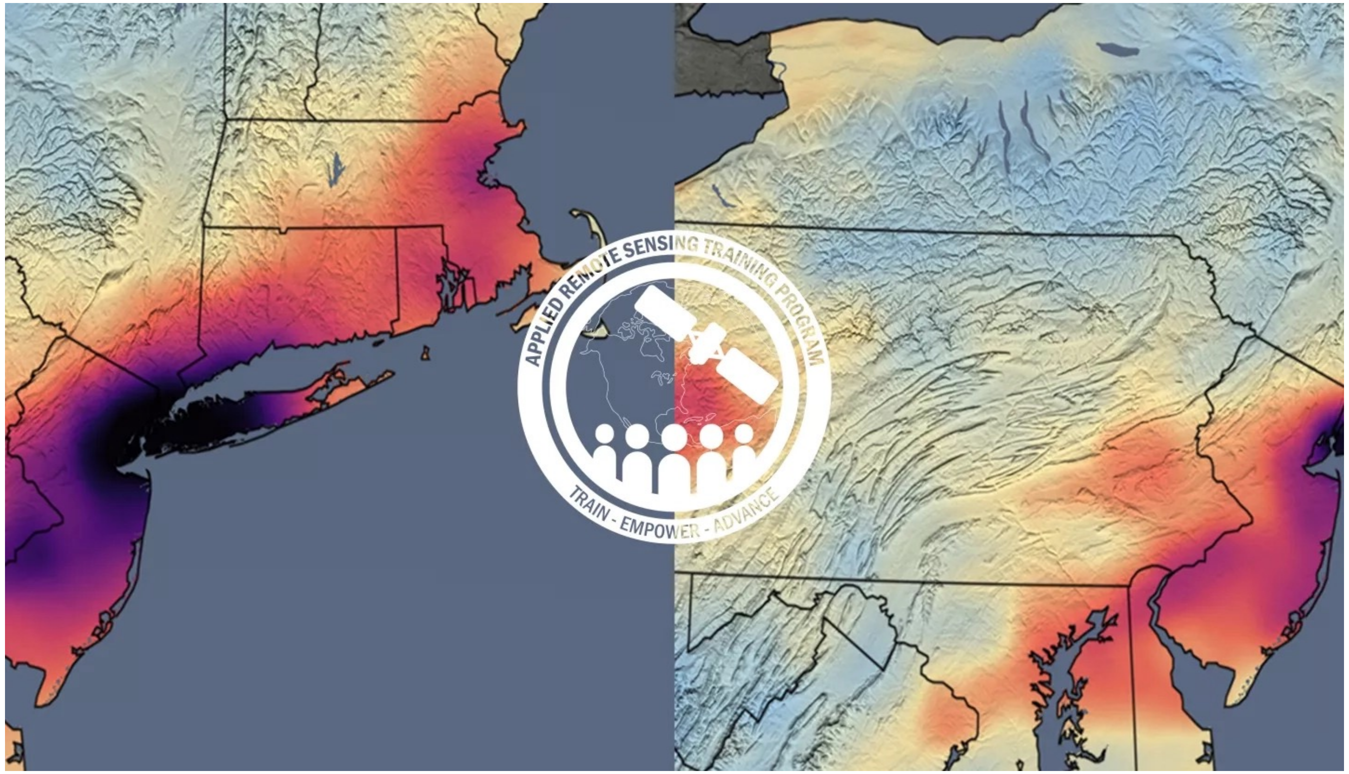


Satellite remote sensing



Basics of Air Quality Remote Sensing

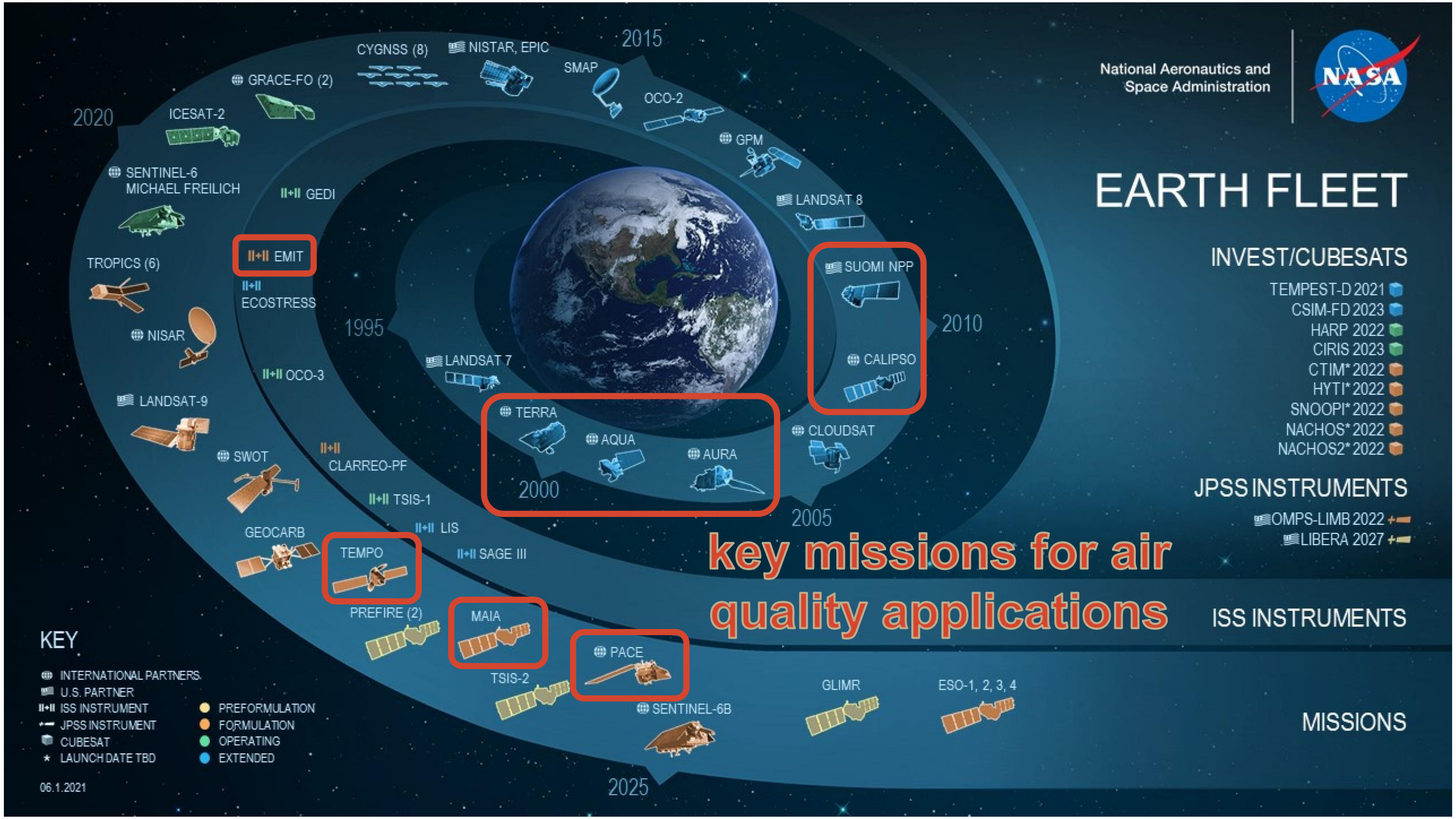
Relevant Prior ARSET Introductory Training



- [ARSET - An Inside Look at How NASA Measures Air Pollution]
- [ARSET - Un Vistazo a Cómo la NASA Mide la Contaminación del Aire]

The NASA Earth Observing Fleet

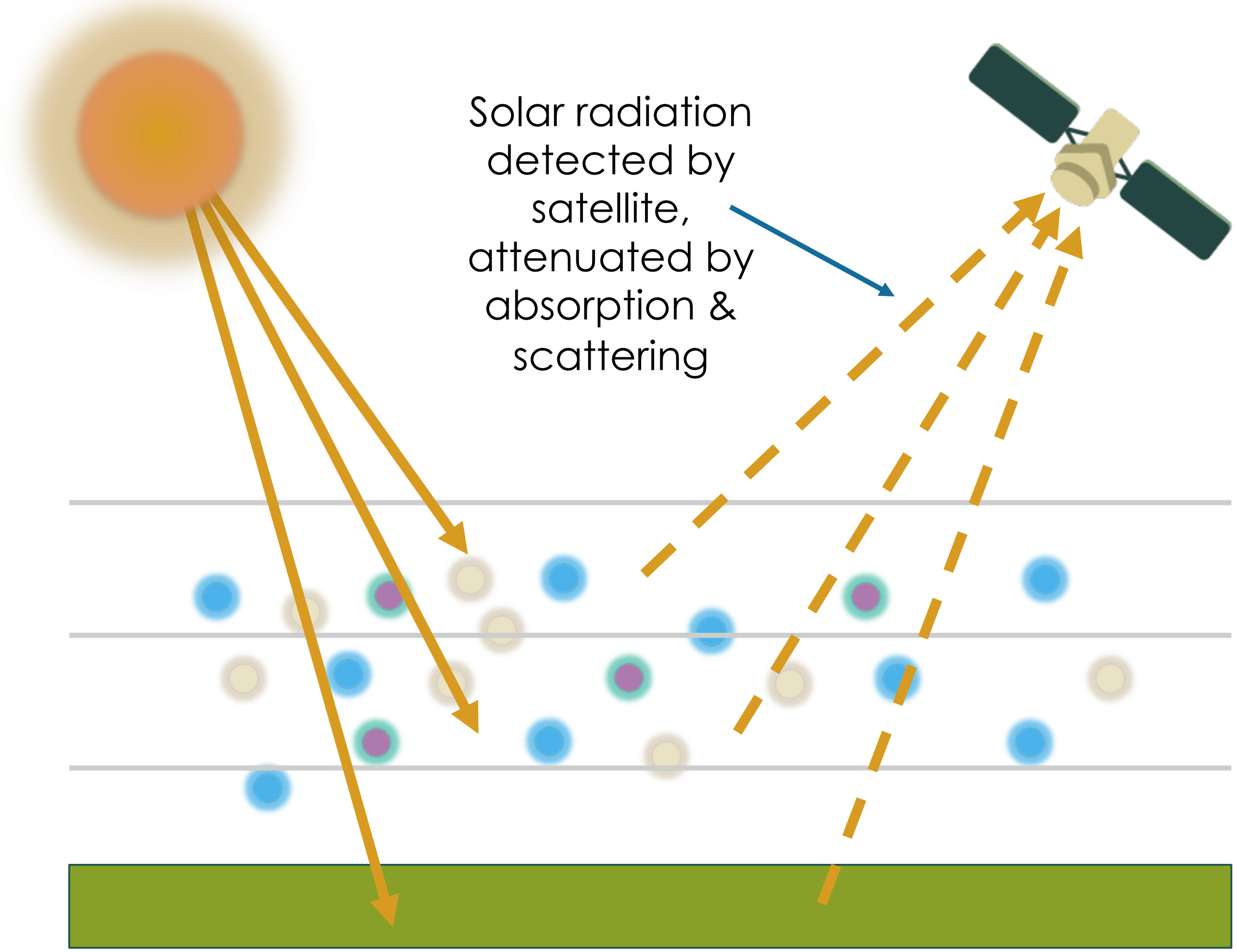
- NASA (and other space agencies) operate **Earth observation satellites.**
- These satellites provide remotely sensed retrievals of **geophysical quantities.**
- These can be interpreted, with the aid of physical and atmospheric chemistry models, to inform us about surface air quality.



Source: NASA Earth Science

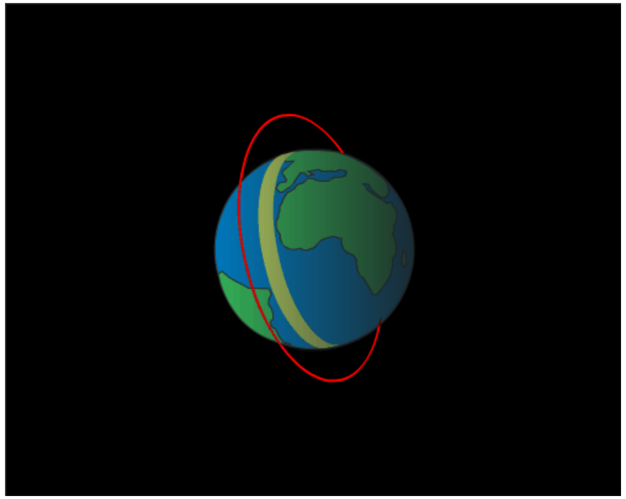
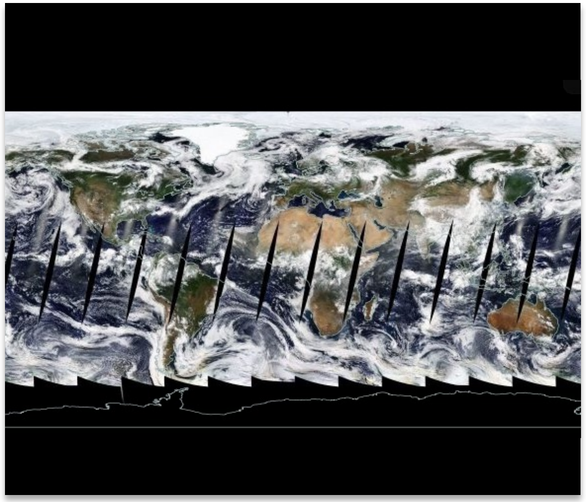
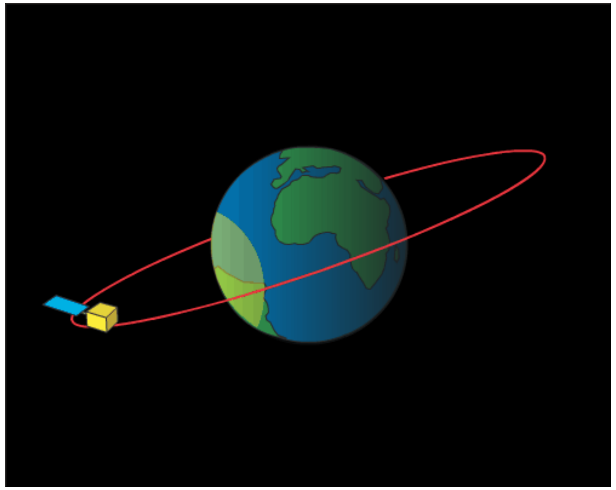
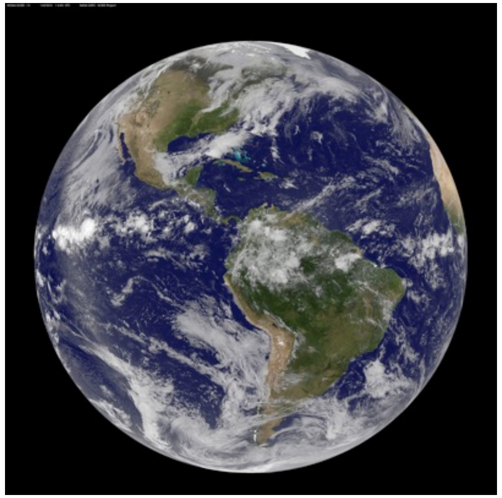
Principles of Remote Sensing for Air Quality

- Satellites measure backscattered **UV**, **visible**, and **IR** radiation from the Earth's surface and atmosphere.
- **Retrieval algorithms** use radiation measurements and physics-informed models to infer **geophysical quantities** such as optical depth, particle number density, or partial pressure.
- **Aerosol Optical Depth** for all aerosols in the atmosphere is calculated using the measured scattering and absorption of visible light at certain wavelengths.
- Unique "spectral fingerprints" for the radiation absorption of certain trace gases are used to retrieve the **trace gas total column density.**



Source: ARSET - Fundamentals of Remote Sensing. *NASA Applied Remote Sensing Training Program (ARSET).*

Typical Satellite Orbits

Polar Orbit (LEO)

- Sun synchronous orbit ~600-1,000 km above Earth passing close to the North and South poles with passes at **similar local solar time** each day
- Most instruments achieve **full global coverage** every 1-2 days.

Geostationary Orbit (GEO)

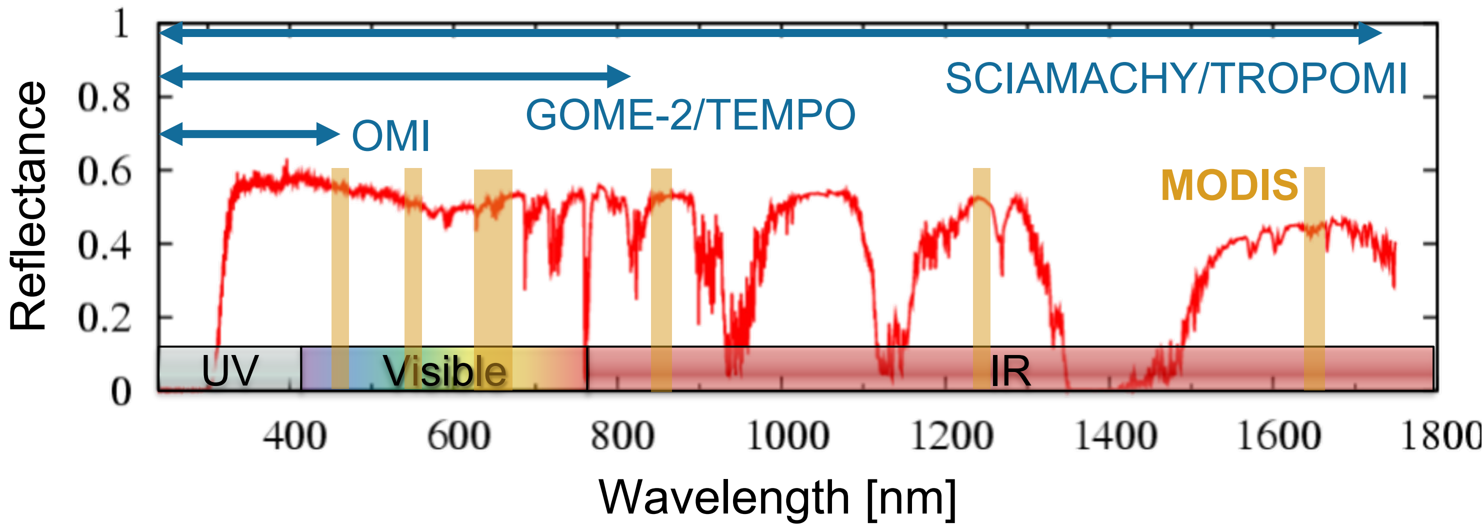
- Orbit ~36,000 km above the Equator with the same rotational period as Earth
- Appears 'fixed' above Earth, offering a **continuous daytime view** of its hemisphere or field of regard
- Always observes in the **same hemisphere**

Source: Gupta, P.; Follette-Cook, M.; Strode, S.; Malings, C. (2023). ARSET - NASA Air Quality-Focused Remote Sensing for EPA Applications. *NASA Applied Remote Sensing Training Program (ARSET).*

Multispectral and Hyperspectral Instruments

- **Multispectral instruments** have larger spectral band widths.
- Coarser spectral resolution is suitable for detecting certain prominent atmospheric features.
- **Aerosol optical depth** at ~550nm wavelength is generally well suited for measuring ambient particulate matter.
- **Hyperspectral instruments** have smaller spectral band widths.
- This higher spectral resolution is necessary for distinguishing the absorption spectra of different **trace gases.**

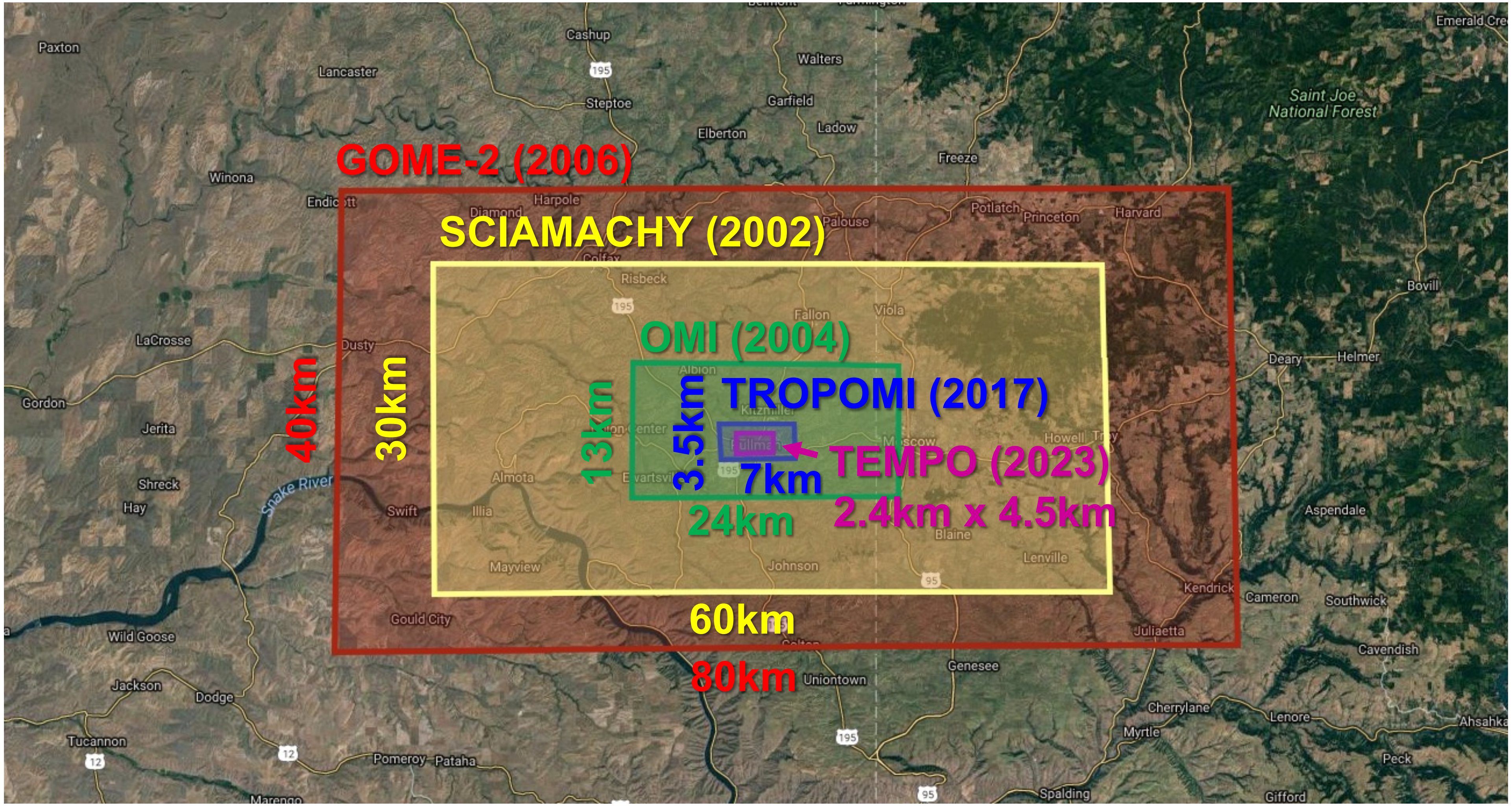
Hyperspectral band width: ~0.5 nm (TROPOMI)



