Satellite Data for Air Quality & Public Health

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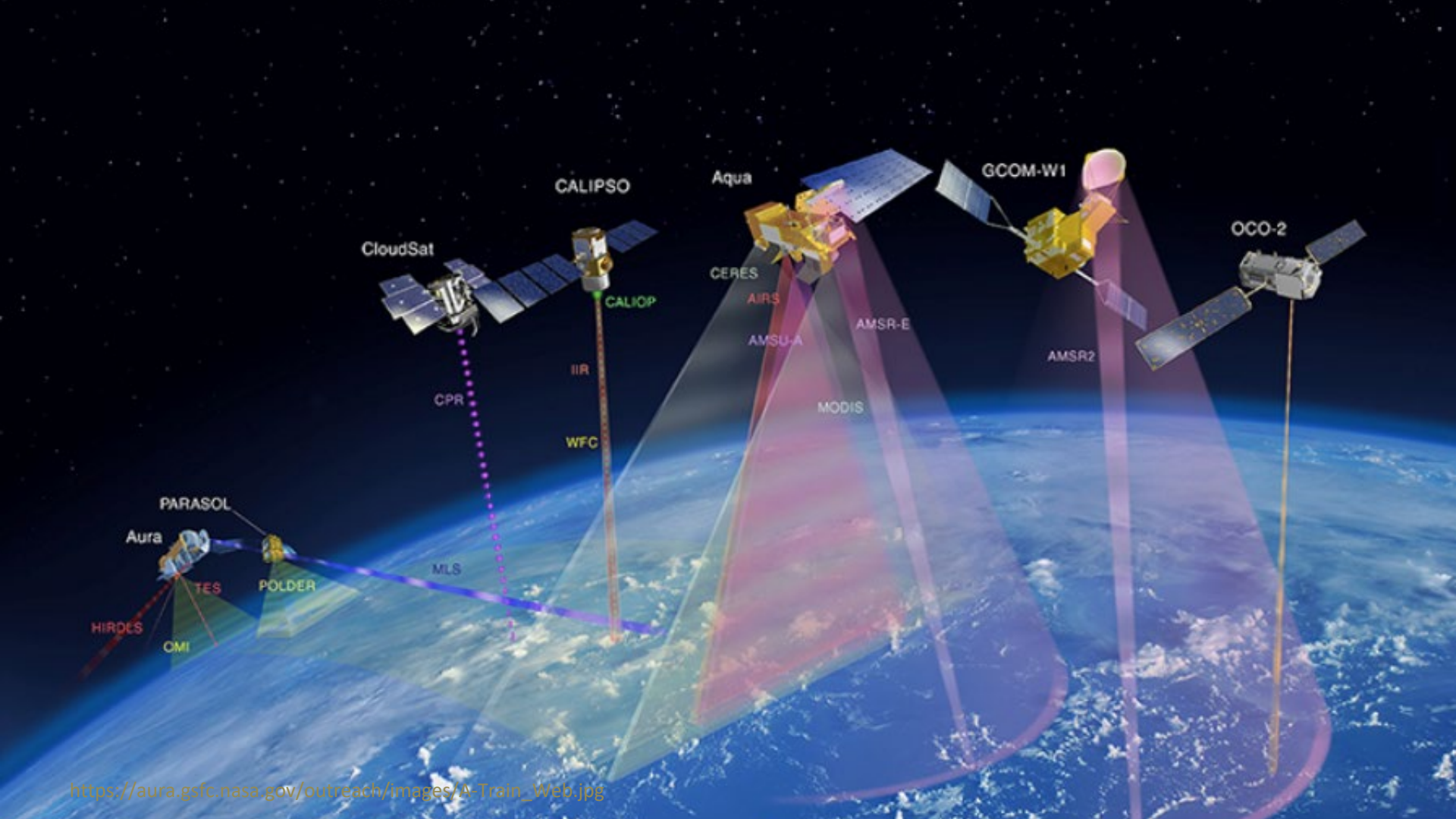

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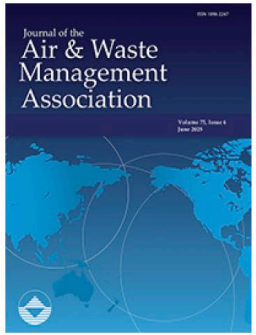

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Satellite data to support air quality assessment and management

Tracey Holloway, Jennifer R. Bratburd, Arlene M. Fiore, Gaige H. Kerr & Jingqiu Mao

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Scientists / Researchers

Stakeholders / Data Users

Group A
Academia/University
Research institute
Private enterprise
Government advisory group

Group B
Government regulatory body
Local authority
Air quality consultancy
Research institute/Government lab
Public health

Investigating the barriers and pathways to implementing satellite data into air quality monitoring, regulation and policy design in the United Kingdom

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Do you consider satellite air quality data, in their current state, to be useful to potential end users?

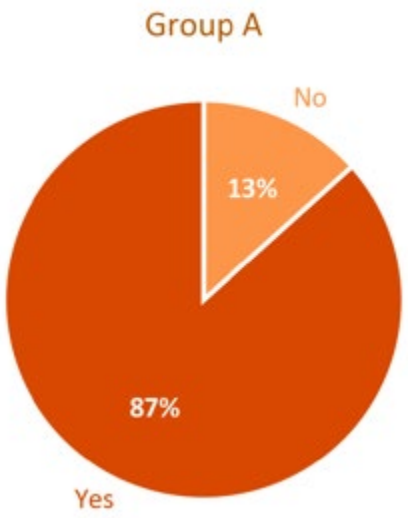
Potts, et al., 2023

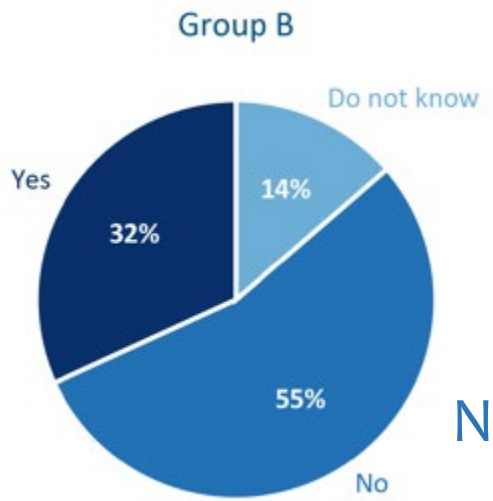
Do you consider satellite air quality data, in their current state, to be useful to potential end users?

Scientists / Researchers

Stakeholders / Data Users

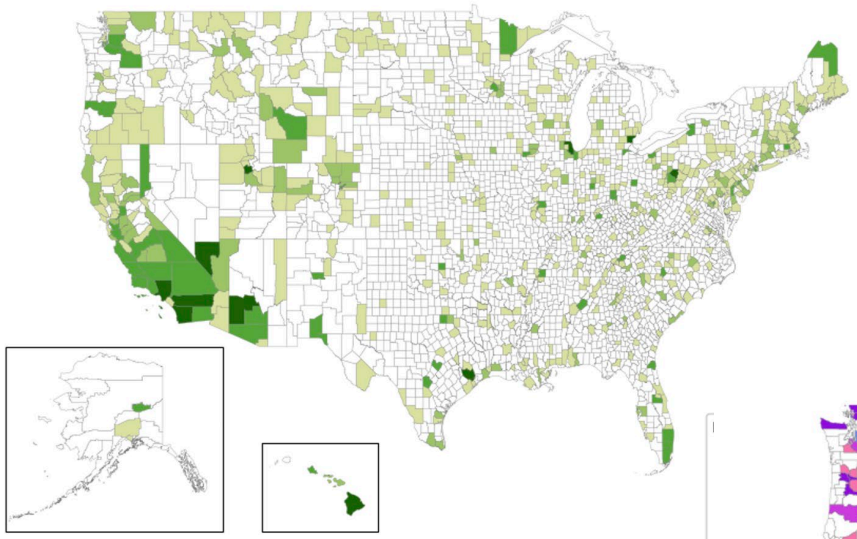
YES

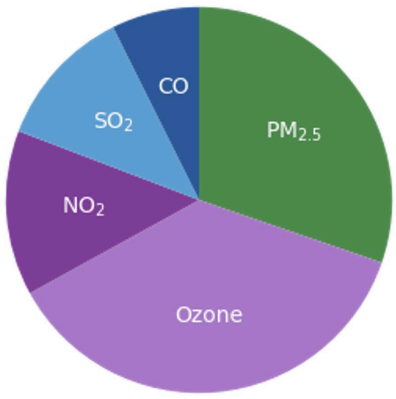


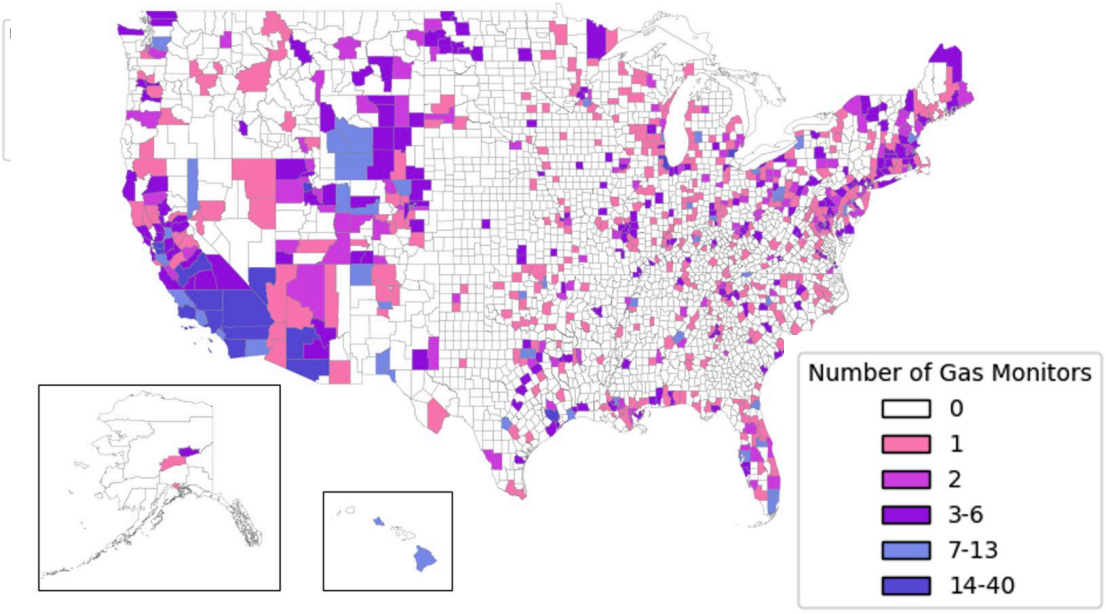


NO

Potts, et al., 2023


Number of $PM_{2.5}$ Monitors
0
1
2
3-6
7-13


CO
SO_2
$PM_{2.5}$
NO_2
Ozone


Number of Gas Monitors
0
1
2
3-6
7-13
14-40

Satellite Data Capabilities

Satellites CANNOT

- Monitor surface-level air quality
- Directly measure emissions
- Detect all pollutants of interest
- Replace ground monitors, in-stack emissions monitors or other standard air quality data

Satellites CAN

- Detect the column – sometimes layers – of some chemicals in the atmosphere (NO_2, aerosols, HCHO, SO_2, NH_3, CO …)
- Track patterns, trends and events
- Combine with other data to calculate surface-level air quality, especially $PM_{2.5}$, or emissions