Multispectral band width: 10-50 nm (MODIS)

Source: Gupta, P.; Follette-Cook, M.; Strode, S.; Malings, C. (2023). [ARSET - NASA Air Quality-Focused Remote Sensing for EPA Applications](). *NASA Applied Remote Sensing Training Program (ARSET).*

Spatial Resolution: Improvements Over Time



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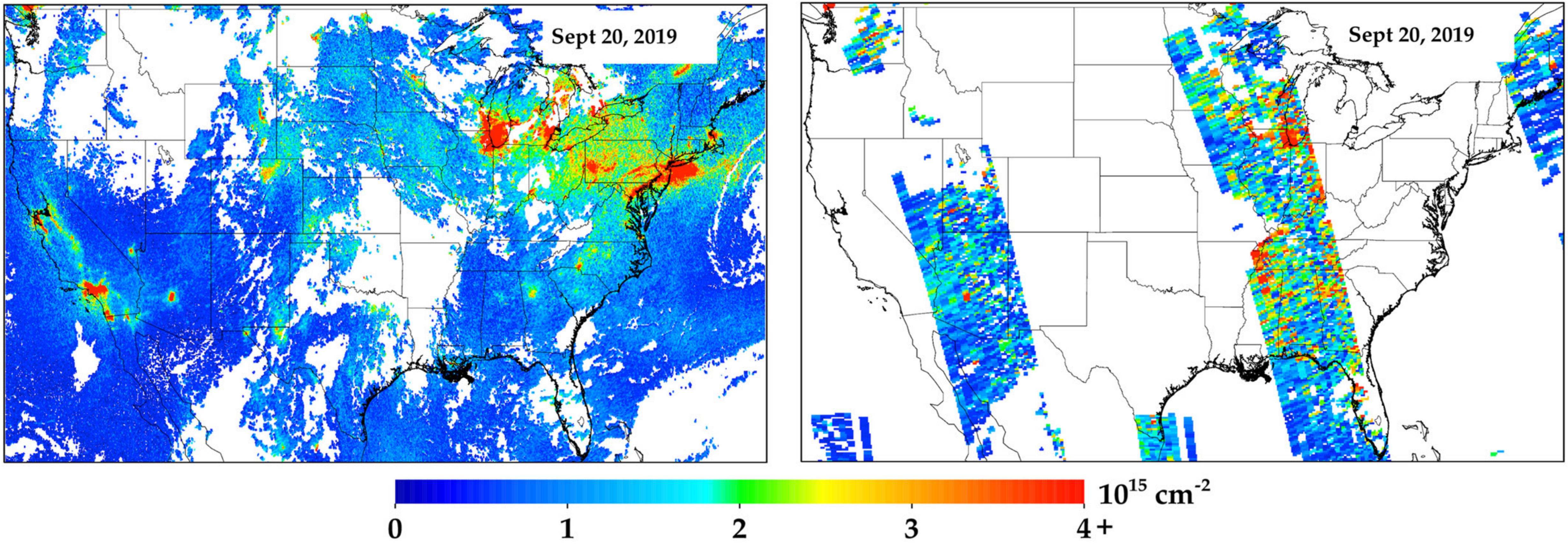
Spatial Resolution: Improvements Over Time

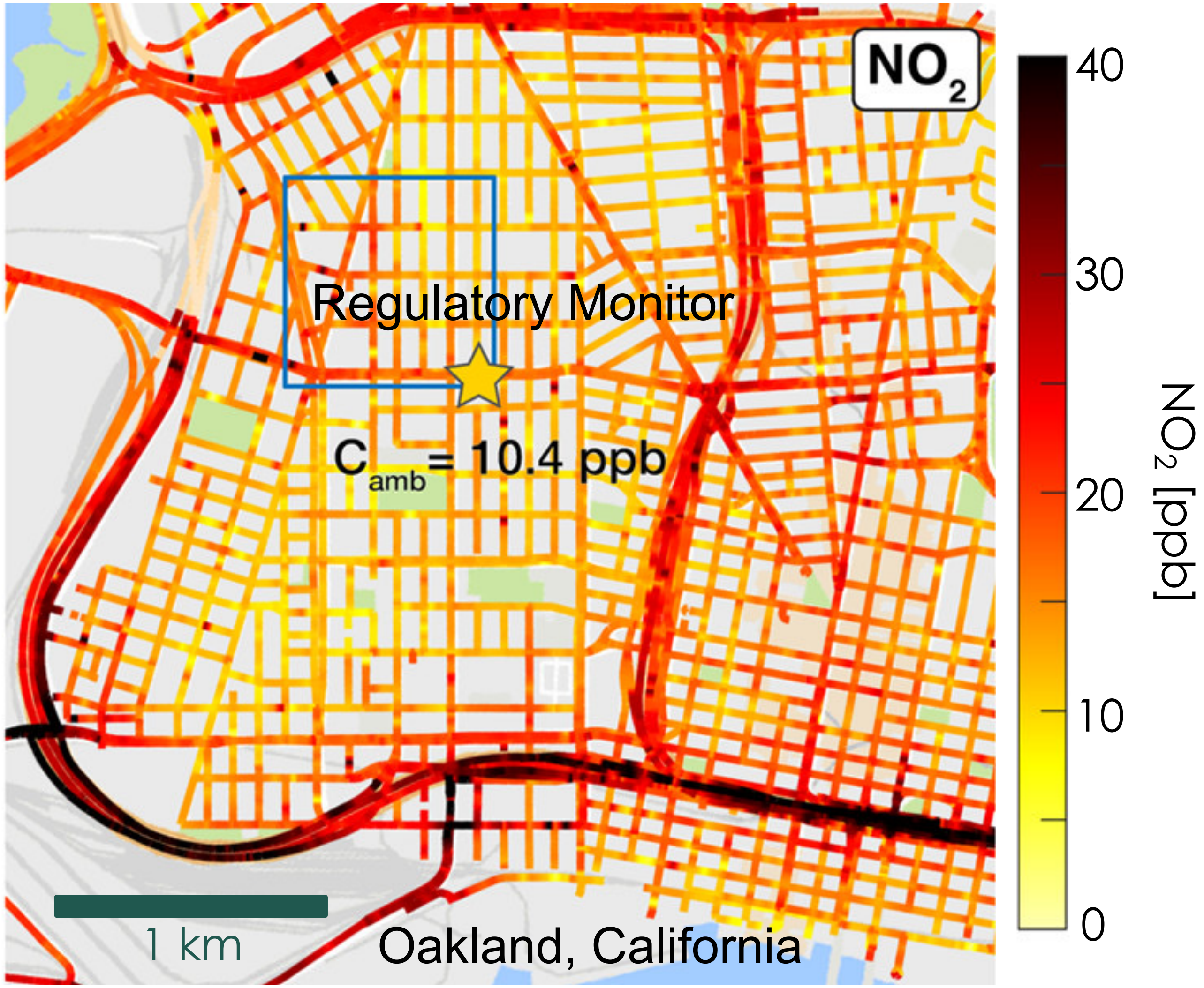
TROPOMI Tropospheric NO_2

OMI Tropospheric NO_2



Source: Goldberg, Anenberg, Kerr, Mohegh, Lu, Streets (2021) [TROPOMI NO_2 in the United States: A Detailed Look at the Annual Averages, Weekly Cycles, Effects of Temperature, and Correlation With Surface NO_2 Concentrations]. *Earth's Future*.

Spatial Resolution: Room for Improvement Remains



Source: Apte et al. (2017) [High-Resolution Air Pollution Mapping with Google Street View Cars: Exploiting Big Data](). *Env. Sci. & Tech.*

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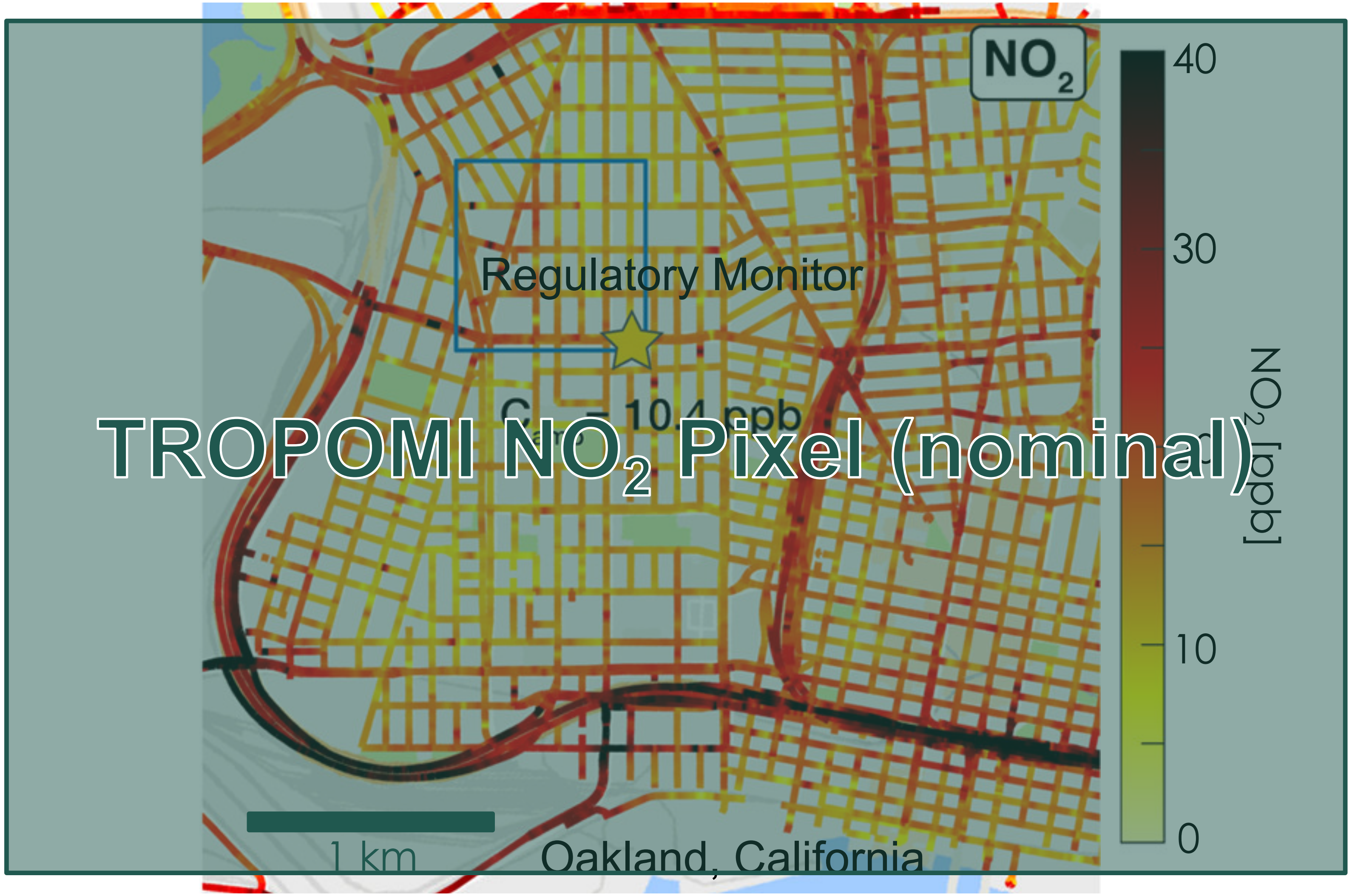

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Spatial Resolution: Room for Improvement Remains

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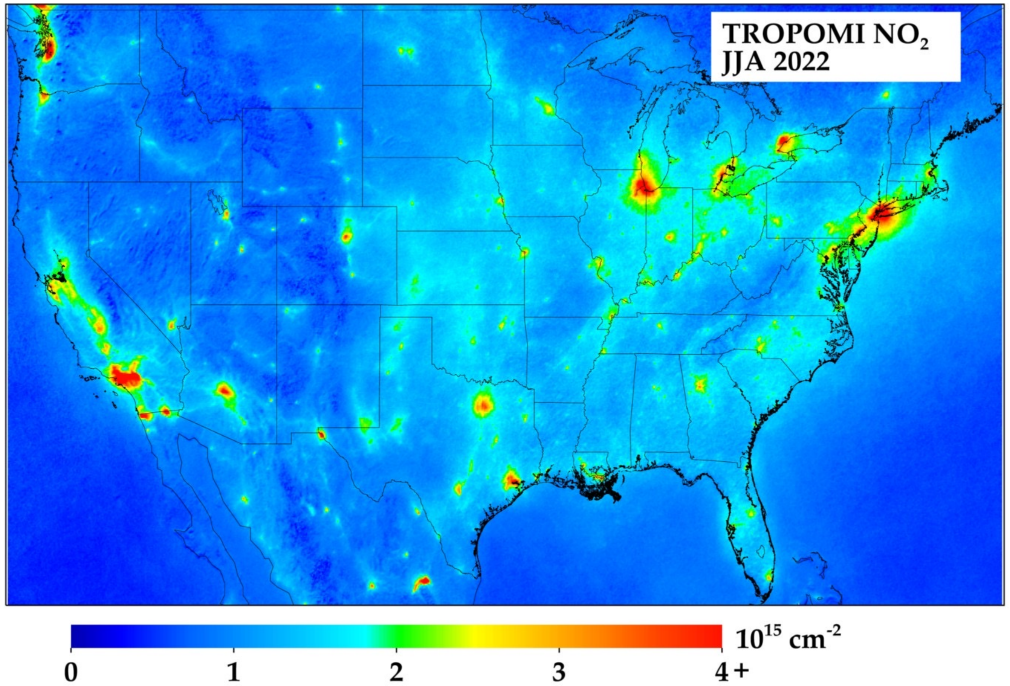
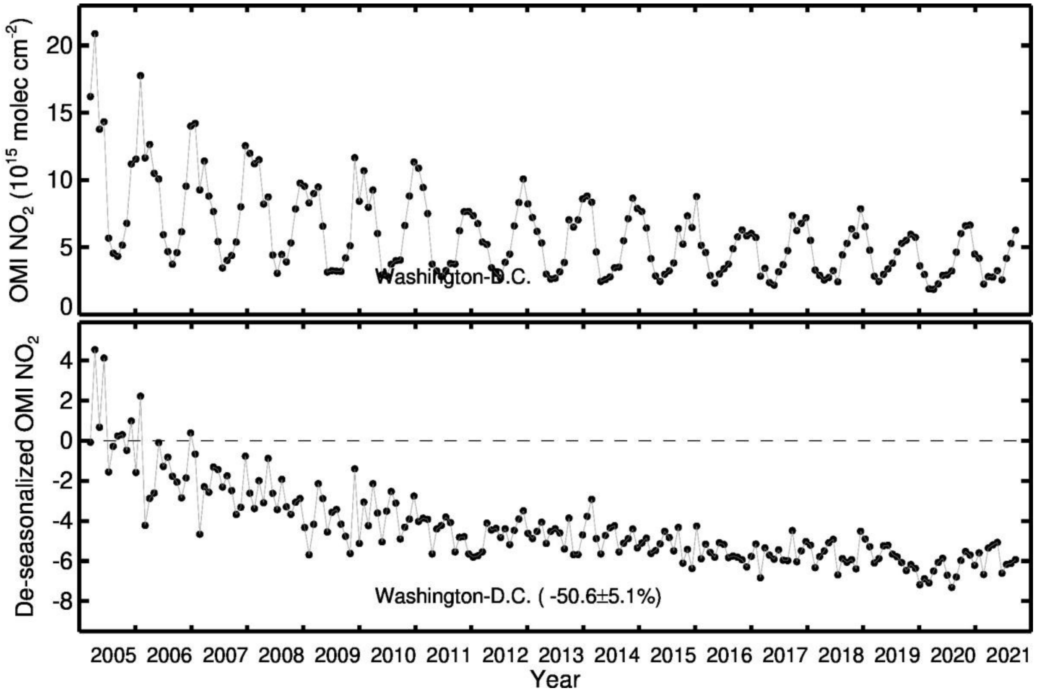
Advantages of Satellites for Air Quality Applications

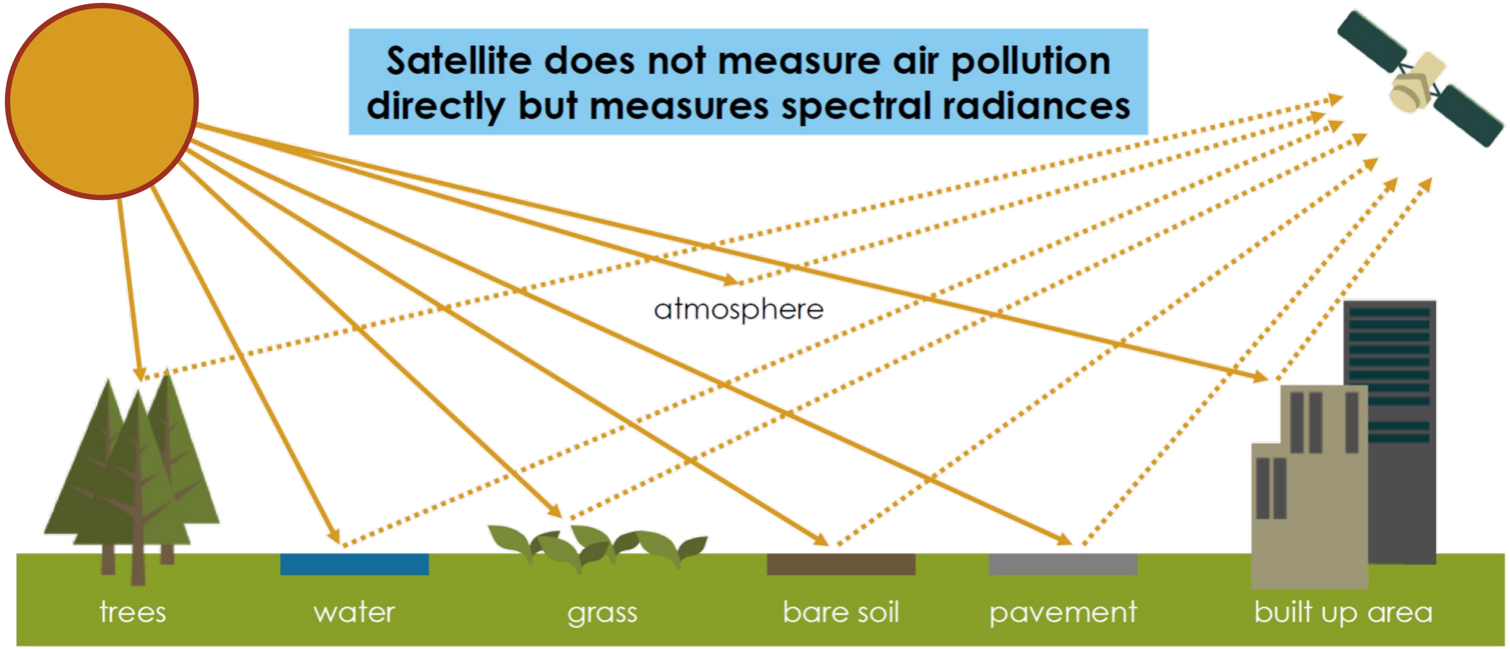


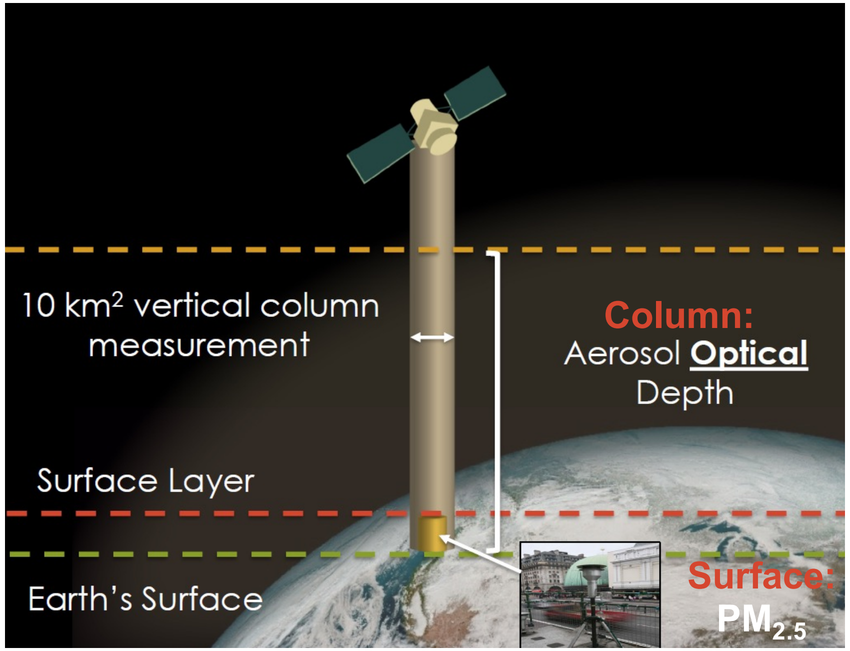


- **Examine a large area with one instrument**: spatial variability, hotspots, transport
- **Track changes over time**: instruments with longer data records can quantify trends, including changes due to policy interventions.
- **Improving spatial resolution**: modern instruments can distinguish intra-urban variations & major point sources, but not yet "block-scale" variability.

Sources: tropomino2.us. *The George Washington University Milken Institute School of Public Health*. (left)
NASA GSFC Nitrogen Dioxide Trends for World Cities (right)

Limitations of Satellites for Air Quality Applications





- **Night:** most satellite instruments require sunlight to make their retrievals.
- **Clouds & Smoke:** most instruments are blocked by clouds and dense smoke.
- **"Nose Level":** most measure the whole atmosphere, not just the surface.
- **Overpass Time**: polar-orbiting satellites observe a location about once per day at similar local times (geostationary satellites can observe throughout daytime).

Source: Gupta, P.; Follette-Cook, M. (2018). Satellite Remote Sensing of Air Quality. *NASA Applied Remote Sensing Training Program (ARSET).*

I want to investigate how gaseous transportation-related air pollutants like NO_2 and CO might vary in different communities throughout the course of the day.

What kind of satellite instrument should I be looking for?

A: Geostationary Multispectral Instrument

B: Geostationary Hyperspectral Instrument

C: Polar-Orbiting Multispectral Instrument

D: Polar-Orbiting Hyperspectral Instrument

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Satellite Data Processing Levels

- **Level 0:** Raw data
- **Level 1:** Geo-referenced raw data
- **Level 2:** Derived geophysical variables (e.g., column concentrations)
- **Level 3:** Data re-mapped to uniform space & time grids (usually with recommended quality controls)
- **Level 4:** Data from multiple sources combined together (e.g., satellite & model)

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Source: [Data Processing Levels](). *NASA EarthData.*

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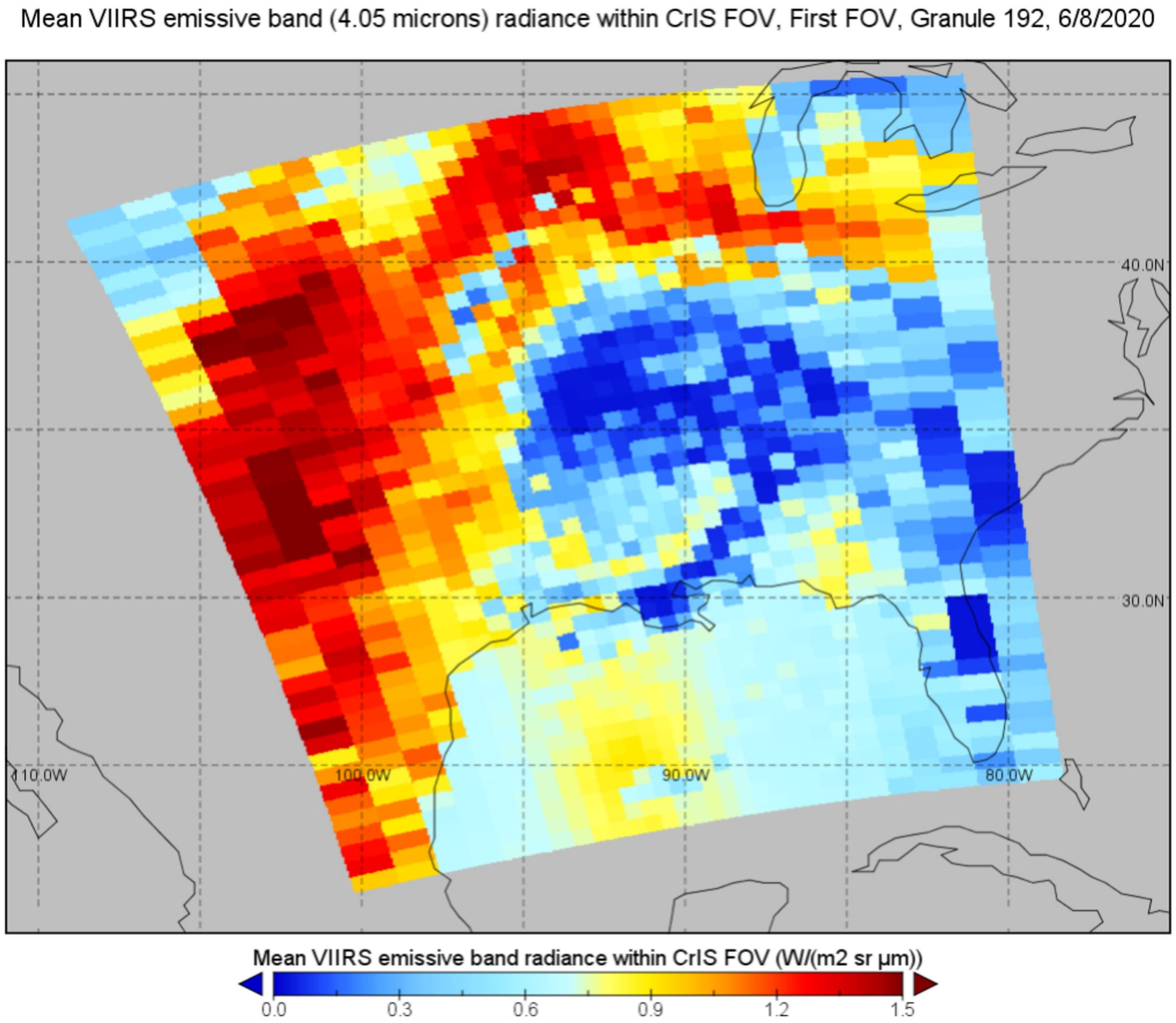

Sources: Data Processing Levels. *NASA EarthData*.
S-NPP CrIS IMG: Collocated VIIRS level 1 / cloud mask statistical summary V2. *NASA GES DISC*.

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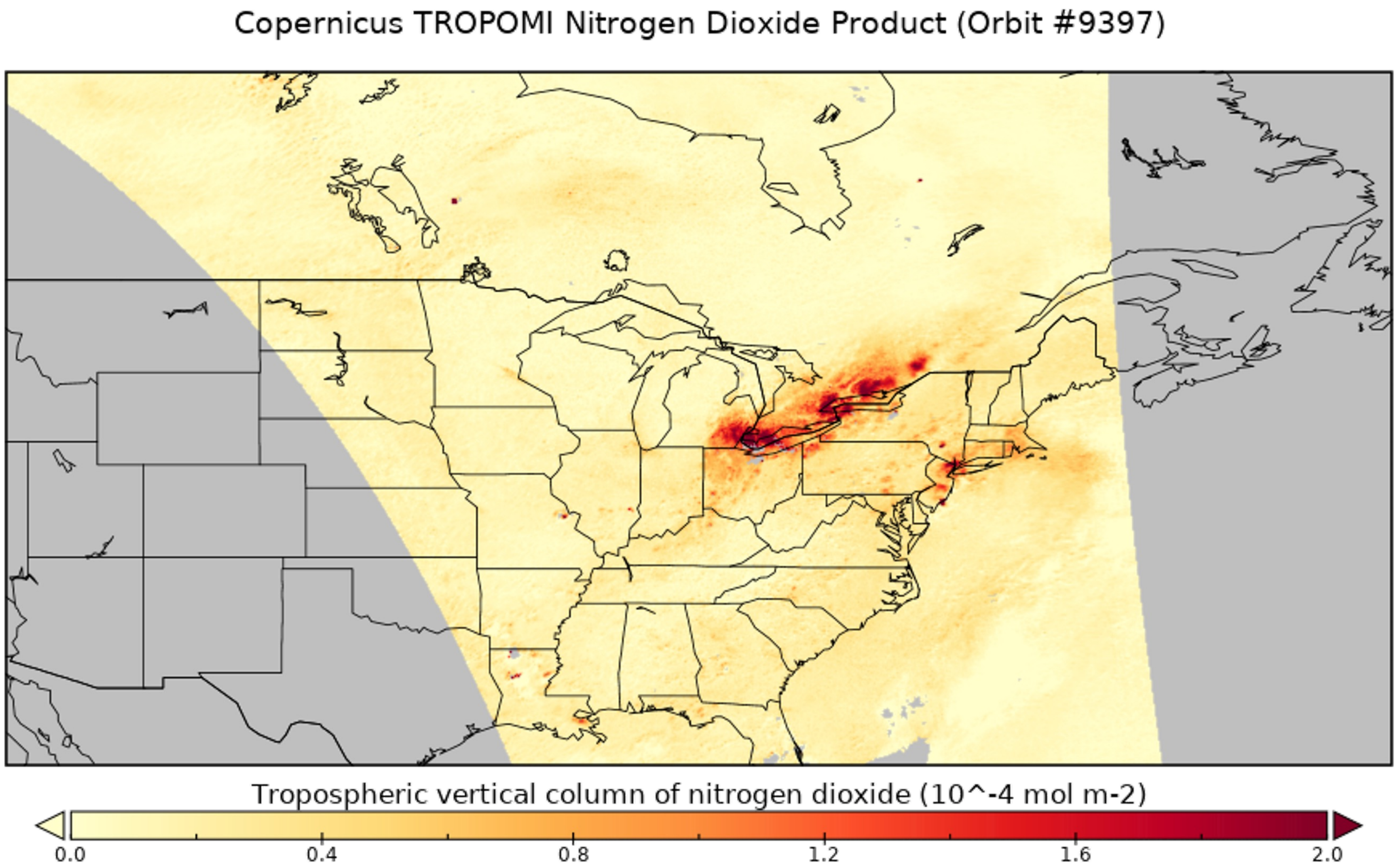

Sources: [Data Processing Levels](). *NASA EarthData*.
[Sentinel-5P TROPOMI Tropospheric NO2 1-Orbit L2 5.5km x 3.5km](). *NASA GES DISC*.

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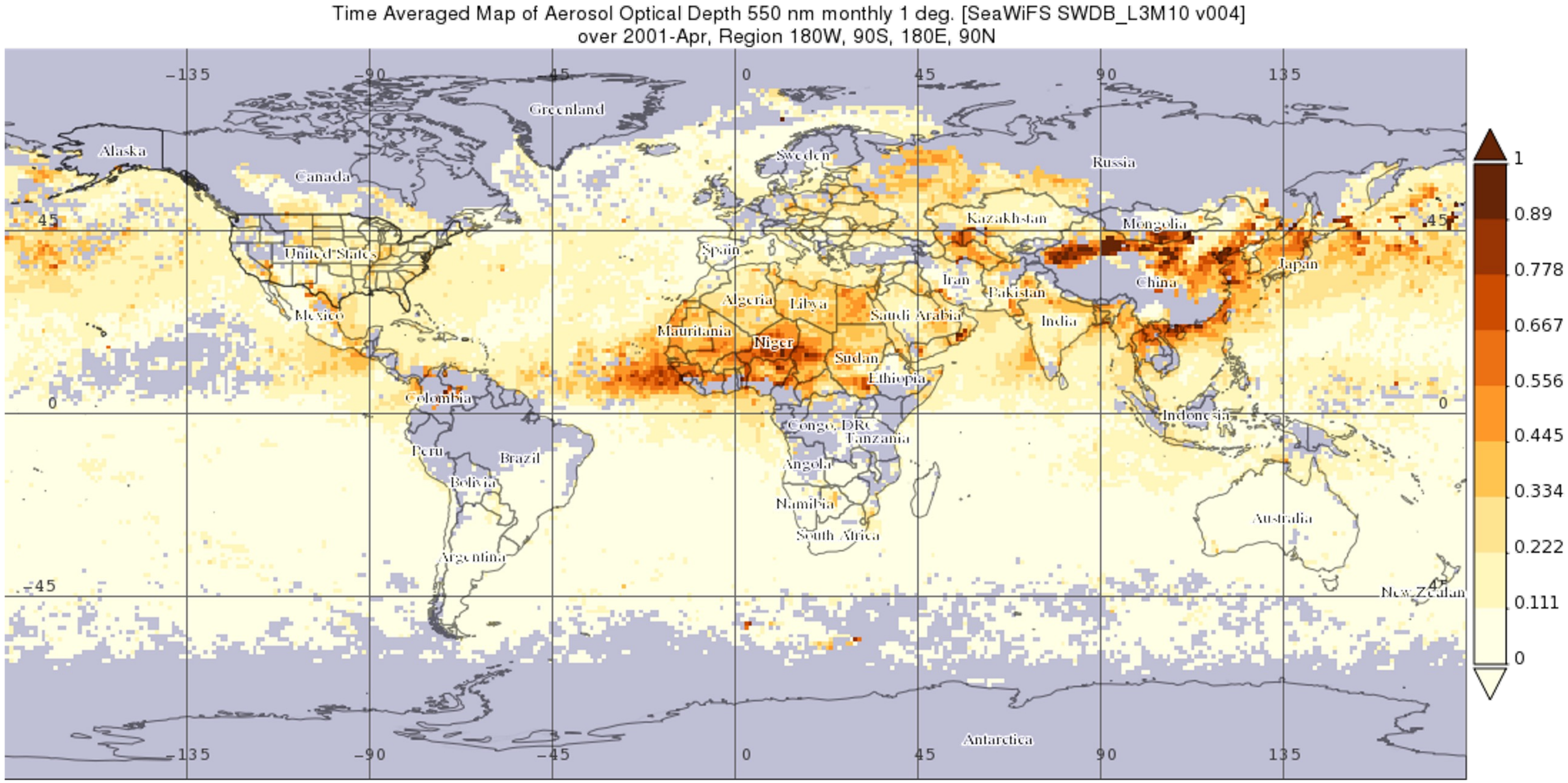

Sources: Data Processing Levels. *NASA EarthData*.
SeaWiFS Deep Blue Aerosol Optical Depth and Angstrom Exponent Monthly Level 3 Data. *NASA GES DISC*.

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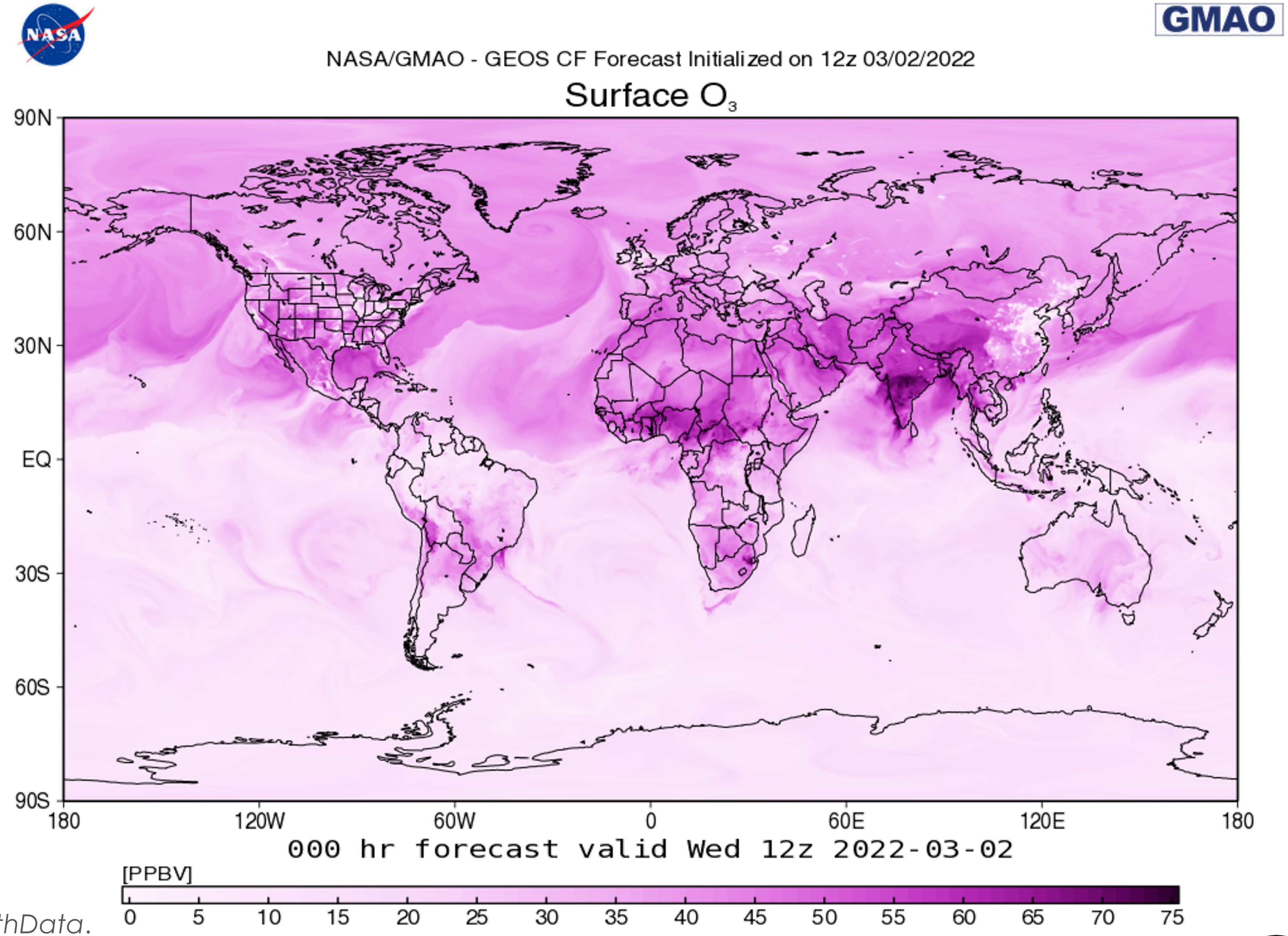


Sources: [Data Processing Levels](). *NASA EarthData*.
[FLUID visualization page for GEOS-CF surface Ozone forecast](). *NASA GMAO*.

Satellite Air Quality Data Products for EJ

Relevant Prior ARSET Advanced Training

- ARSET - MODIS to VIIRS Transition for Air Quality Applications

MODIS and VIIRS

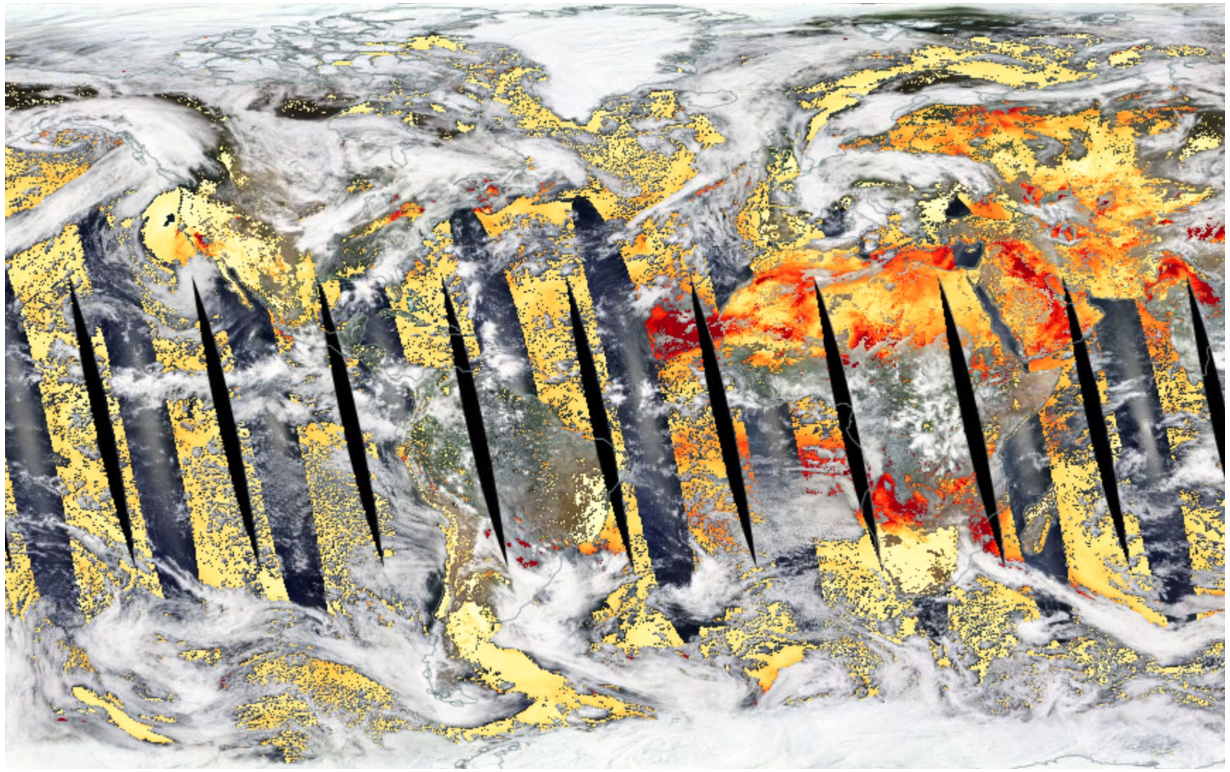
MODIS		VIIRS
Aqua, Terra	Satellites	SNPP, NOAA-20, NOAA-21
1999, 2002	Launched	2011, 2017, 2022
Moderate Resolution Imaging Spectroradiometer	Instrument	Visible Infrared Imaging Radiometer Suite
405 - 14385 nm (IR, Visible)	Spectral Range	412 - 12100 nm (IR, Visible)
36	Spectral Bands	22
0.5 – 2 km pixel edge	Spatial Resolution	0.75 – 1.5 km pixel edge
1-2 Days	Global Coverage	Daily
~ 10:30, 13:30 LST	Local Overpass Time	~ 12:30, 13:30 LST