https://eos.com/blog/satellite-constellation/

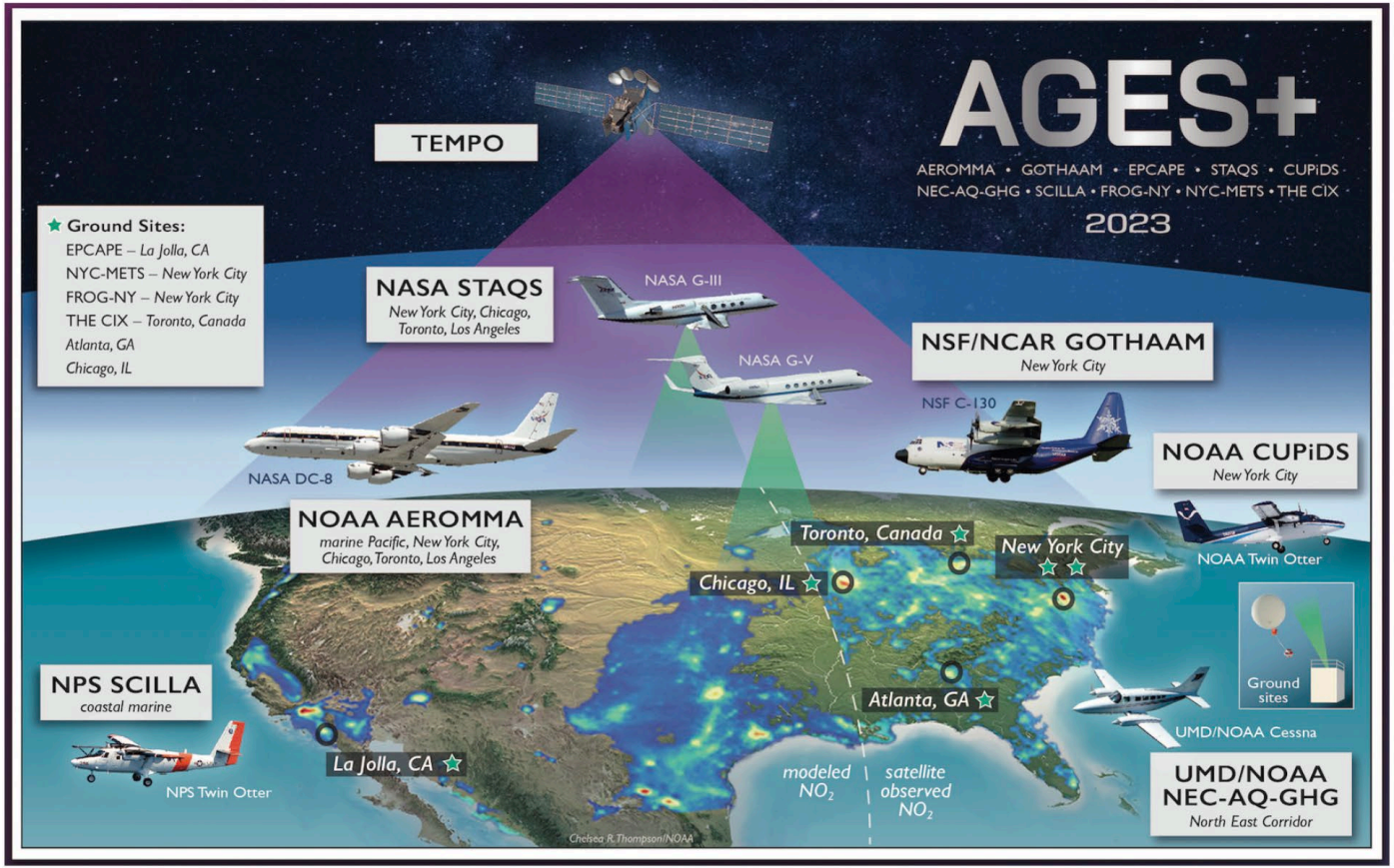


Figure 1. Example of the combined utilization of data data products to understand air quality through the set of field campaigns known as AGES+. In this schematic, satellite data from TEMPO (purple) provides a top-down estimate of NO_2, to complement ground-based monitors, model data, and research-focused aircraft and balloon measurements (NOAA 2023).

Grey = missing data
(usually due to clouds)

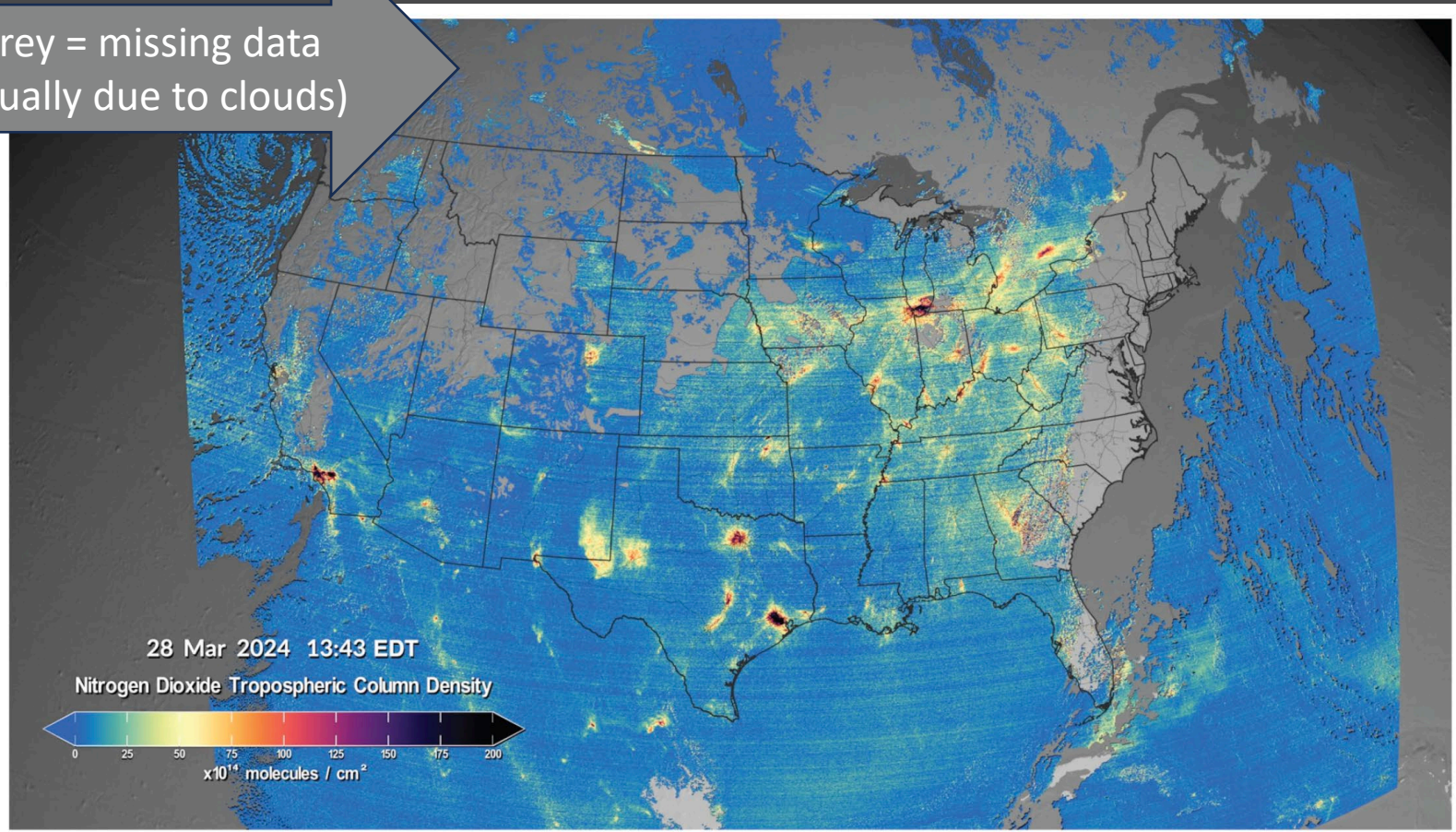
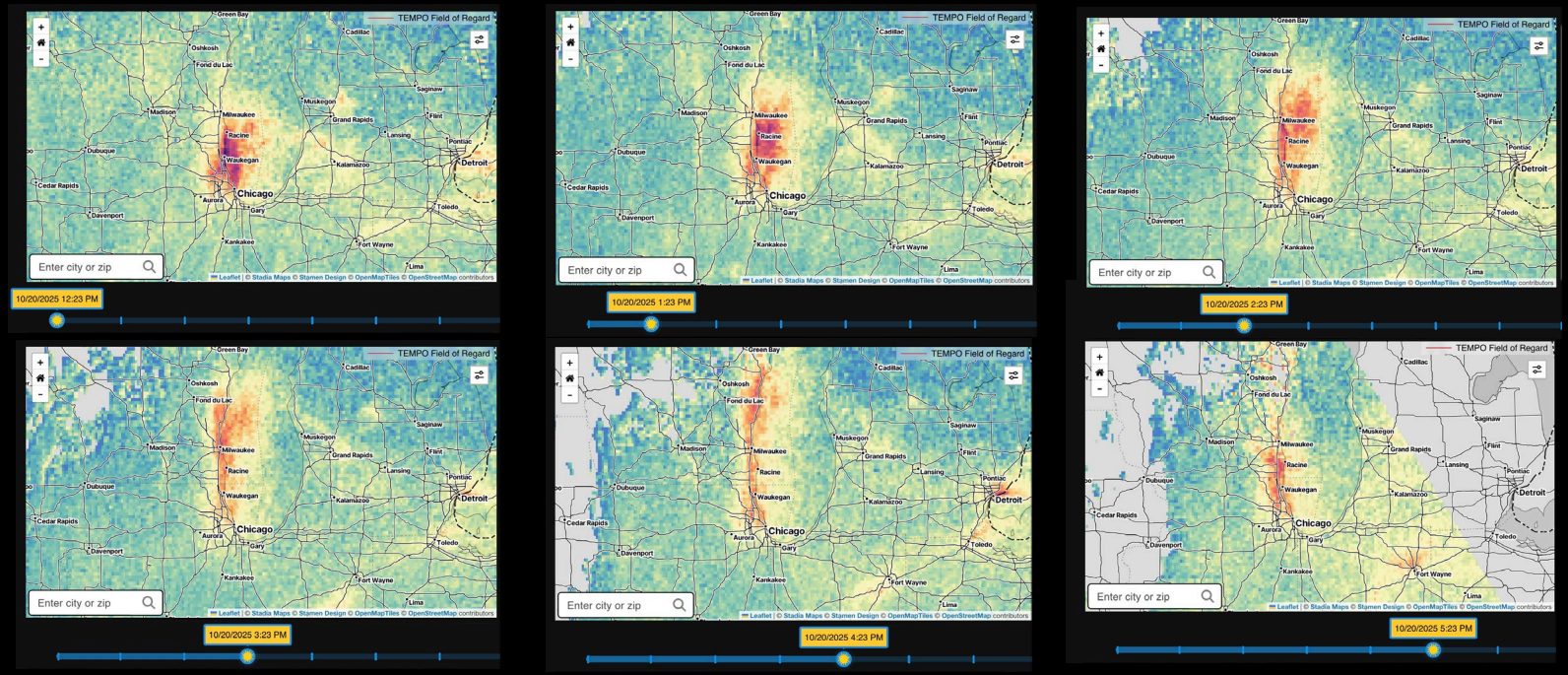


Figure 4. Example of nitrogen dioxide (NO_2) from the TEMPO instrument, here for March 28, 2024, mid-day conditions. (Schindler, NASA scientific visualization Studio, 2024).