MODIS and VIIRS: Air Quality Data Products

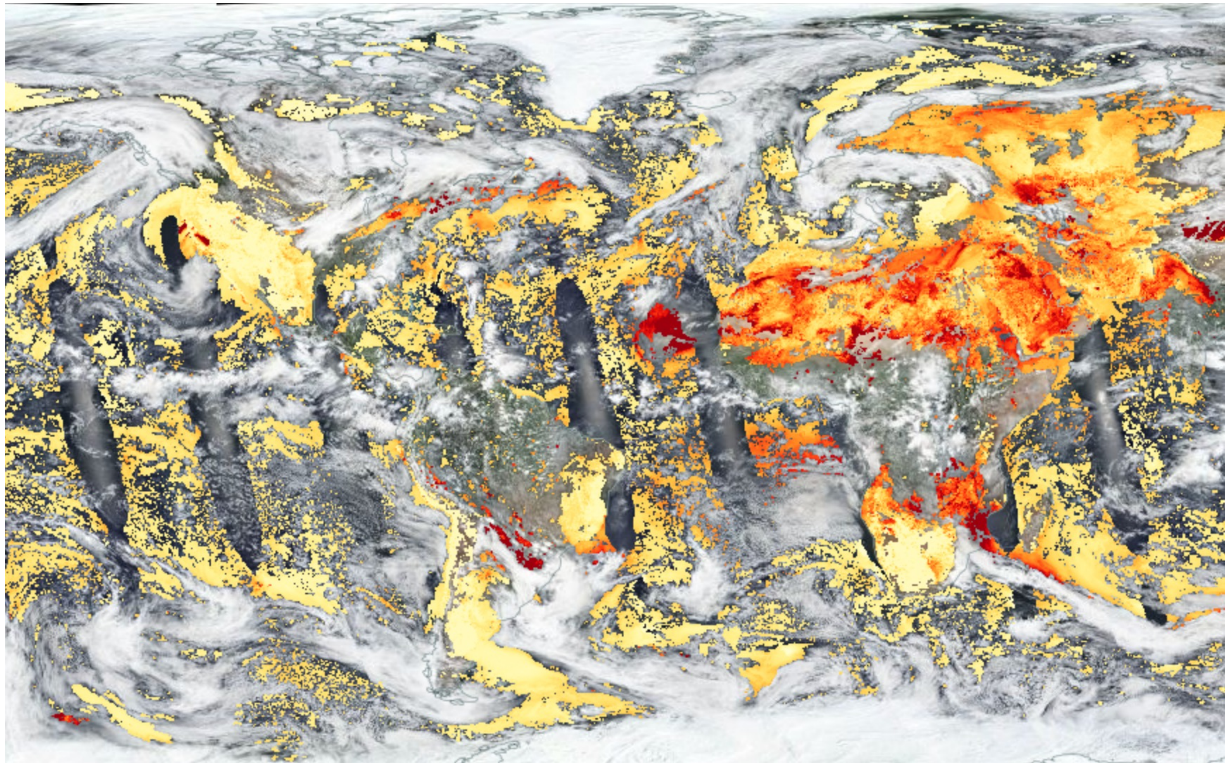
MODIS		VIIRS	
True Color Image	-	True Color Image	-
Aerosol Optical Depth	MOD/MYD04_L2 (10km) MOD/MYD04_3K (3km) MCD19A2 (1km) Gridded (1°)	Aerosol Optical Depth	AERDB_L2_VIIRS (6km) AERDT_L2_VIIRS (6km) JRR-AOD (0.75km) Gridded (1°)
Fire Detection	MOD/MYD04A1 (1km)	Fire Detection	VNP12IMGTDL_NRT VJ114IMGTDL_NDT (0.375km)
		Smoke & Dust Detection	JRR-ADP (0.75km)

Aerosol Optical Depth

MODIS-Aqua



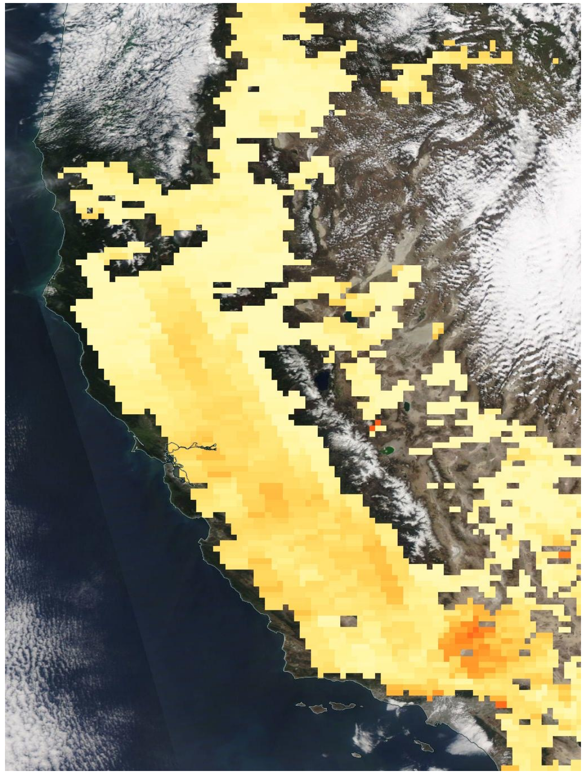
VIIRS-SNPP



Source: [NASA Worldview]

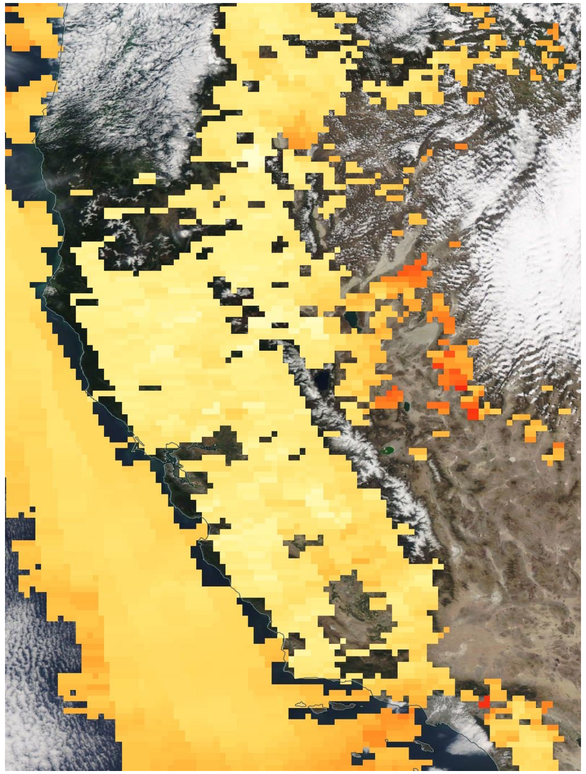
Aerosol Optical Depth Retrieval Algorithms

Deep Blue (10km)
MOD/MYD04_L2



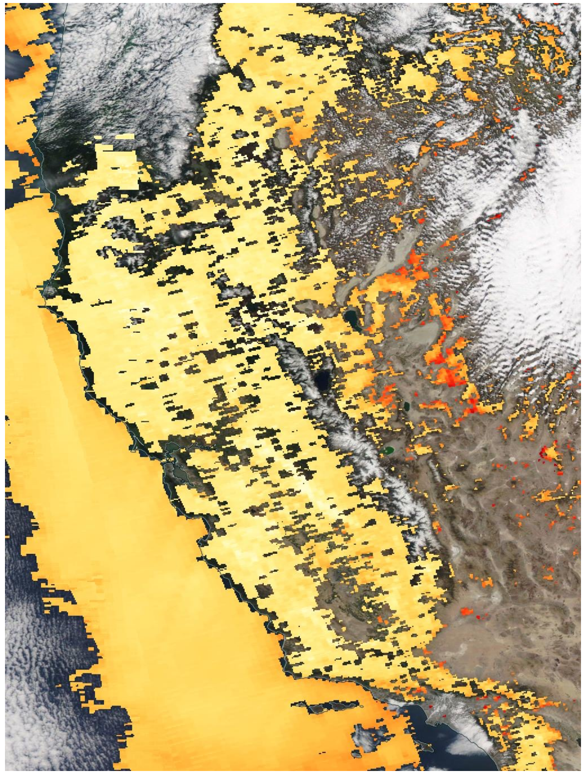
Land only,
best for bright surfaces

Dark Target (10km)
MOD/MYD04_L2



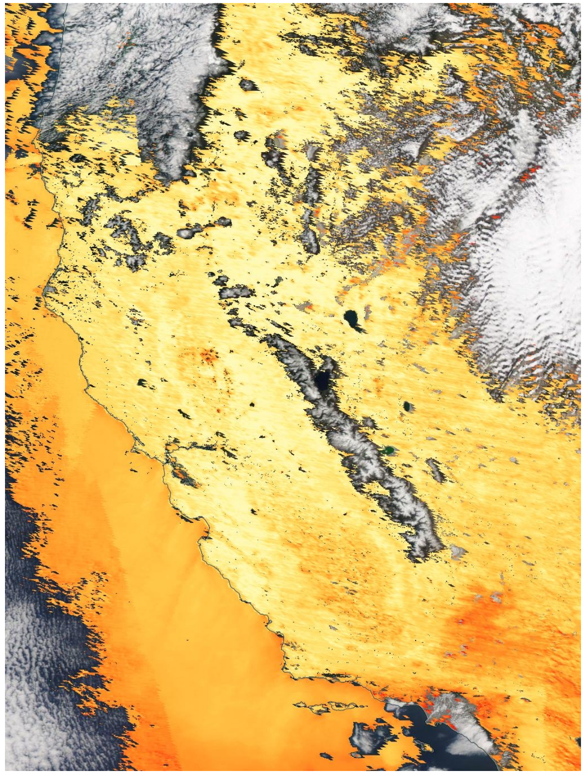
Land & water,
best for dark surfaces

Dark Target (3km)
MOD/MYD04_3K



Higher resolution,
issues in urban areas

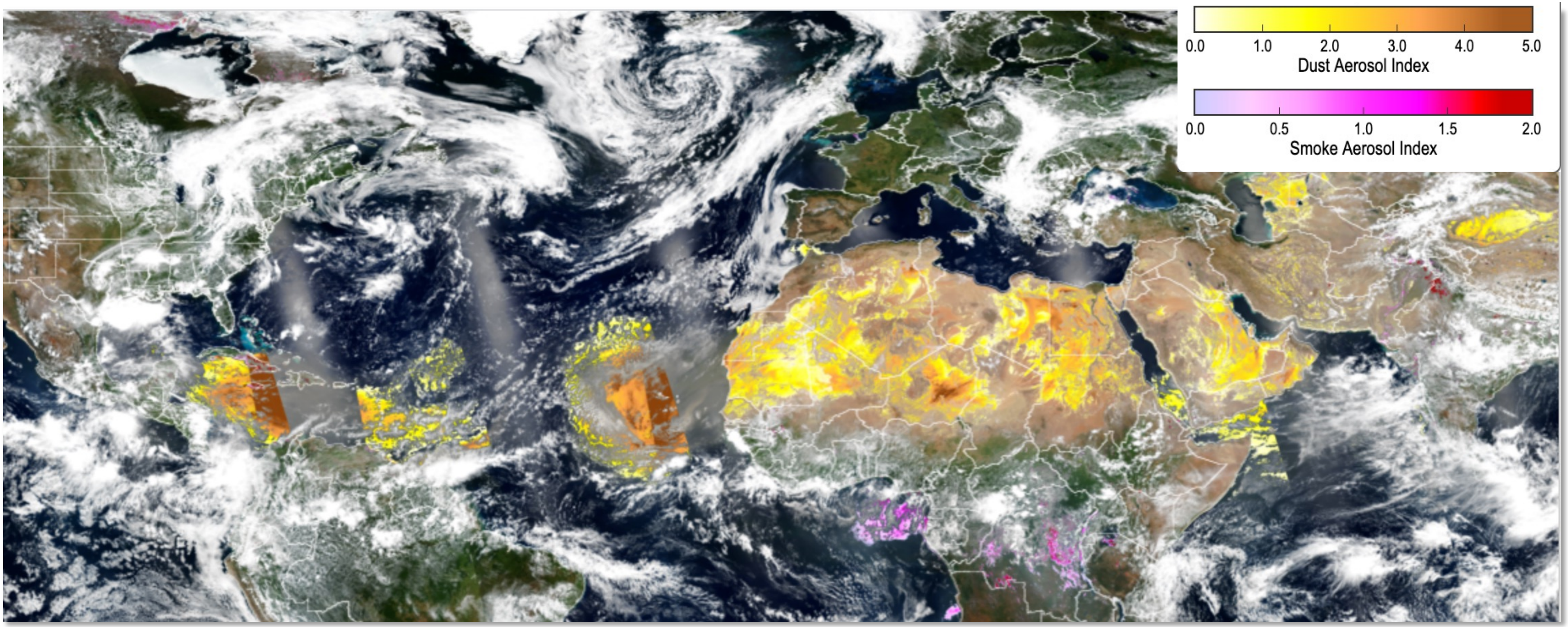
MAIAC (1km)
MCD19A2



Highest resolution,
combine Aqua & Terra

Source: [NASA Worldview]

VIIRS Smoke and Dust Index

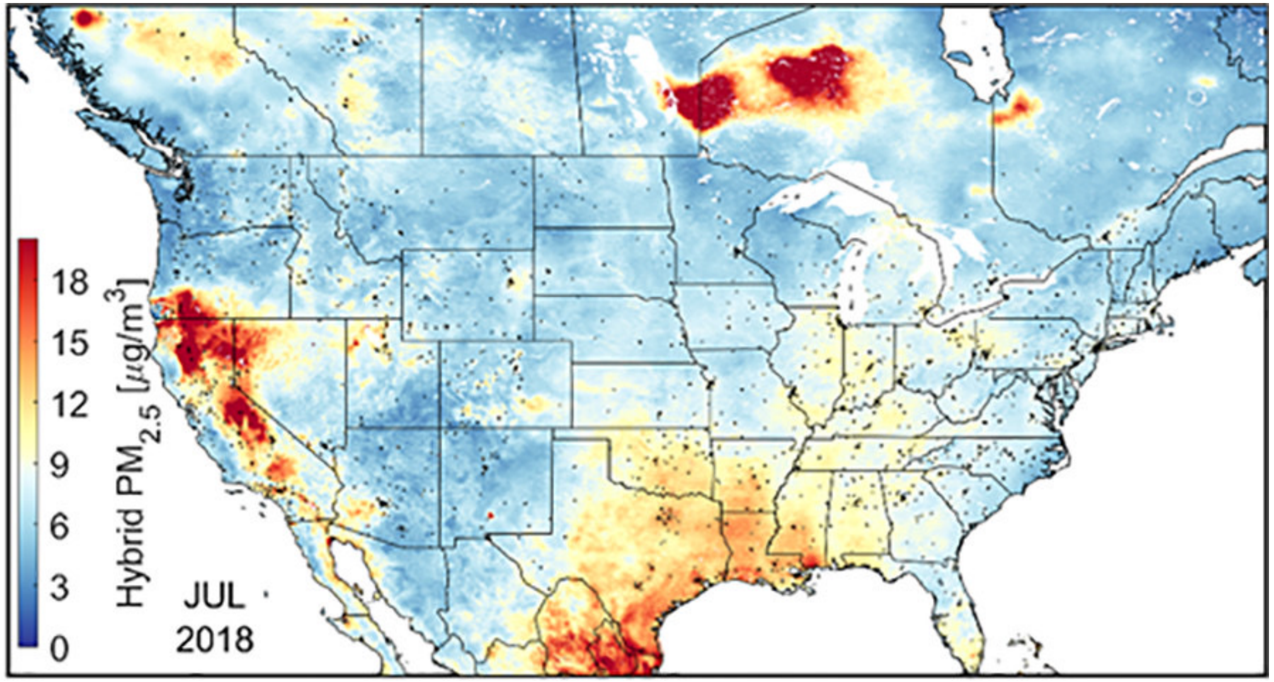


Source: [NOAA JSTAR Mapper]

Satellite-Derived Surface $PM_{2.5}$

- Examples of Level 4 products
- Combine satellite data with other information (models, surface monitors) to derive high spatial resolution maps of surface $PM_{2.5}$ (globally or locally)
- annual, monthly, and daily temporal resolution (with different approaches)
- 1km (or sometimes finer) spatial resolution
- May lag significantly behind real-time
- Many datasets available through [NASA Socioeconomic Data and Applications Center (SEDAC)]

Estimated surface $PM_{2.5}$ concentration
July 2018

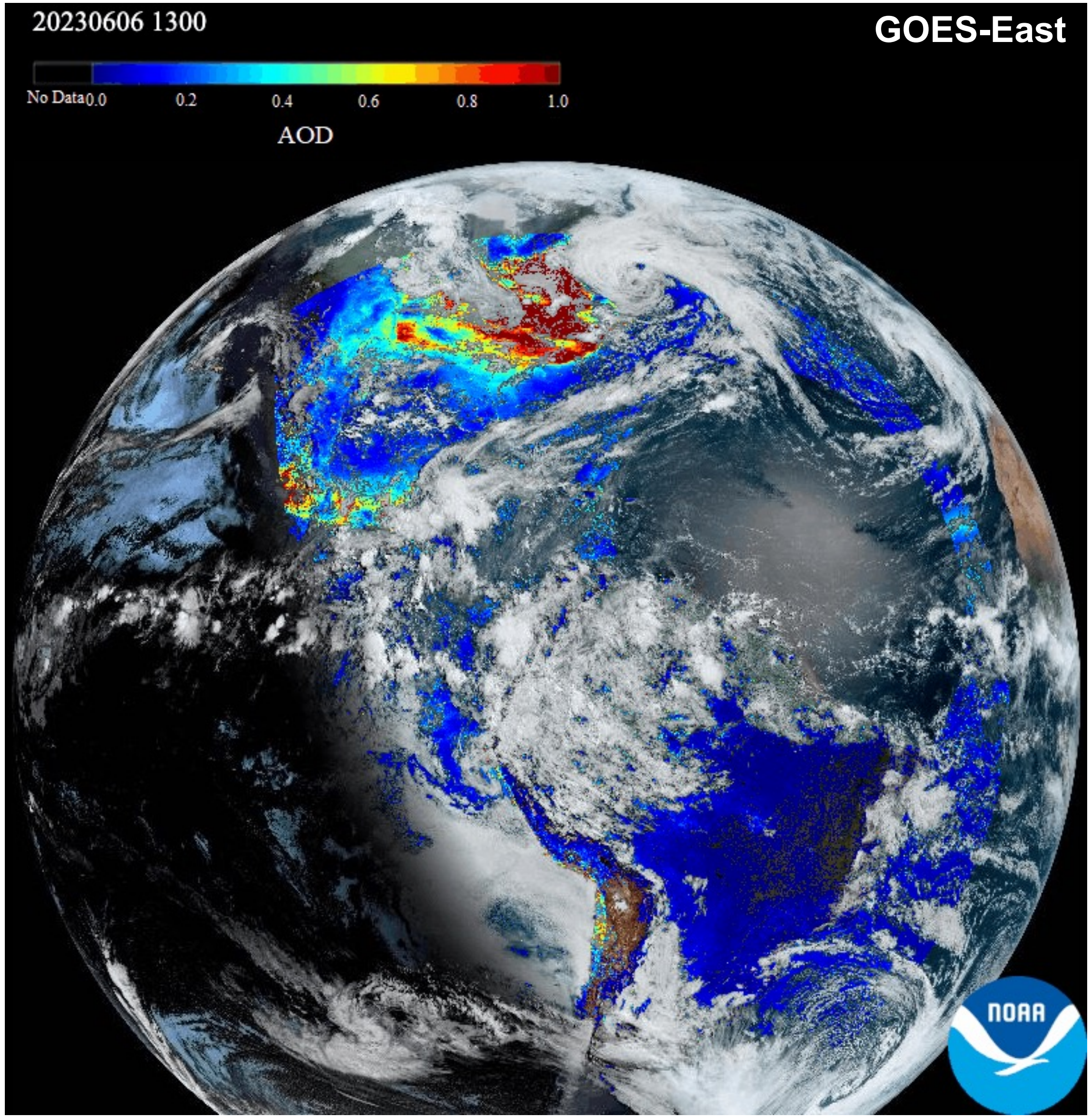


Van Donkelaar et al. (2021)

Sources: Di et al. (2019) An ensemble-based model of $PM_{2.5}$ concentration across the contiguous US … . *Environmental International*.
van Donkelaar et al. (2021) Monthly Global Estimates of Fine Particulate Matter and Their Uncertainty. *Env. Sci. & Tech*.