NO_2 over Chicago area;
Oct. 20, 2025 (11:30 am to 6:30 pm

https://tempo.si.edu/data_for_public.html

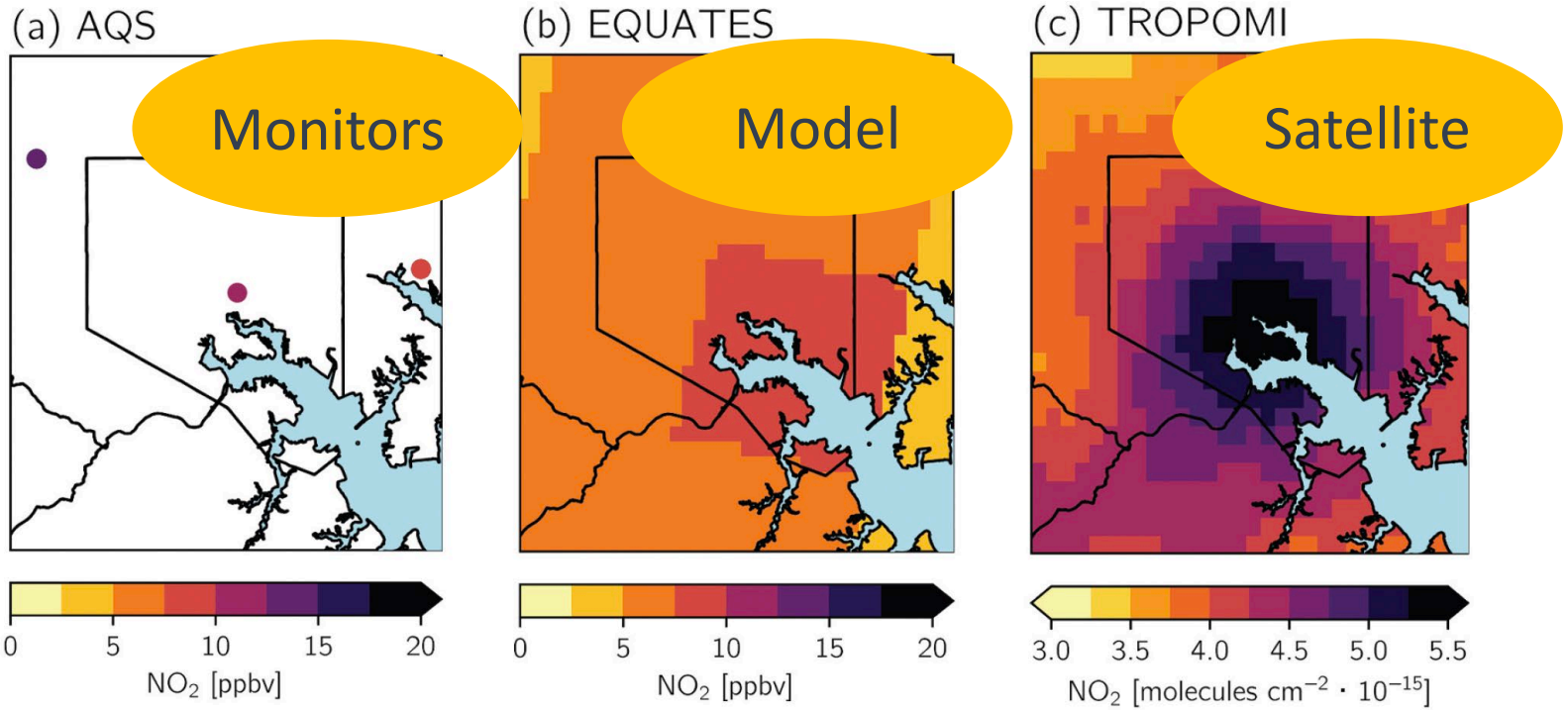


Figure 2. 2019 annual average NO_2 levels for different observational or modeled datasets with different spatial coverage and resolution over the Baltimore, MD metropolitan area: (a) NO_2 surface measurements; (b) estimated surface-level concentrations from the 12 km x 12 km EQUATES photochemical model, (c) tropospheric column measurements from an oversampled 1 km x 1 km TROPOMI product.

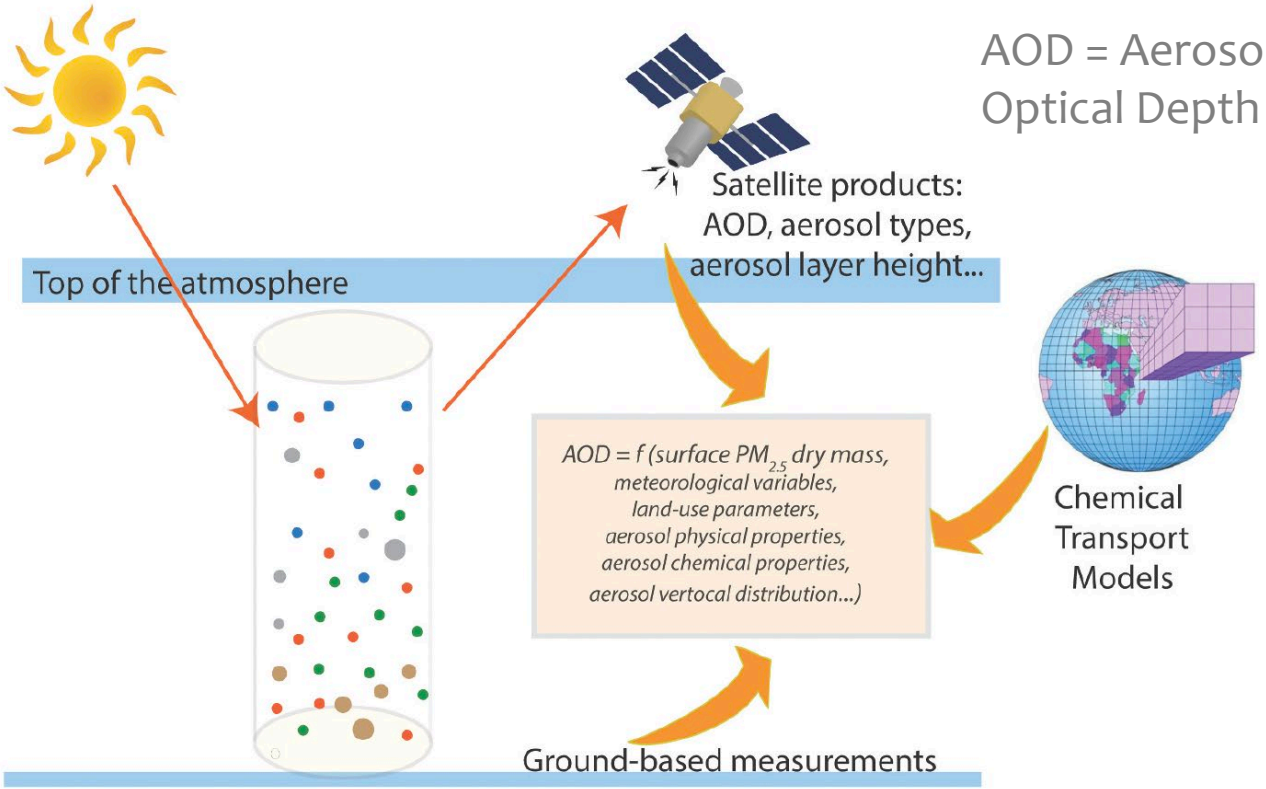


Figure 6. Schematic representation of satellite AOD, ground-based $PM_{2.5}$ measurements, and the role of chemical transport models in calculating AOD-$PM_{2.5}$ relationships.

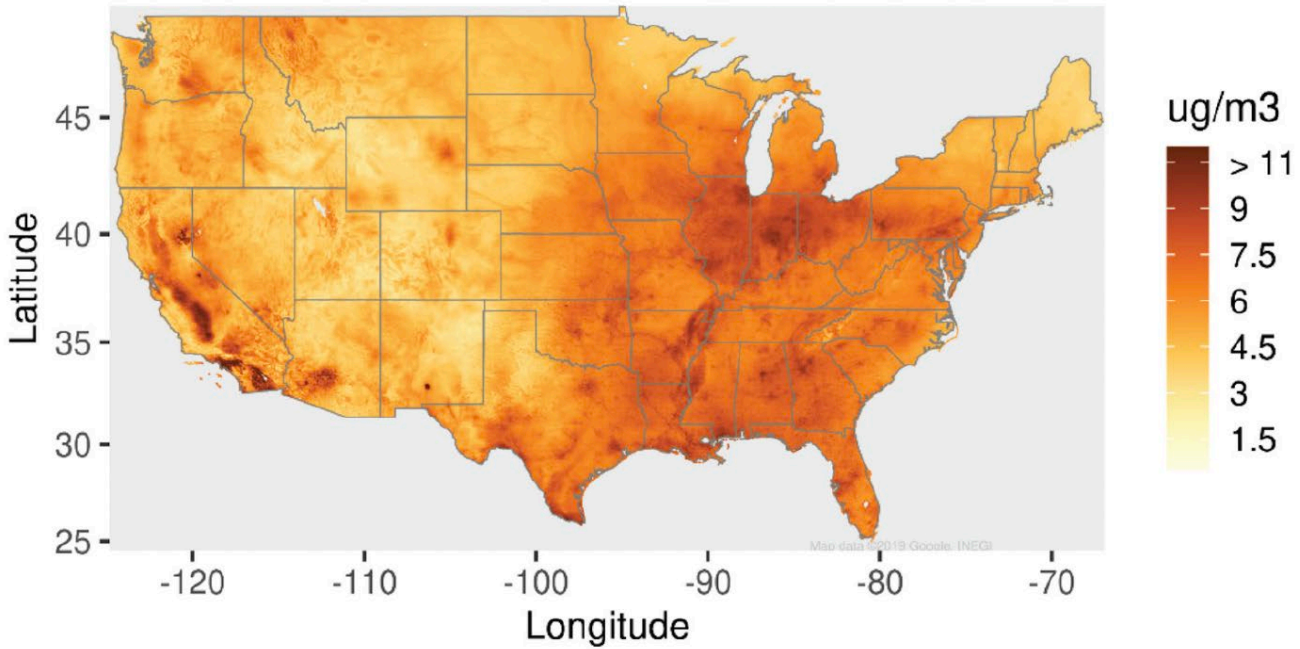


Figure 7. 2019 average $PM_{2.5}$ concentrations from Van Donkelaar et al. (2021), as presented by the EPA in the 2022 $PM_{2.5}$ Regulatory Impact Analysis (Figure 2–1, EPA 2022).

Table 1. Instruments relevant to air quality management, discussed in this paper, organized based on common use for AOD and/or for gas-phase species NO_2, HCHO and SO_2. Relevance to other chemical species is noted. We have generalized some domain and resolution information, which may vary depending on retrieval version or changes in operations.

Major Product for Air Quality Applications	Instrument(s) and Satellite(s)	General Domain and Resolution*
Low-Earth Orbiting		
AOD (+ related aerosol characteristics) modis.gsfc.nasa.gov	Instrument: Moderate Resolution Imaging Spectroradiometer (MODIS) Satellites: NASA Terra and Aqua Terra: 1999 - Present† Aqua: 2002 - Present†	Global, daily at Terra: 10:30 AM† Aqua: 1:30 PM† 10 km x 10 km*
AOD (+ NO_2, SO_2, HCHO, NH_3) www.nesdis.noaa.gov/our-satellites/currently-flying/joint-polar-satellite-system.	Instrument: Ozone Mapping and Profiler Suite - Nadir Mapper Spectrometer (OMPS-NM)/Visible Infrared Imaging Radiometer Suite (VIIRS)/Cross-track Infrared Sounder (CrIS) Satellite(s): NASA/NOAA Suomi National Polar-orbiting Partnership (S-NPP): 2011 - Present NOAA-20: 2017 - Present NOAA-21: 2022 - Present	All: Global, daily S-NPP: 1:30 AM, 1:30 PM NOAA-20 ~25 min behind S-NPP; NOAA-21 ~25 min ahead of S-NPP S-NPP: 7.5 km x 3 km NOAA-20: 17 km × 12 km NOAA-21: 10 km × 10 km
AOD (+ composition and vertical structure) misr.jpl.nasa.gov	Instrument: The Multi-angle Imaging SpectroRadiometer (MISR) Satellites: NASA Terra and Aqua Terra: 1999 - Present†	Global, Every 9 days, with repeat coverage between 2 and 9 days depending on latitude, at Terra: 10:30 AM† 17.6 km x 17.6*
AOD (+ composition and vertical structure) www-calipso.larc.nasa.gov	Instrument: Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) Satellite: Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO), collaboration between NASA and the French Space Agency, CNES 2006 – 2023	Every 16 days/Global 5 km x 5 km

... + 3 more for AOD..