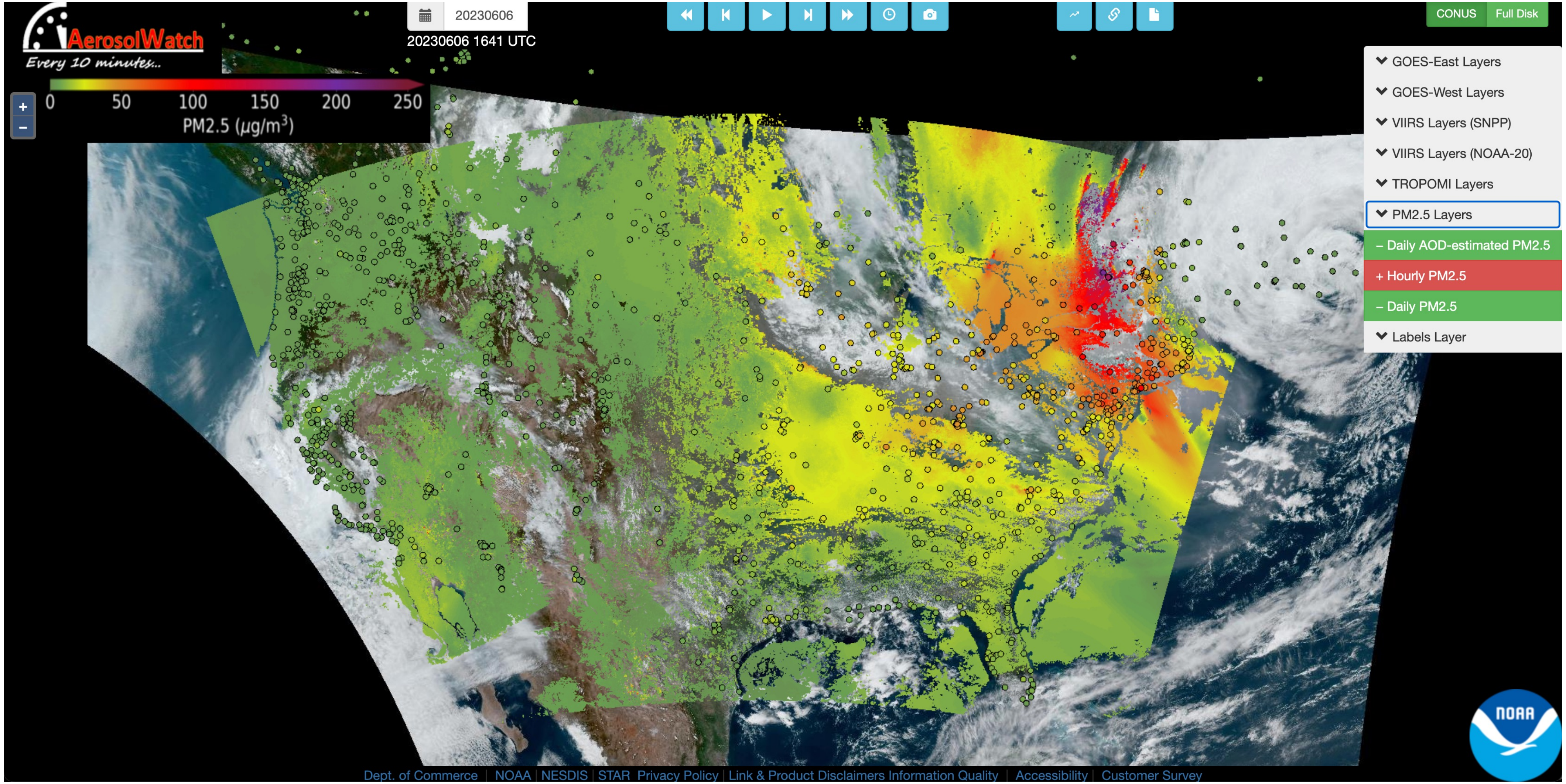
Aerosol Optical Depth (AOD) with Geostationary Instruments

- Current geostationary satellites provide high temporal resolution (~10 min) full-disk imagery
- Multiple satellites form a global constellation for AOD
  - GOES-16 (East US, South America)
  - GOES-18 (West US, Pacific)
  - Himawari-8/9 (Japan)
  - GEO-KOMPSAT-2A (Korea)
  - Fengyun-4 (China)
  - GSAT (India)
  - Meteosat-12 (Europe, Africa)
- Instrument capabilities vary



Source: [NOAA Aerosol Watch]

Surface $PM_{2.5}$ from Geostationary AOD



Sources: NOAA Aerosol Watch

Zhang & Kondragunta (2021) Daily and Hourly Surface $PM_{2.5}$ Estimation from Satellite AOD. Earth and Space Science.

Relevant Prior ARSET Intermediate Training

- [ARSET - Accessing and Analyzing Air Quality Data from Geostationary Satellites]

Fire Detection

Thermal Anomalies

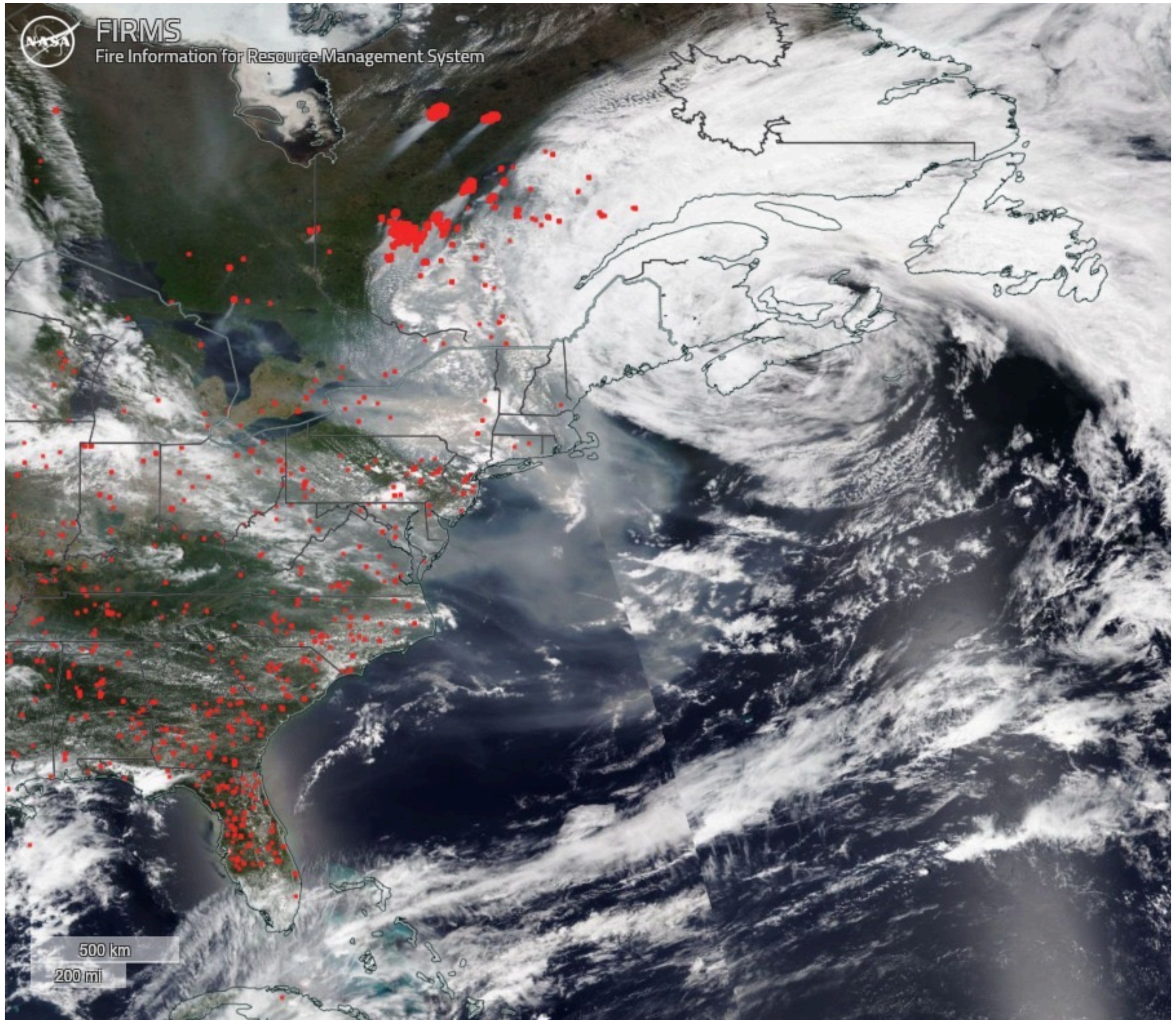
- Detection of extreme temperatures
- Indicative of active burning
- Thick smoke can block signal
- May miss small fires

Fire Radiative Power (FRP)

- Rate of emitted radiative energy by a fire

Fire Radiative Energy (FRE)

- Time integrated FRP
- Correlation between FRE and fire emissions



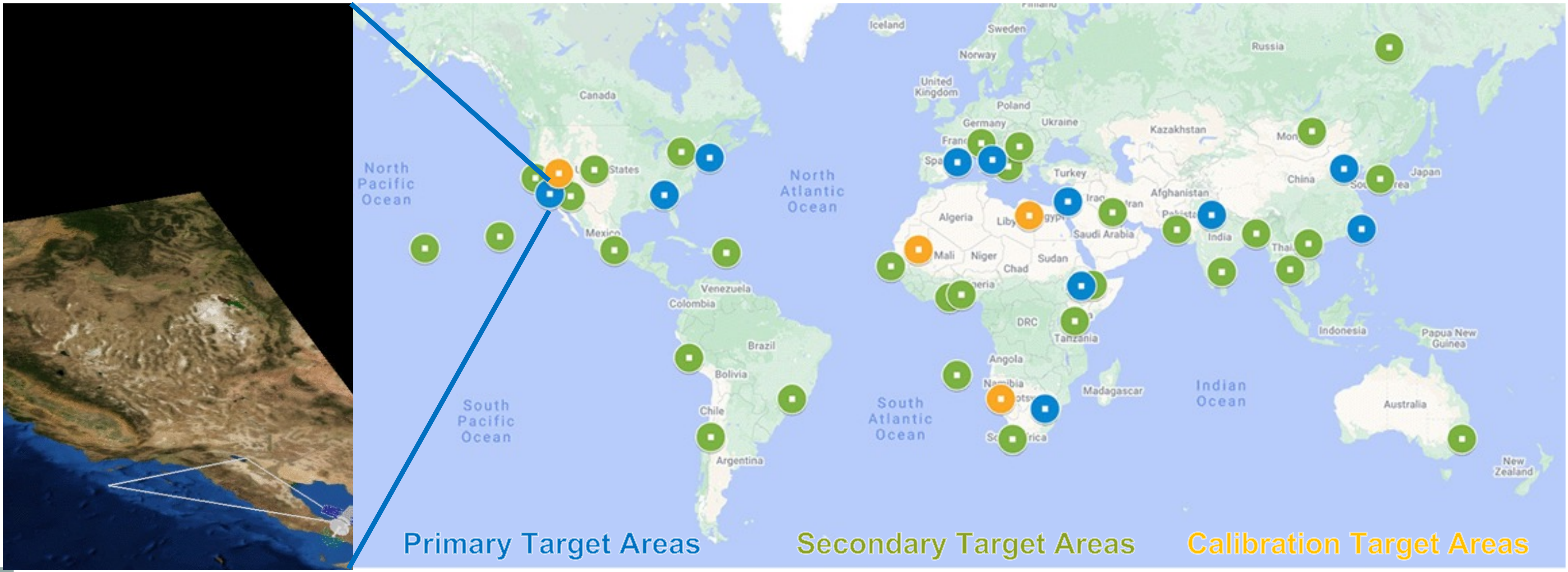
Source: NASA FIRMS, 06 June 2023

Relevant Prior ARSET Intermediate Training

- ARSET - Satellite Observations and Tools for Fire Risk, Detection, and Analysis
- ARSET - Observaciones de Satélites y Herramientas para el Riesgo, Detección y Análisis de Incendios

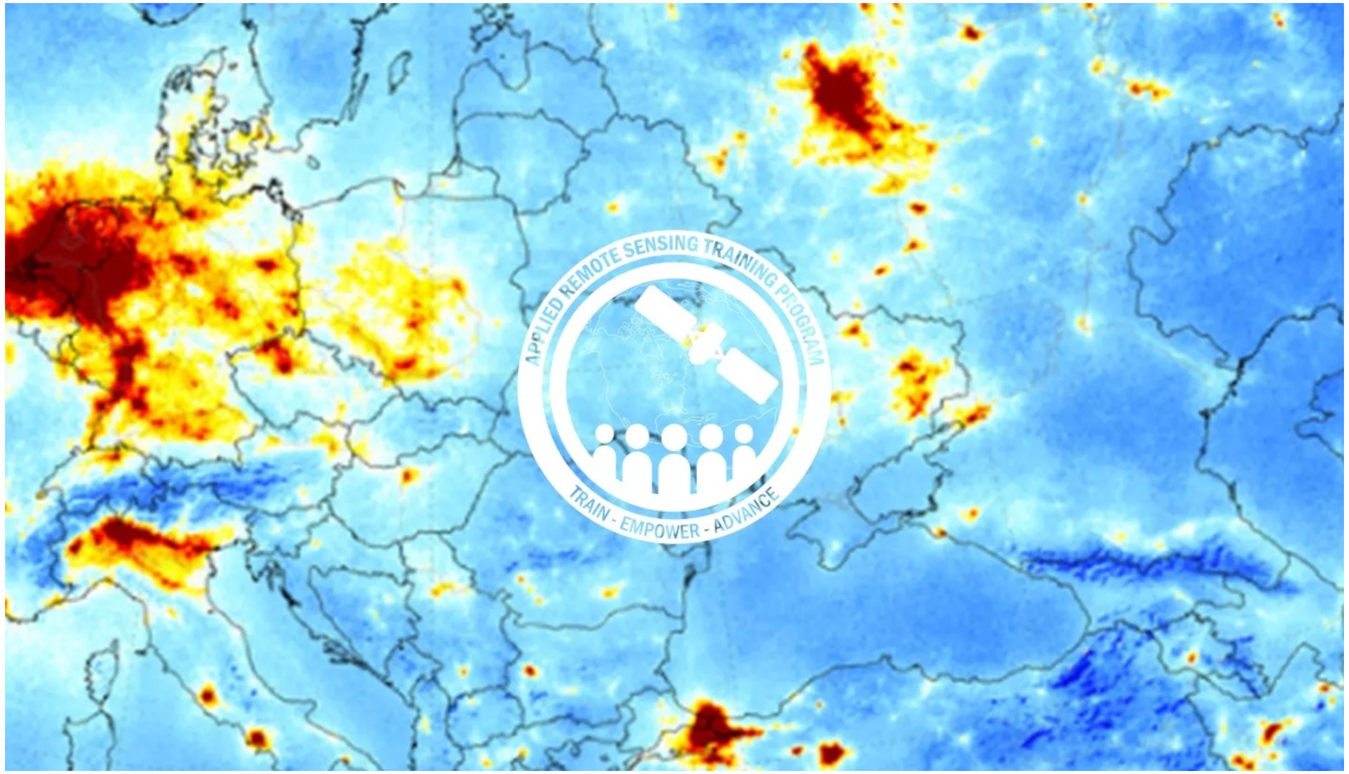
Upcoming Mission: Multi-Angle Imager for Aerosols (MAIA)

Targetable satellite instrument coordinated with surface PM measurements & health studies



Source: [MAIA Website]

Relevant Prior ARSET Advanced Training



- ARSET - High Resolution NO2 Monitoring From Space with TROPOMI

OMI and TROPOMI

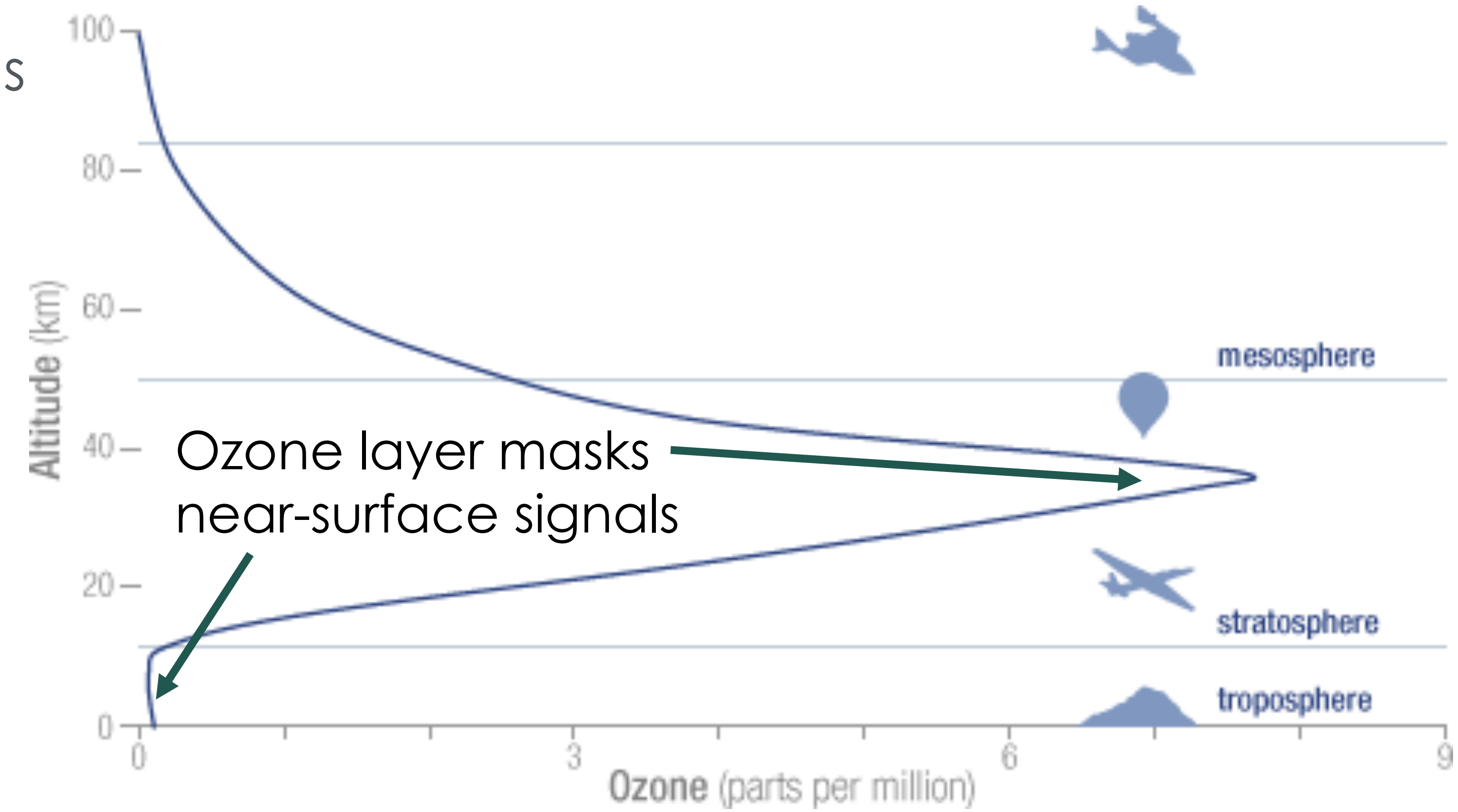
OMI (NASA)		TROPOMI (ESA)
Aura	Satellite	Sentinel-5P
July 2004	Launched	Oct 2017
Nadir-Viewing Imaging Spectrometer	Instrument	Nadir-Viewing Imaging Spectrometer
264 – 504 nm (UV/VIS)	Spectral Range	270 nm – 2.3 µm (UV/VIS/NIR/SWIR)
0.42 – 0.63 nm	Spectral Resolution	0.55 nm
13x24 km^2 at Nadir	Spatial Resolution	5.5 x 3.5 km^2 at Nadir 7 x 28 km^2 (UV1 Band) 7 x 7 km^2 (SWIR Bands)
Daily	Global Coverage	Daily
~ 13:45 LST	Local Overpass Time	~ 13:30 LST

OMI and TROPOMI: Trace Gas Data Products

OMI (NASA)		TROPOMI (ESA)	
Tropospheric and Total Column NO_2	Swath, Gridded (0.25° and 0.1°)	Tropospheric and Total Column NO_2	Swath (5.5 km x 3.5km)
Total Column SO_2	Swath, Gridded (0.25°)	Total Column SO_2	Swath (5.5 x 3.5 km)
Total Column HCHO	Swath, Gridded (0.1°)	Tropospheric Column HCHO	Swath (5.5 x 3.5 km)
Tropospheric and Total Column O_3	Gridded (0.25°)	Tropospheric, Total Column O_3, Profiles	Swath (5.5 x 3.5 km)
		Carbon Monoxide (CO)	Swath (7 km x 5.5 km)
		Methane (CH_4)	Swath (7 km x 5.5 km)

Ozone

- Negative health impacts for humans, crops, and ecosystems
- Important to tropospheric chemistry
- High stratospheric concentrations (Ozone layer) mask more air-quality-relevant tropospheric concentrations
- Use of satellite Ozone is **not recommended** for air quality applications at this time.