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Major Product for Air Quality Applications	Instrument(s) and Satellite(s)	General Domain and Resolution*
NO_2, HCHO & SO_2 (+ ozone + profiles, BrO, OClO, aerosols + aerosol characterization, cloud properties) aura.gsfc.nasa.gov/omi.html.	Instrument: Ozone Monitoring Instrument (OMI) Satellite: NASA Aura satellite 2004 - Present	Global, daily at 1:30 PM 13 km x 24 km
NO_2, HCHO & SO_2 (+ CO, CH_4, AOD + aerosol vertical structure via O_2 A bands or A & B bands) https://www.tropomi.eu/.	Instrument: TROPOspheric Monitoring Instrument (TROPOMI) Satellite: ESA Copernicus Sentinel-5 Precursor 2017 - Present	Global, daily at 1:30 PM 5.5 km × 3.5 km‡
NO_2, HCHO & SO_2 (+ ozone, aerosol index + reflectivity, cloud parameters) https://acsaf.org/gome-2.php.	Instrument: ESA Global Ozone Monitoring Experiment 2 (GOME-2); Infrared atmospheric sounding interferometer (IASI) Satellites: EUMETSAT Metop-A -B and -C Metop-A: 2006–2021; Metop-B: 2012 - Present; Metop-C: 2019	Global, every 1.5 days at 9:30 AM 40 × 40 km^2 on Metop-A 80 × 40 km^2 on Metop-B and -C

Table 1. Instruments relevant to air quality management, discussed in this paper, organized based on common use for AOD and/or for gas-phase species NO_2, HCHO and SO_2. Relevance to other chemical species is noted. We have generalized some domain and resolution information, which may vary depending on retrieval version or changes in operations.

Major Product for Air Quality Applications	Instrument(s) and Satellite(s)	General Domain and Resolution*
Geostationary		
AOD (+ related aerosol characteristics) www.goes-r.gov.	Instrument: Advanced Baseline Imager (ABI) Satellite Series: NOAA Geostationary Operational Environmental Satellites (GOES-R) GOES-16/GOES-East: 2017 - Present, Centered over 75.2° W GOES-18/GOES-West: 2023 - Present, Centered over 137.2° W GOES-17 serves as backup *GeoXO planned as next generation 2030s*	North America, full disk every 15 minutes, continental United States every 5 minutes 2 km x 2 km
AOD www.data.jma.go.jp/mscweb/en/himawari89/space_segment/spsg_ahi.html.	Instrument: Advanced Himawari Imager (AHI) Satellites: Japanese Space Agency Himawari-8 and Himawari-9, over 140.7° E, Himawari-8: 2014 - Present Himawari-9: 2016 - Present	Asia, Full disk every 10 minutes 2 km x 2 km
NO_2, HCHO & SO_2 (+ AOD, aerosol layer height via O_2-O_2 dimer, ozone)	Instrument: Geostationary Environment Monitoring Spectrometer (GEMS) Satellite: KARI's Geostationary Korea Multipurpose Satellite (GEO-KOMPSAT-2B), over 128.2° E 2020 - Present	Asia, hourly (during daylight) 3.5 km x 8 km
NO_2, HCHO & SO_2[§] (+ AOD[§], ozone) https://tempo.si.edu/.	Instrument: NASA Tropospheric Emissions: Monitoring of Pollution (TEMPO) Satellite: Intelsat 40e (commercial satellite), over 91° W 2023 - Present	North America, hourly (during daylight) 2 km x 4.75 km