Source: [NASA Ozone Watch]

Nitrogen Dioxide

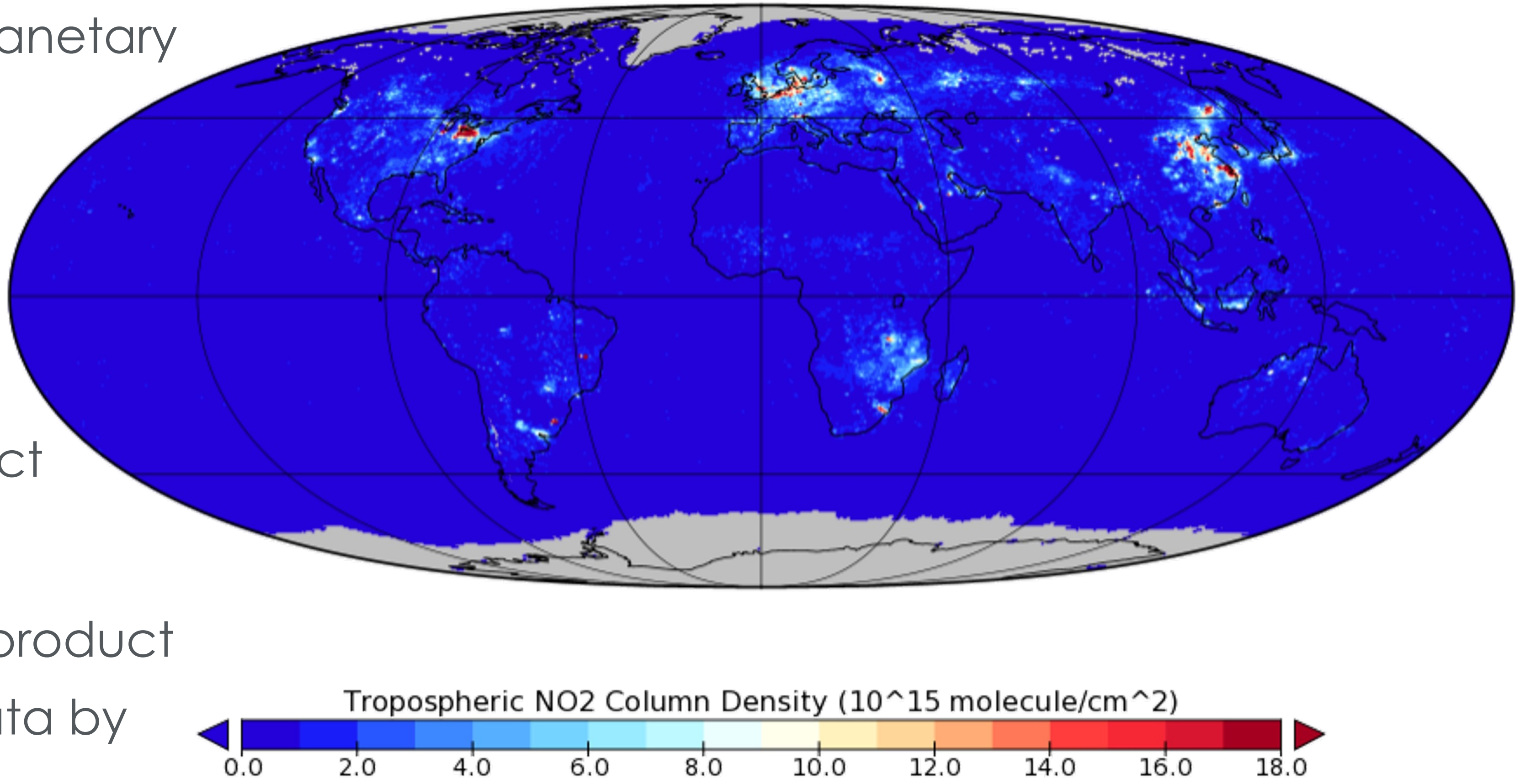
- Surface sources: fire, agricultural burning, transportation, industry, power generation
- High concentrations in the planetary boundary layer (PBL)

OMI: long data record

- OMNO2 Level 2 product
- OMNO2g gridded product
- OMNO2d daily Level 3 Product

TROPOMI: high resolution

- S5P_L2__NO2____HiR Level 2 product
- Available from NASA Earthdata by agreement with ESA



Source: NASA GES DISC

Formaldehyde

- Precursor for O_3; allows indirect estimates for near-surface O_3 potential using $HCHO/NO_2$ ratios
  - $HCHO/NO_2 < 1$: VOC-Limited
  - $HCHO/NO_2 > 2\text{-}4$: NO_X-Limited

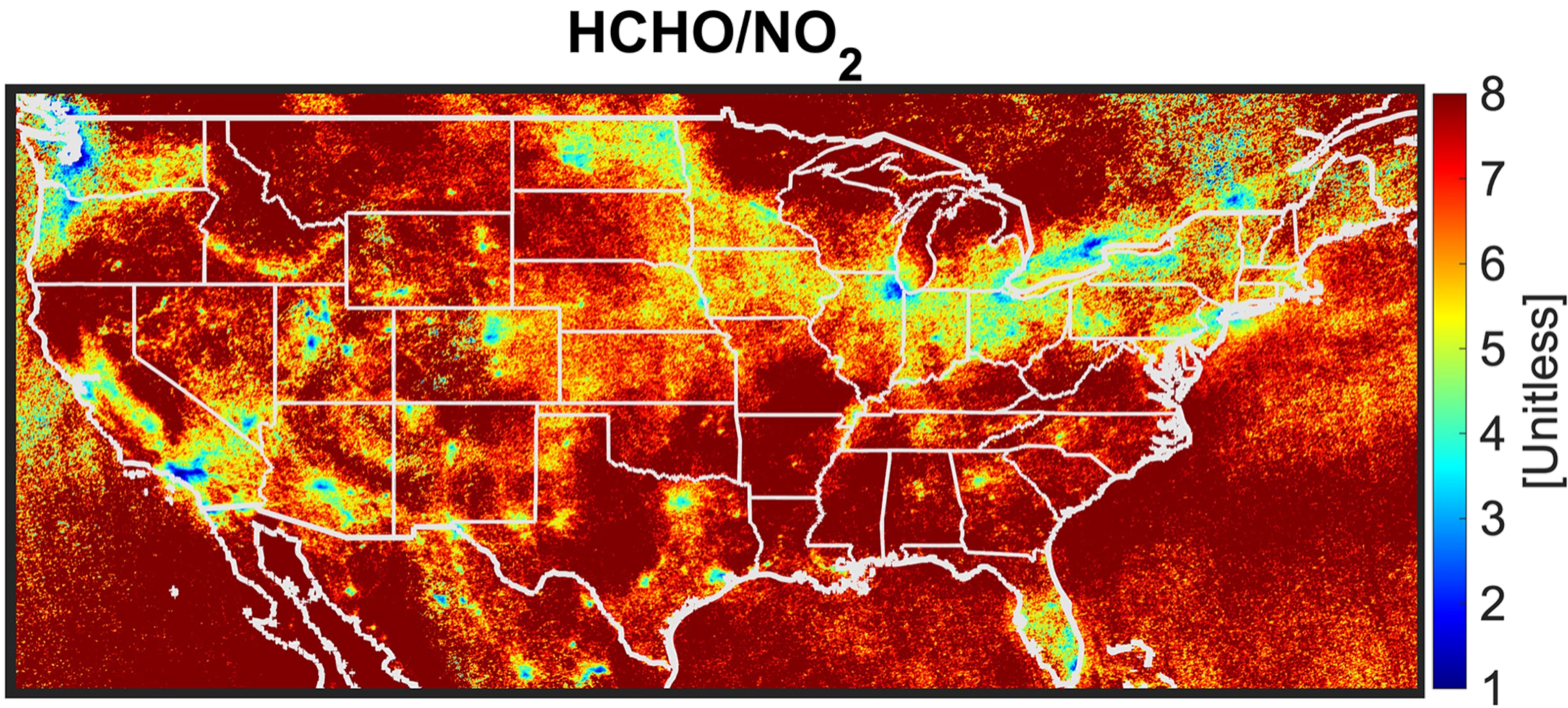
OMI: long data record

- OMHCHO Level 2 product
- OMHCHOg gridded products
- OMHCHOd daily Level 3 product

TROPOMI: high resolution

- S5P_L2__HCHO___HiR_2
- Available from NASA Earthdata by agreement with ESA

Comparing HCHO and NO_2 from TROPOMI to determine Ozone Formation Potential over the US



Source: Souri et al. (2023) [Characterization of errors in satellite-based HCHO/NO2 tropospheric column ratios with respect to chemistry, column-to-PBL translation, spatial representation, and retrieval uncertainties](). *Atmospheric Chemistry & Physics.*

Sulfur Dioxide

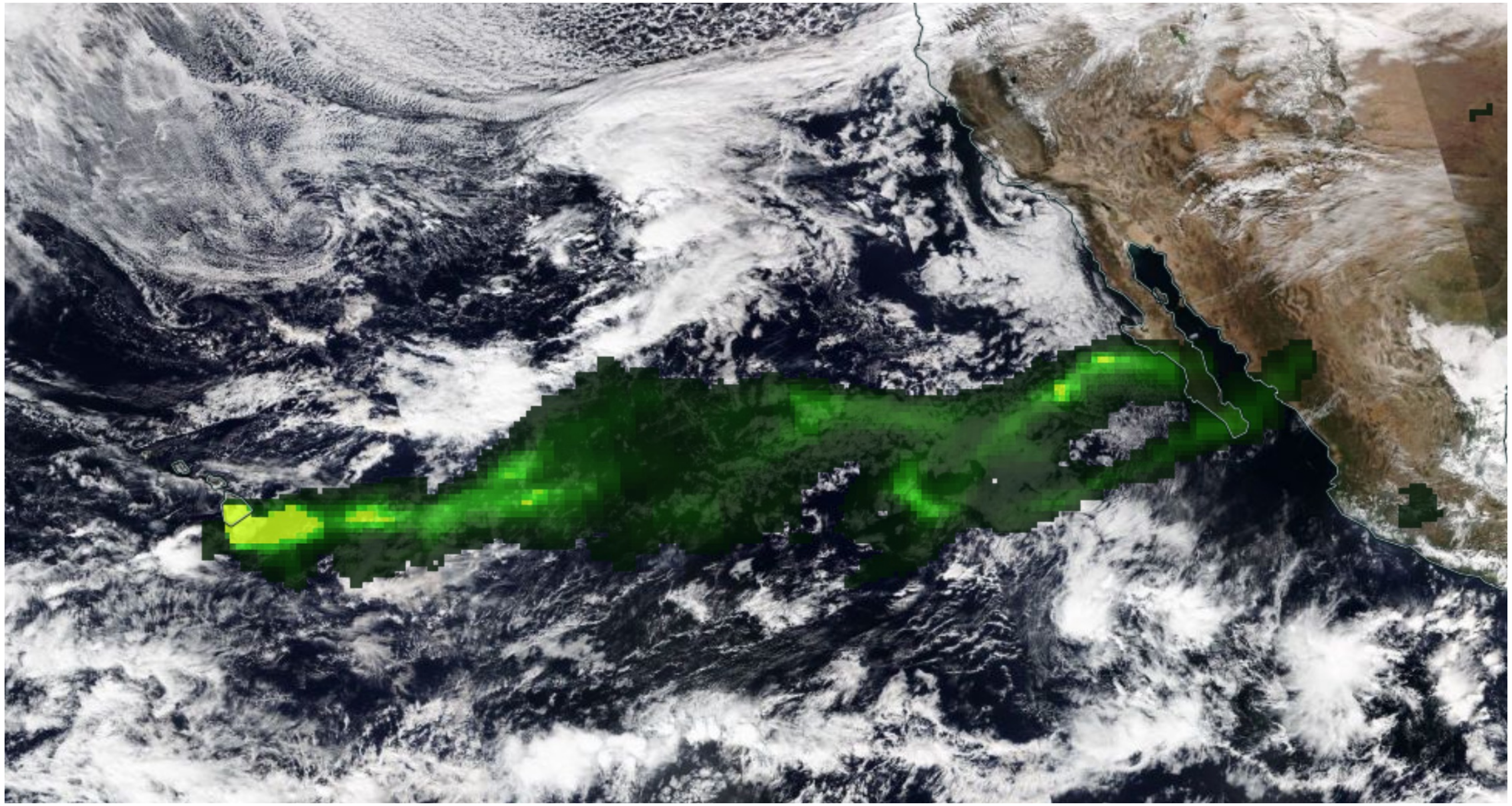
- Satellites are generally better suited to large sources: volcanoes, coal & oil burning, smelting.

OMI: long data record

- OMSO2 Level 2 product
- OMSO2e gridded product, assumes near-surface emissions: most relevant to air quality applications

TROPOMI: high resolution

- S5P_L2__SO2____HiR
- Available from NASA Earthdata by agreement with ESA



TROPOMI SO_2 Plume (lower troposphere) from Mauna Loa Eruption, Nov. 30, 2022

Source: [NASA Worldview]

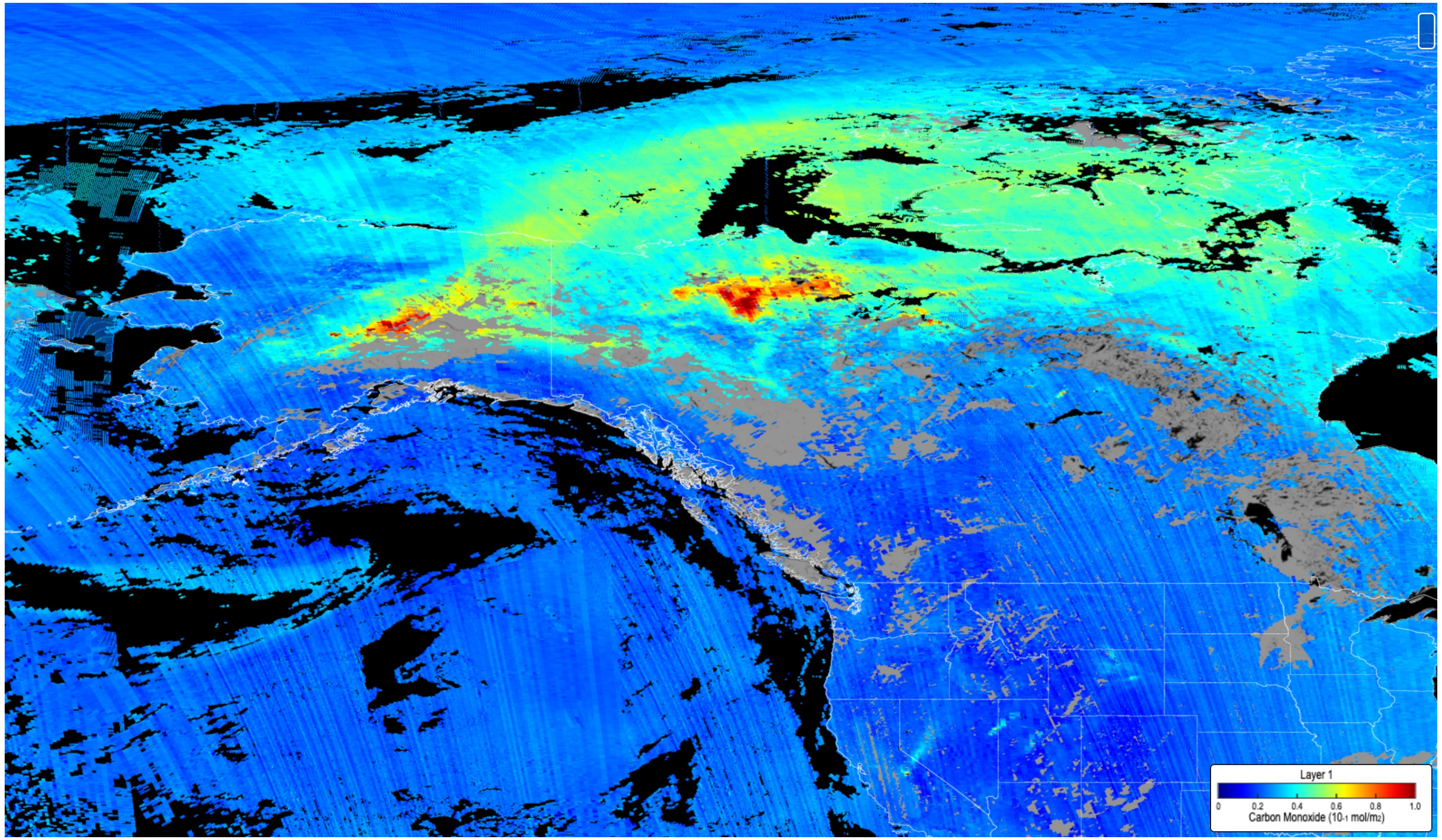
Carbon Monoxide and Methane

CO

- Major precursor for O_3
- Relatively long lifetime (~1-2 months) makes it a useful tracer
- TROPOMI: S5P_L2__CO____HiR

CH_4

- Potent greenhouse gas
- “Super-emitter” point sources (e.g., natural gas leaks)
- Distributed sources are hard to quantify from the ground (e.g., agriculture)
- TROPOMI: S5P_L2__CH4____HiR



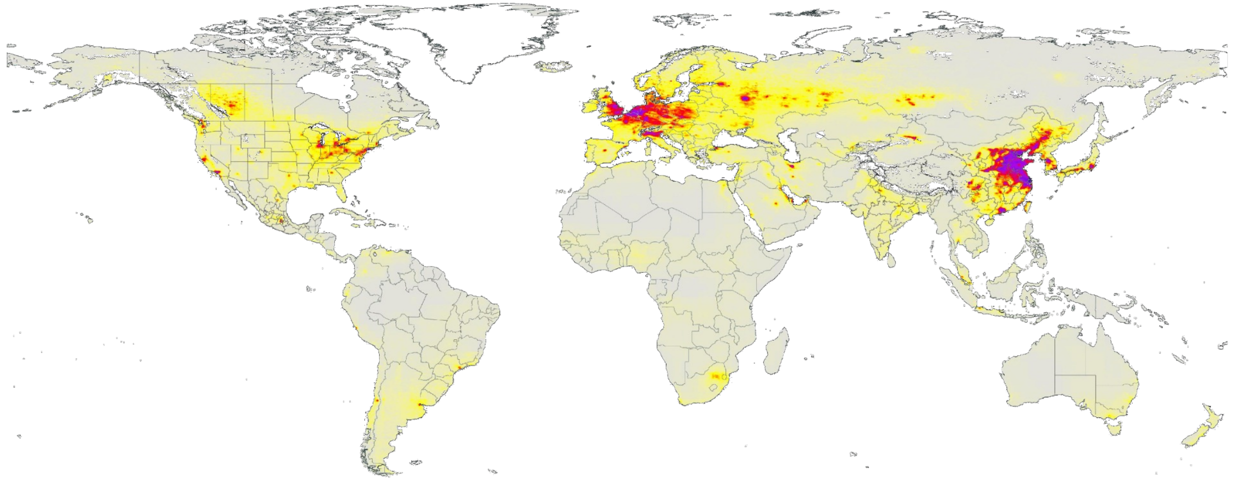
TROPOMI CO from various wildfires, July 9, 2022

Source: NOAA JSTAR Mapper

Satellite-Derived Surface Trace Gases

- Examples of Level 4 products
- Combine satellite data with other information (models, surface monitors) to derive high spatial resolution near-surface trace gas concentration
- Annual to daily temporal resolution (with different approaches)
- 1km or finer (50m) spatial resolution
- May lag significantly behind real-time
- Datasets are available through the NASA Socioeconomic Data and Applications Center (SEDAC)

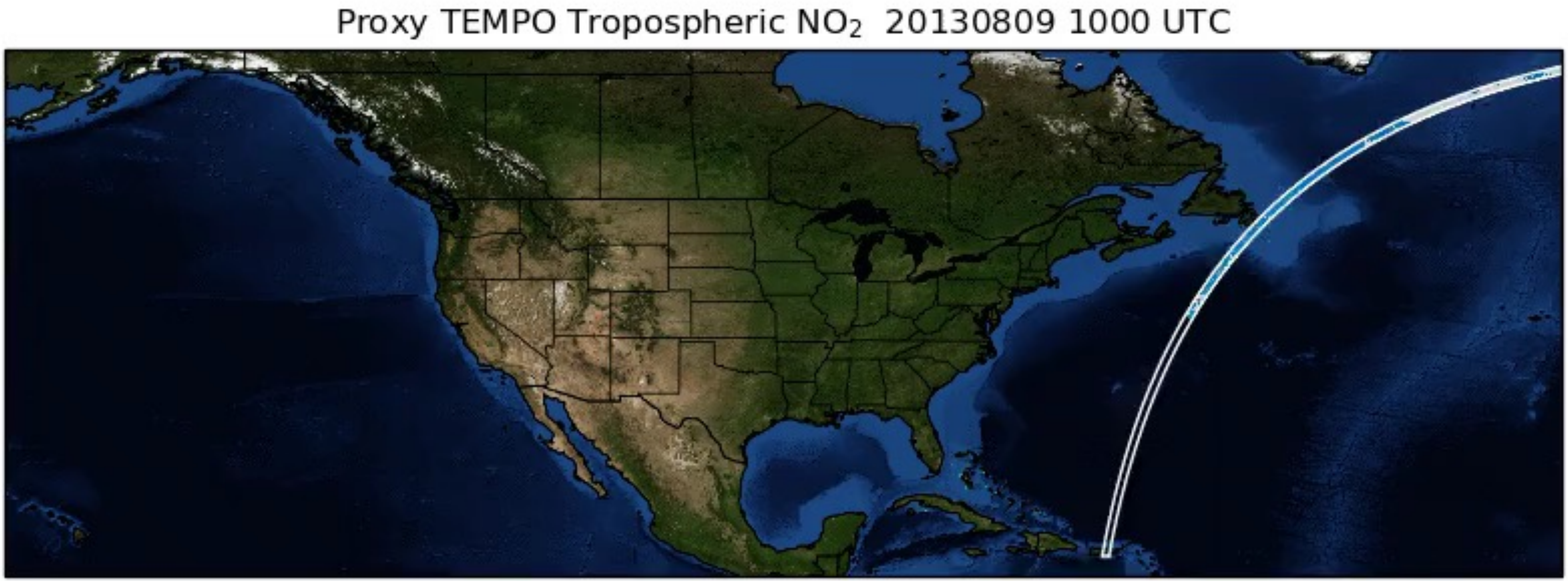
2010-2012 Average Surface NO_2 from GOME, GOME-2, and SCIAMACHY



Data in NASA SEDAC
Visualization in NASA Worldview

Sources: Di et al. (2020) Assessing NO2 Concentration and Model Uncertainty with High Spatiotemporal Resolution... *Env. Sci. & Tech.*
Larkin et al. (2023) A global spatial-temporal land use regression model for nitrogen dioxide air pollution. *Frontiers in Env. Sci.*

Tropospheric Emissions: Monitoring of POllution (TEMPO)



Geostationary instrument providing **hourly trace gas products** over North America
Launched April 7, 2023, Level 2 & 3 data products **expected April 2024**

Sources: Animation provided by Aaron Naeger, TEMPO applications & early adopter program
TEMPO Website

I want to track trends in particulate matter from 2000 to 2020, comparing averages across US states to see if different state-level policies have had different impacts on particulate concentrations.

Which of these satellite instruments would be my best choice?

A: MODIS

B: VIIRS

C: OMI

D: TROPOMI

I want to track trends in particulate matter from 2000 to 2020, comparing averages across US states to see if different state-level policies have had different impacts on particulate concentrations.

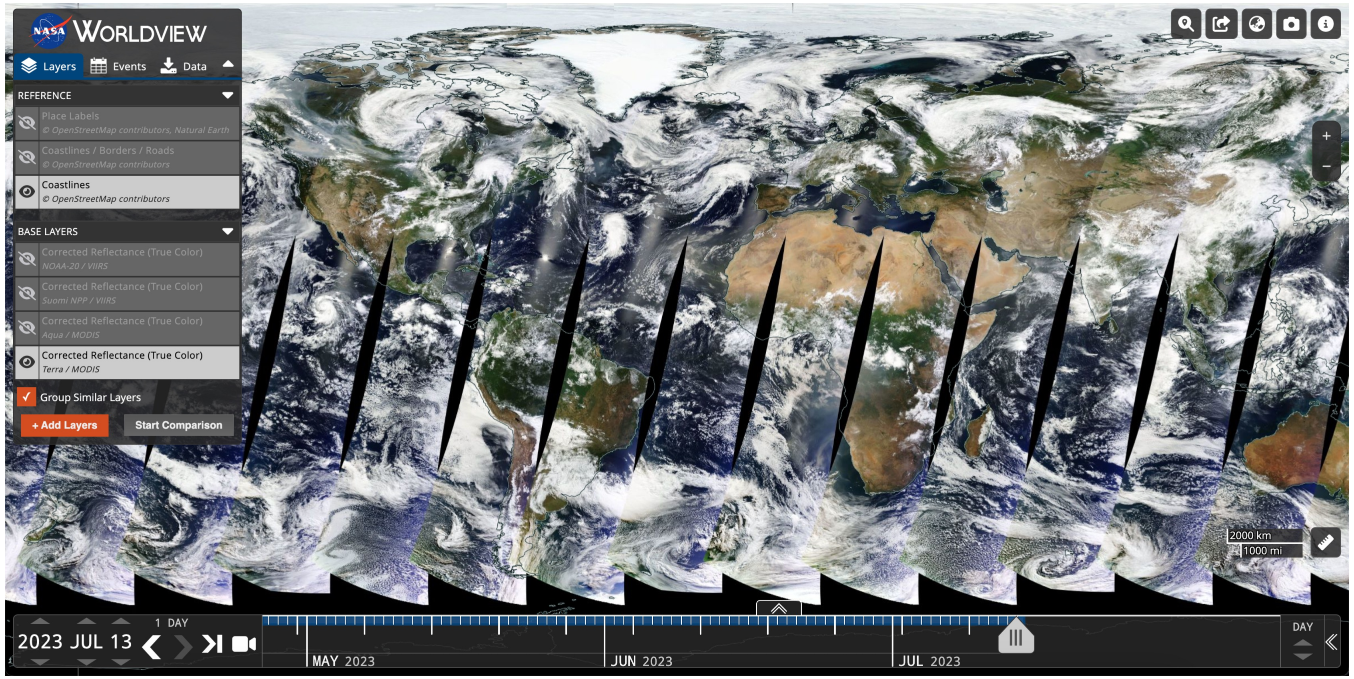
Which of these satellite instruments would be my best choice?

- ✓ A: MODIS
- B: VIIRS
- C: OMI
- D: TROPOMI

Accessing & Visualizing Remote Sensing Data

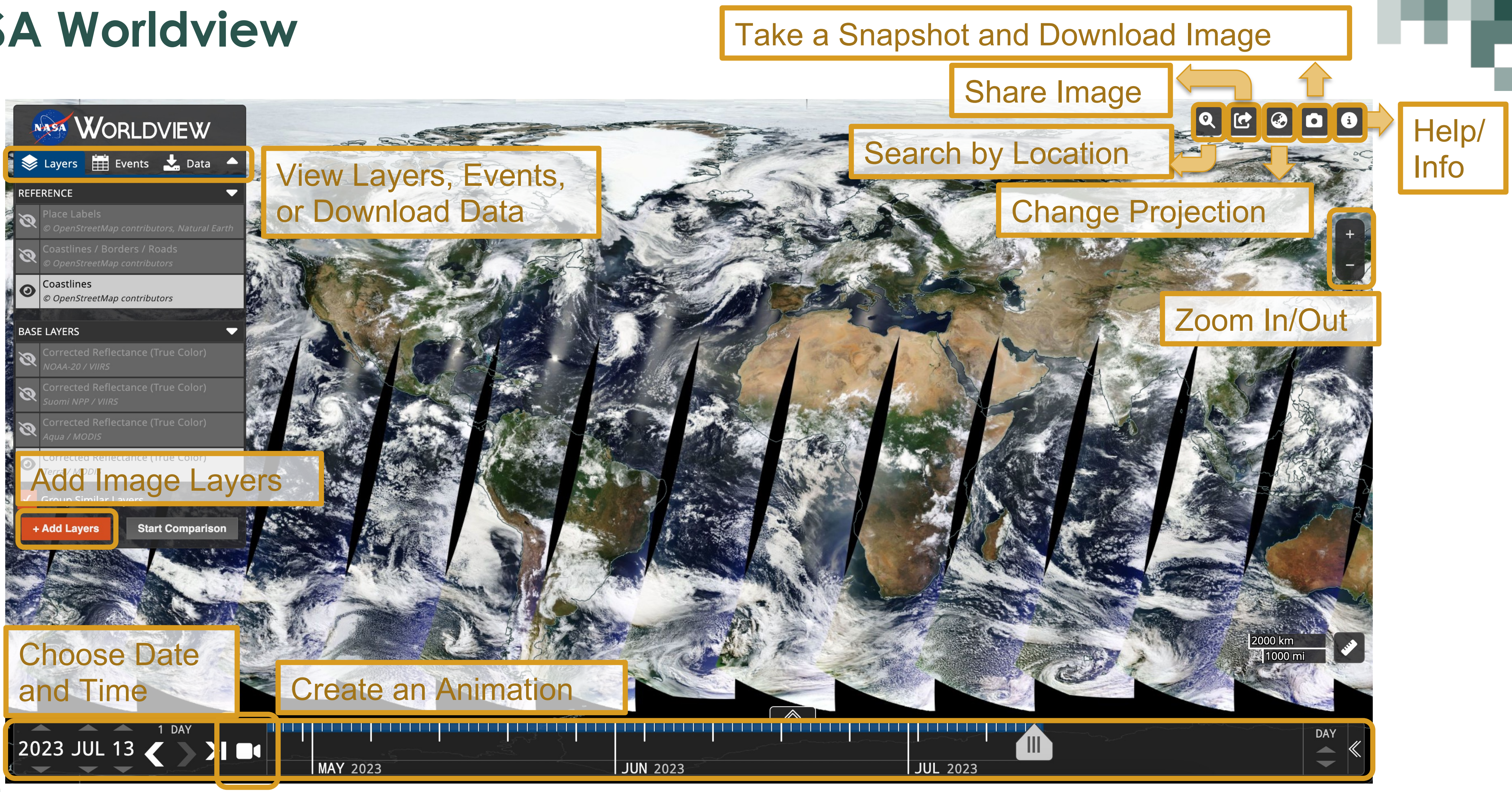
NASA Worldview

- Application that allows the user to:
  – Interactively browse, save, or share satellite imagery layers
  – Download the data
- Some imagery available in near real time (NRT) or within 3 hours of observation



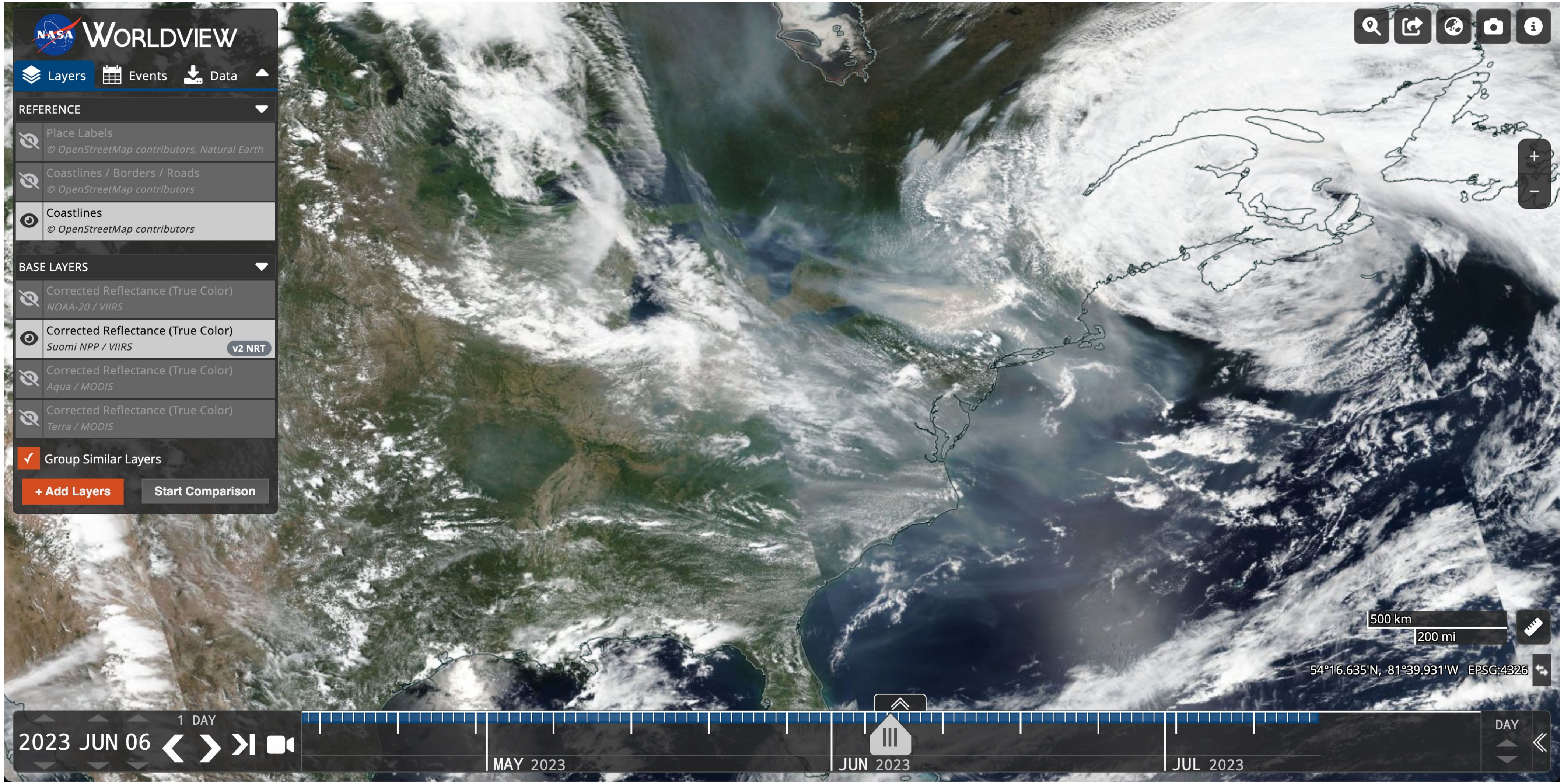
https://worldview.earthdata.nasa.gov/

NASA Worldview



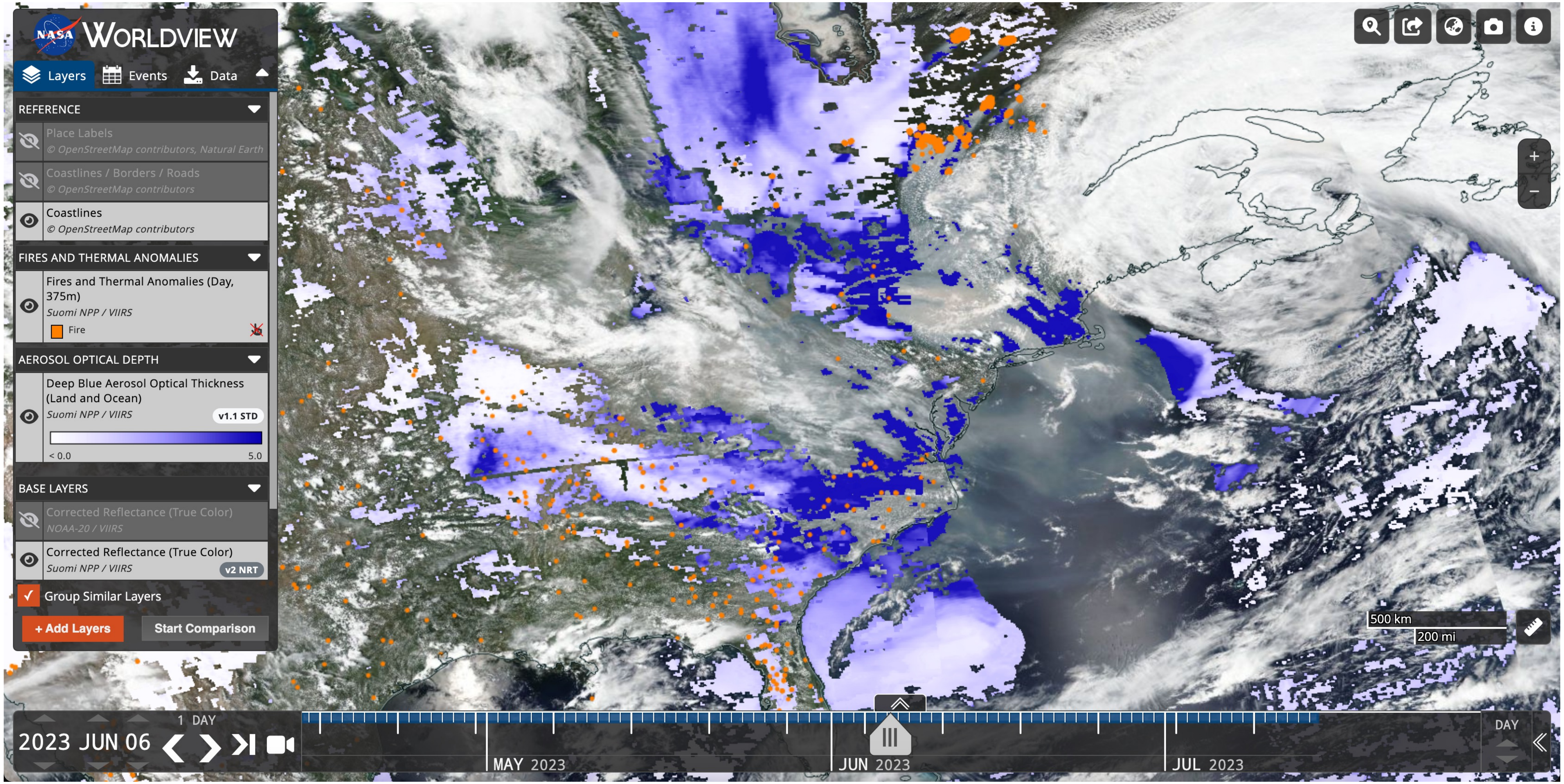
https://worldview.earthdata.nasa.gov/

NASA Worldview: True-Color Imagery



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

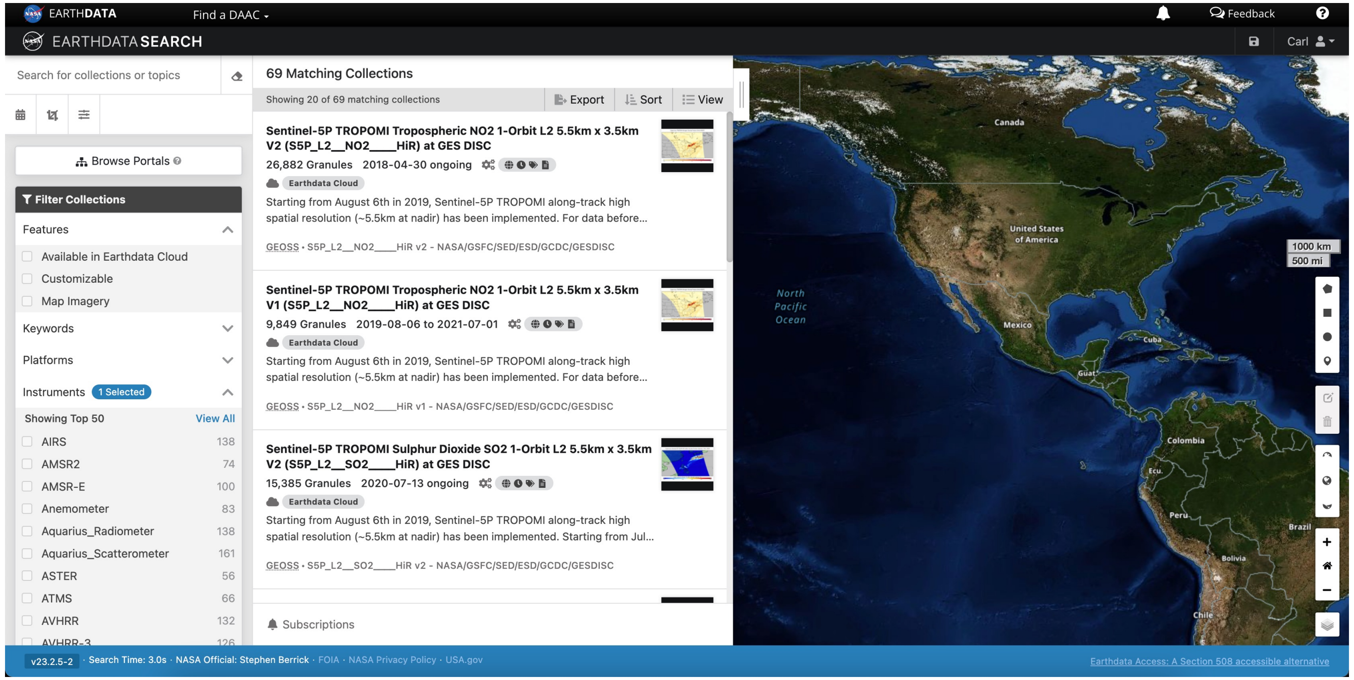
NASA Worldview: Compare Multiple Layers



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

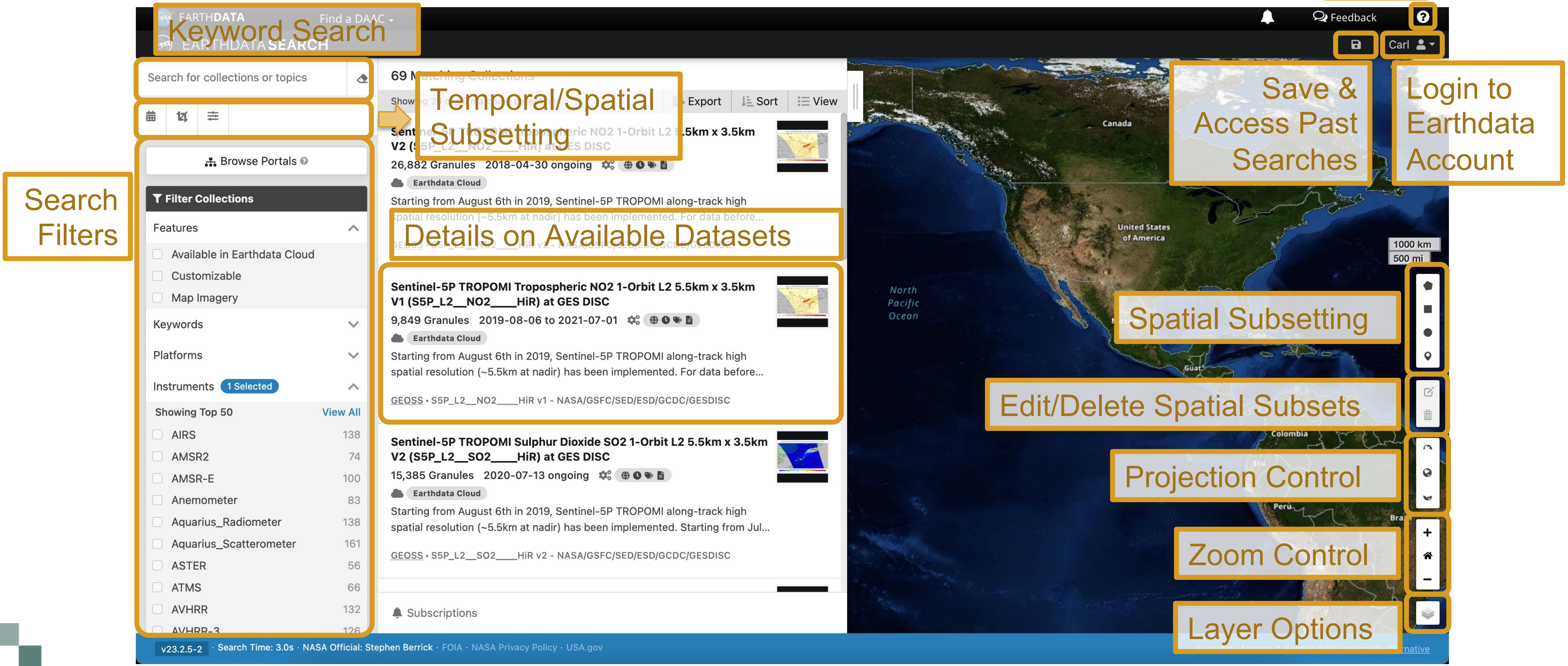
NASA Earthdata Search

- A “one stop shop” for searching and downloading NASA Earth datasets
  - Filter & Search data products by keyword, instrument, processing level, etc.
  - Subset datasets in space and time
  - Generate lists of file names for download



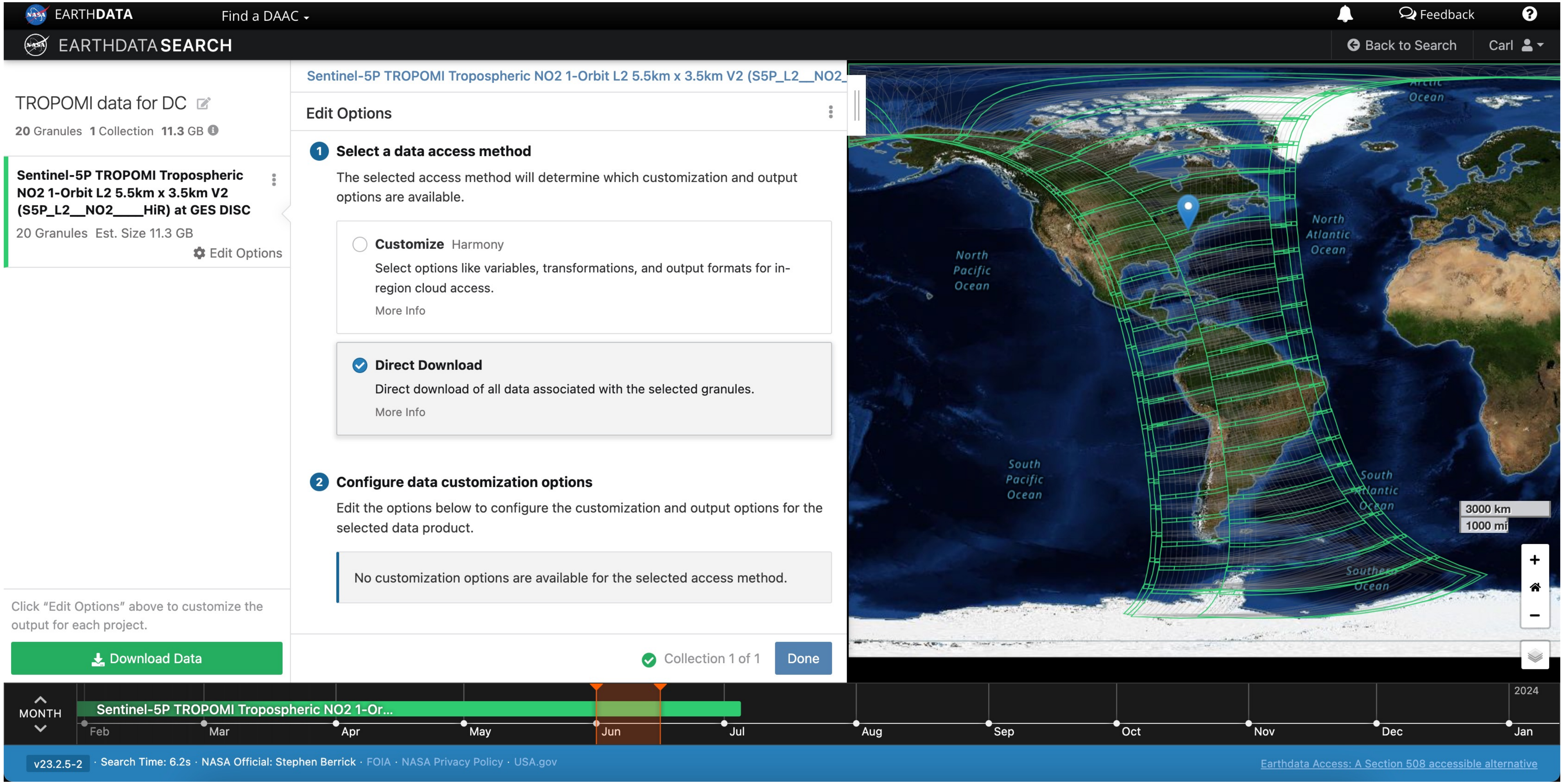
https://search.earthdata.nasa.gov/search

NASA Earthdata Search



https://search.earthdata.nasa.gov/search

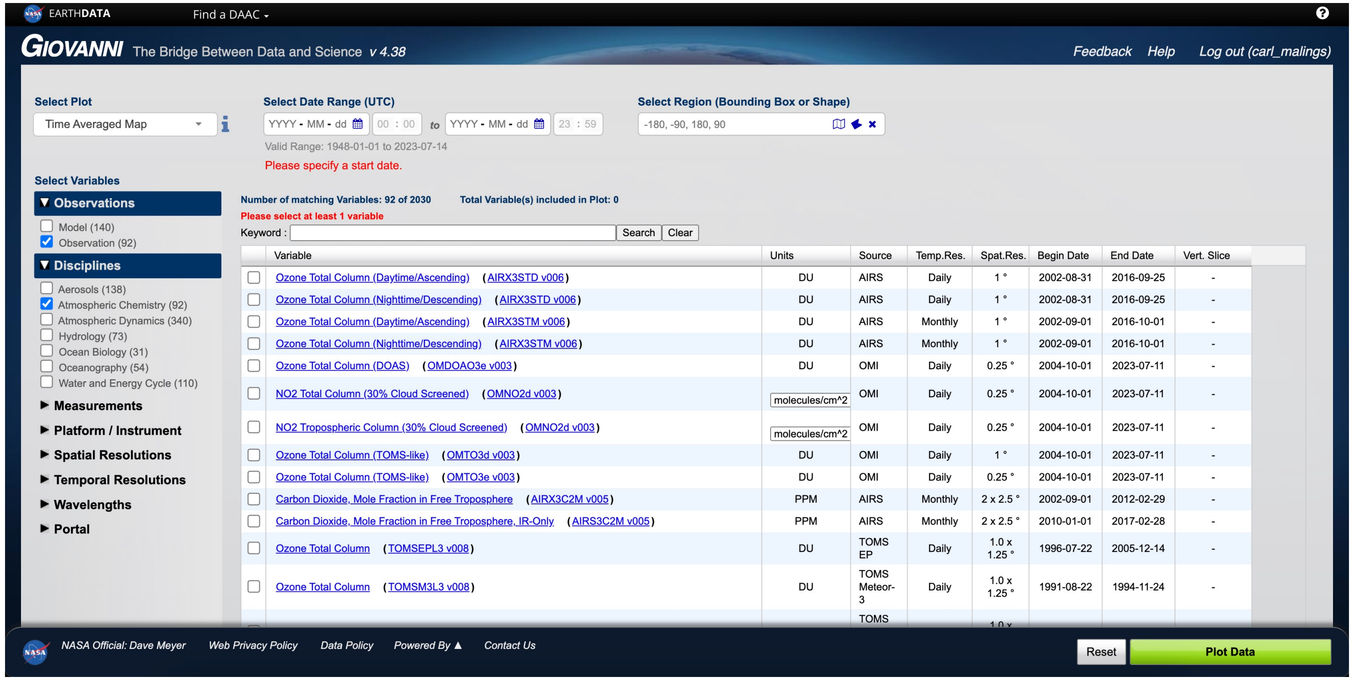
NASA Earthdata Search: Select & Download TROPOMI Data



https://search.earthdata.nasa.gov/search

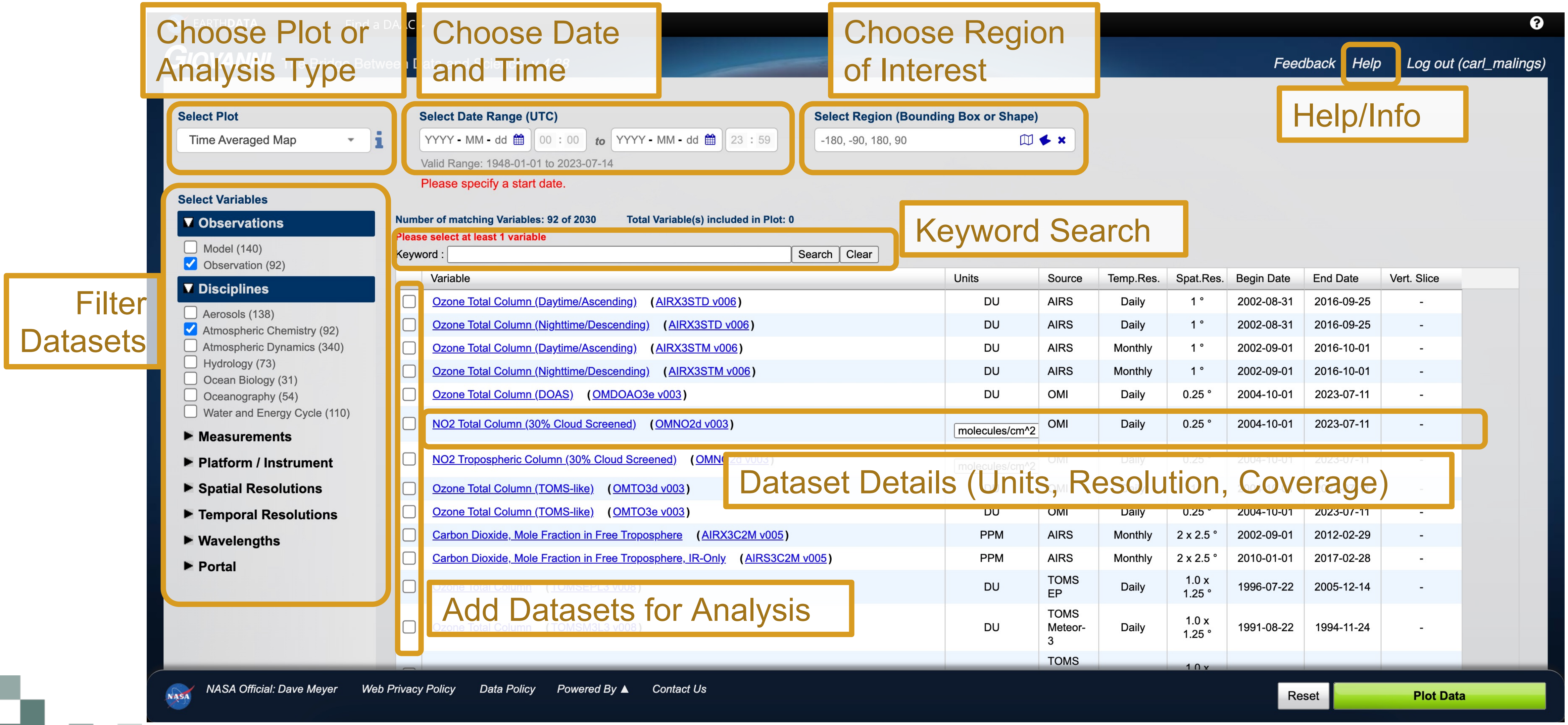
NASA Giovanni

- Allows the user to work with datasets without needing to download them
  – Select & subset Level 3 & 4 (gridded) NASA data products
  – Perform simple analysis (spatial & temporal averaging, differences)
  – Plot results (e.g., area colormaps, time series, scatterplots, correlation plots)



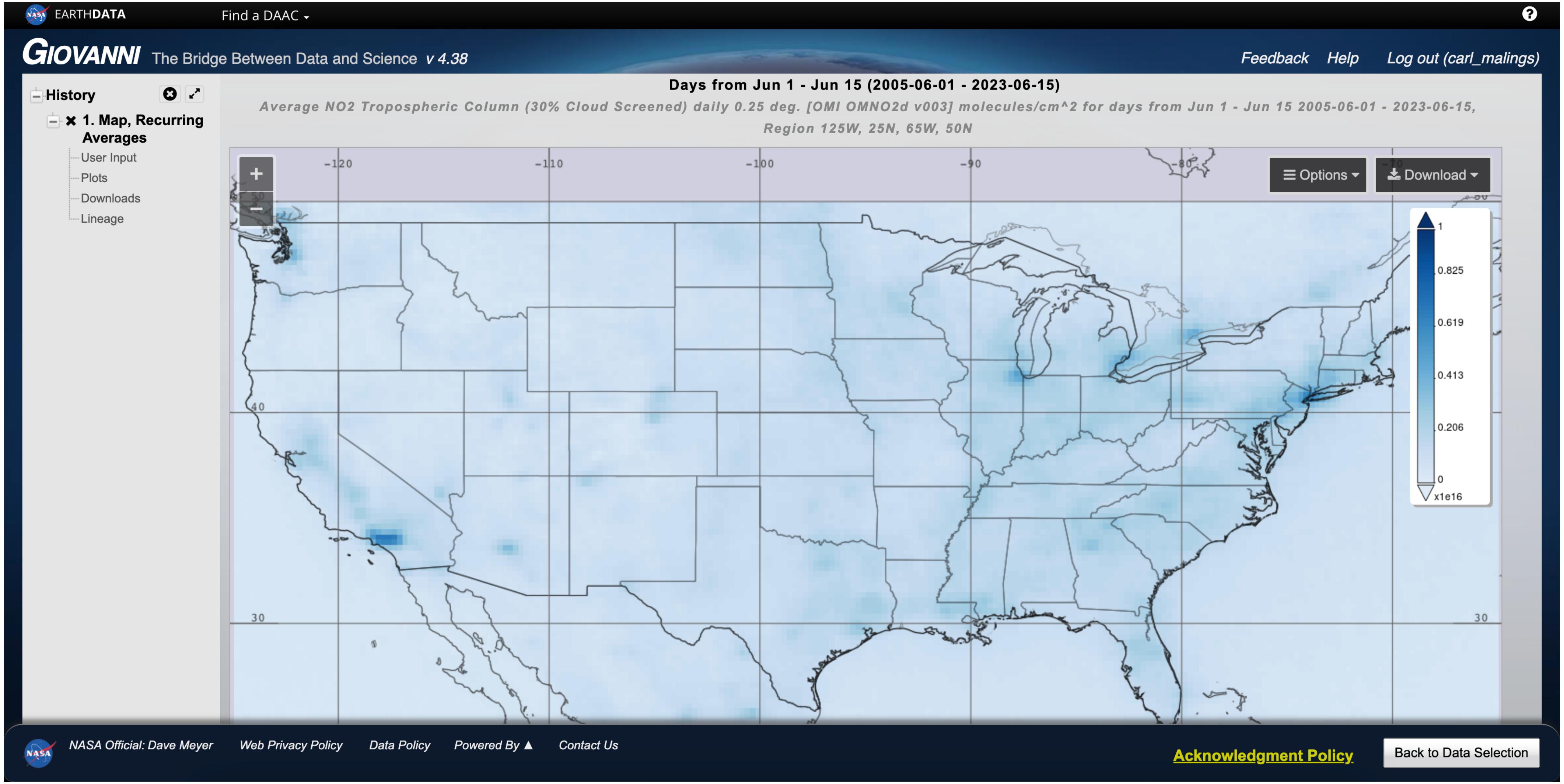
https://giovanni.gsfc.nasa.gov/giovanni/

NASA Giovanni



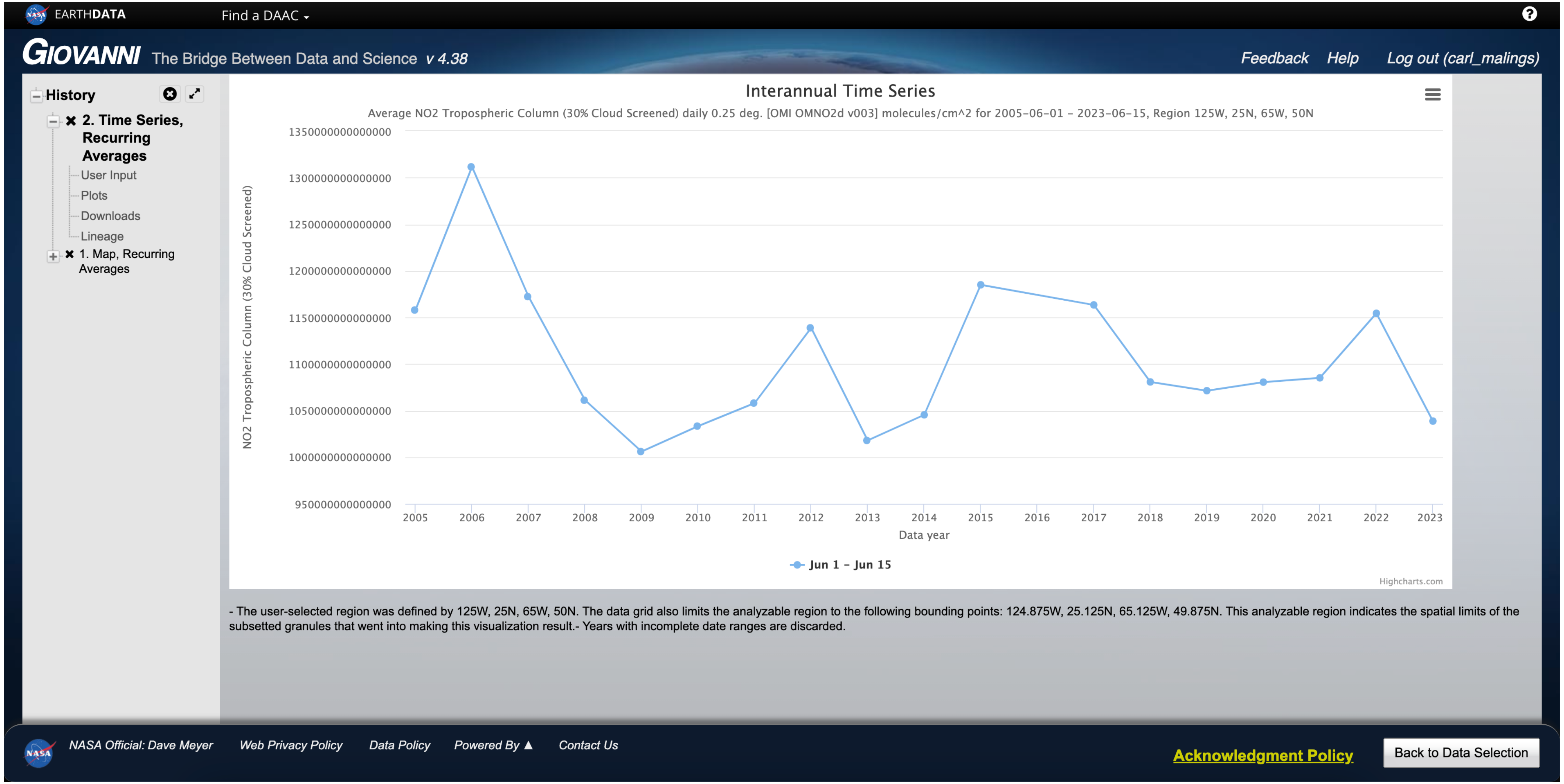
https://giovanni.gsfc.nasa.gov/giovanni/

NASA Giovanni: Recurring Average Map



https://giovanni.gsfc.nasa.gov/giovanni/

NASA Giovanni: Time Series



https://giovanni.gsfc.nasa.gov/giovanni/

Part 2:
Summary

Summary

- Satellite remote sensing data can complement surface monitoring and other data sources to help fill in global and local data gaps in air quality information.
- Atmospheric column quantities (e.g., AOD) can relate to surface air quality parameters (e.g., $PM_{2.5}$) but are not the same; patterns and trends observed by satellites should be validated with ground-based data where possible.
- Spatial and/or temporal resolution and coverage of satellite data products varies, making different products suitable for different applications.
- For environmental justice applications, spatial and temporal resolution of satellite datasets should match or be finer than the desired scale of analysis.
- NASA provides resources for accessing and analyzing satellite datasets online.

Looking Ahead to Part 3

- Interactive Exercises for using Satellite and Demographic Data
  - EJSCREEN
  - Python

- Optional Activity
  - Use NASA Worldview and/or Giovanni to look at your hometown or an area of interest to you and overlay some of the data products we discussed today.
  - Try to find an interesting air quality event for the area and see how it shows up in the satellite data. What did you expect to see? What surprised you?
  - If you registered for the HAQAST Forum, feel free to post what you find there!
  - **This is an optional exercise and is NOT part of the required homework.**

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on 06/09/2023
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by 20/09/2023**

- **Certificate of Completion:**
  - Attend all three live webinars (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.

Contact Information

Trainers:

- Carl Malings
  - carl.a.malings@nasa.gov

- ARSET Website
- Follow us on Twitter!
  - @NASAARSET
- ARSET YouTube

Visit our Sister Programs:

- DEVELOP
- SERVIR

Resources

- NASA Worldview (Visualize satellite data online)
- NASA Earthdata Search (Search for & download satellite data)
- NASA Giovanni (Analyze level 3 & 4 data online)
- NASA HAQAST (Health & Air Quality Applied Sciences Team)
  - Guide to getting started with satellite data
  - Health and Air Quality Community Forum
- NASA Air Quality Data Pathfinder (see next slide)
- NASA GSFC Air Quality Observations from Space
- NASA SEDAC (Socioeconomic Data and Applications Center)
- Prior ARSET Health & Air Quality Trainings

EARTH**DATA** Offers

The Air Quality Data Pathfinder

for Your Research & Applications

Air pollution is one of the largest global environmental and health threats. NASA provides data resources to better understand the movement of pollutants and the impact of events leading to poor air quality. This Pathfinder helps you access, and leverage data acquired from NASA's satellite, airborne, and ground-based missions and campaigns.

Available Data Types:

- Aerosols
- Trace Gases (e.g., Nitrogen Dioxide, Sulfur Dioxide, Carbon Monoxide, etc.)
- Weather (e.g., Air Temperature, Clouds, Precipitation, etc.)
- Land Surface (e.g., Soil Moisture, Surface Reflectance, Topography, etc.)
- Human Dimensions

Data are from satellites, airborne and ground-based platforms, and models, including:

- AIRS
- AMSR2
- GPM
- MODIS
- OLI/TIRS
- OMI
- OMPS
- SMAP
- TROPOMI
- VIIRS
- GEOS
- MERRA-2

Visit the EARTH**DATA**
Air Quality Data Pathfinder
for more information:

- Commonly Used Datasets for Air Quality Research and Applications
- Tools for Using Data
- Resources for Applying and Connecting NASA Data
- GIS Resources
- Tips for Getting Help and Connecting with NASA experts
- Tutorials and more!

Thank You!