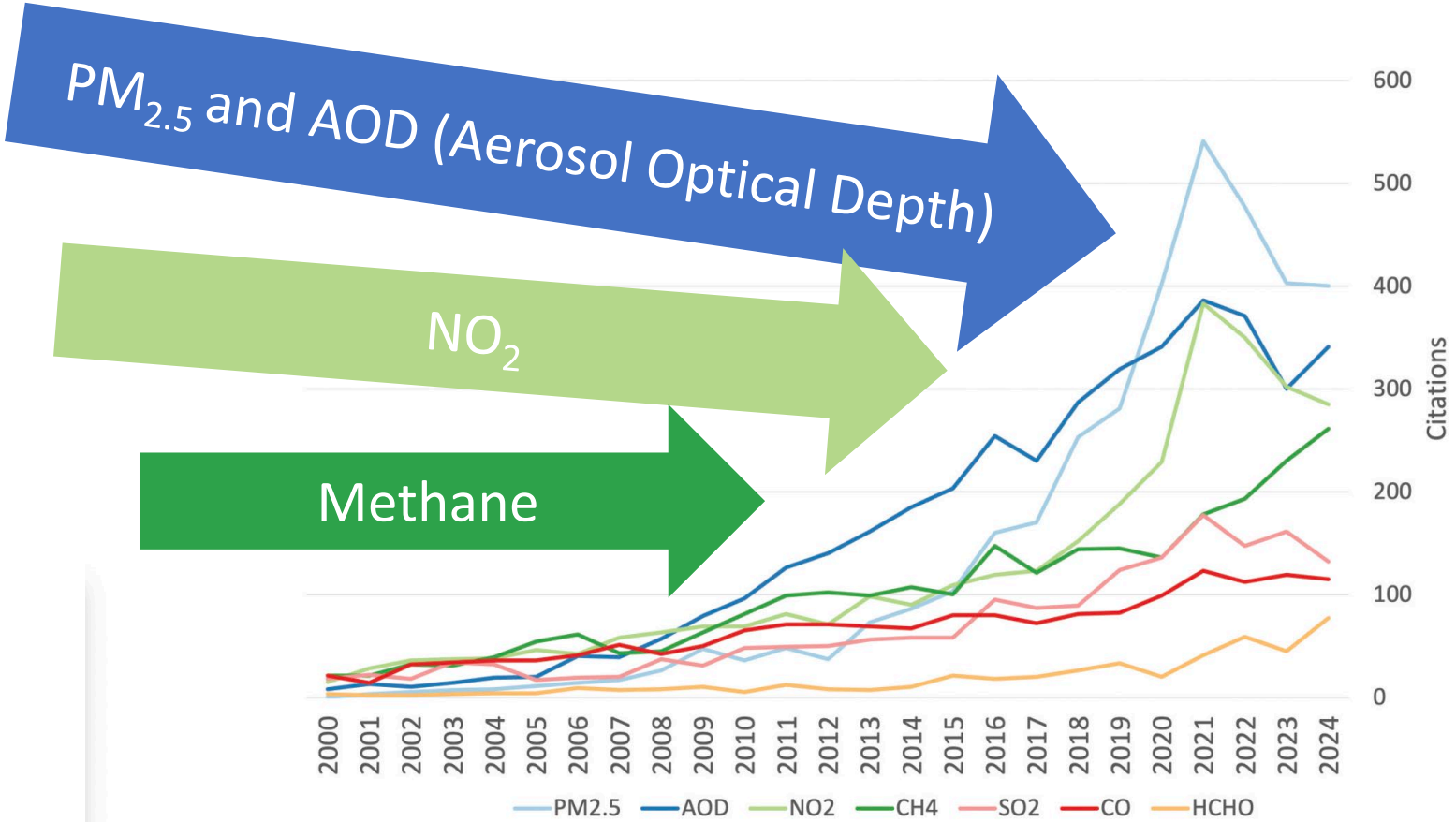
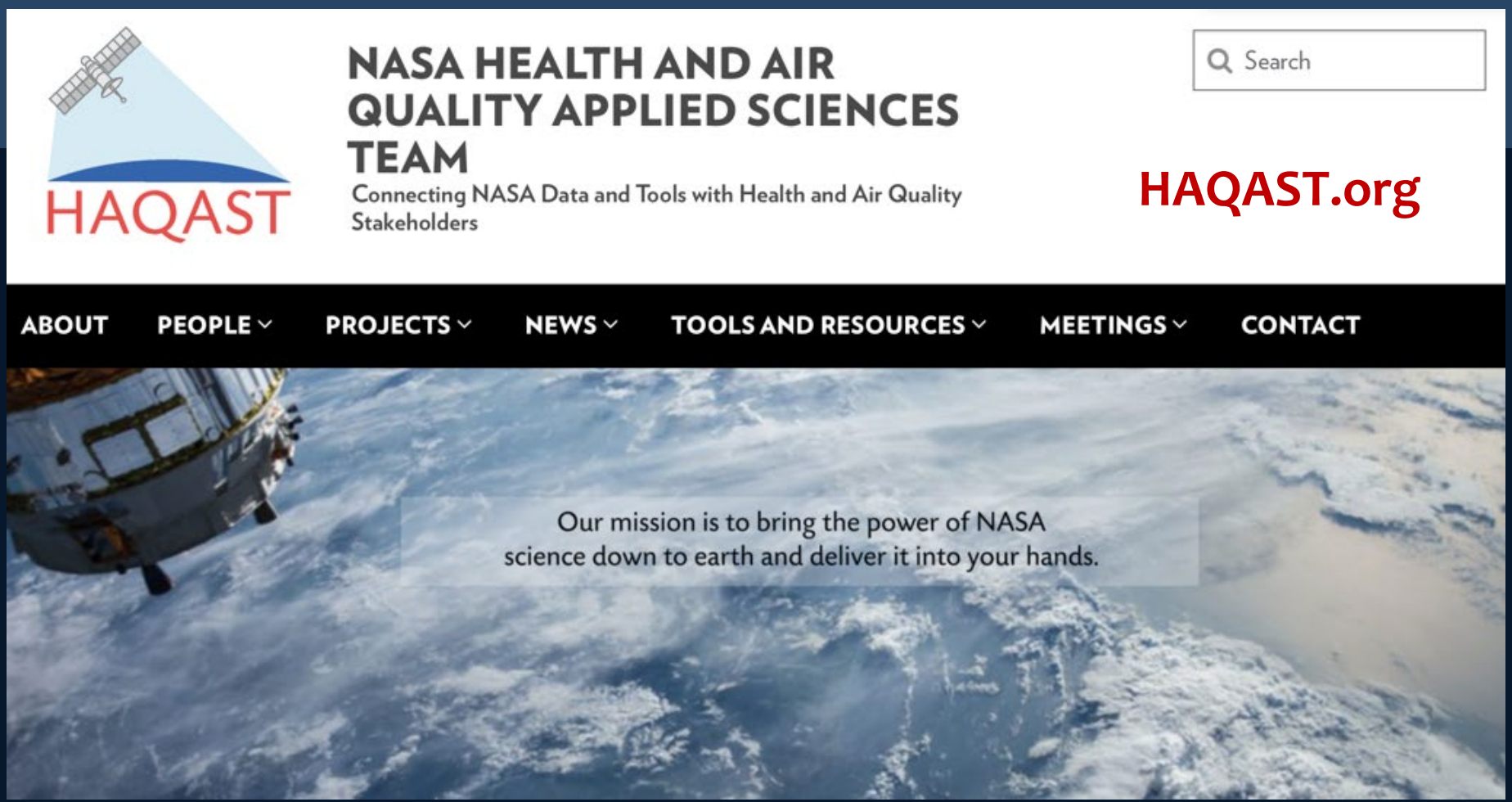


Figure 3. Comparison of citations from Web of Science, based on queries with keywords "PM2.5," "AOD," "NO2," "CH4," "SO2," "CO," "HCHO," and "satellite" over time. All terms searched in web of science (March 6, 2025) as the pollutant term itself with "AND satellite."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HAQAST1:
2011-2016

HAQAST2: *2016-2020*
HAQAST3: *2021-2025*
HAQAST4: 2025-2029

The team structure fundamentally changes outcomes.

- Increased visibility of work and resources to end-users
- Culture to support and promote collaborations
- Growth of two-way dialogue
- Increased collaborations to meet stakeholder needs
- Rapid spin-up of high-value activities

HAQAST Ambassadors

Zac Adelman
Lake Michigan Air Directors Consortium (LADCO)

Temilayo Adeyeye
New York State Department of Health

Doug Boyer
Texas Commission on Environmental Air Quality

Eric Choi
Mission Control

Kelly Crawford
Bay Area Air District

Barron H. Henderson
United States Environmental Protection Agency

Tabassum Z Insaf
New York State Department of Health

Alex Karambelas
NESCAUM

Byeong-Uk Kim
Georgia Environmental Protection Division

Maeve MacMurdo
Cleveland Clinic

Libby Mohr
Environmental Defense Fund

Amirhosein Mousavi
Google / University of Southern California

Leticia Nogueira, PhD MPH
American Cancer Society

Pallavi Pant
Health Effects Institute

Allison Patton
Health Effects Institute

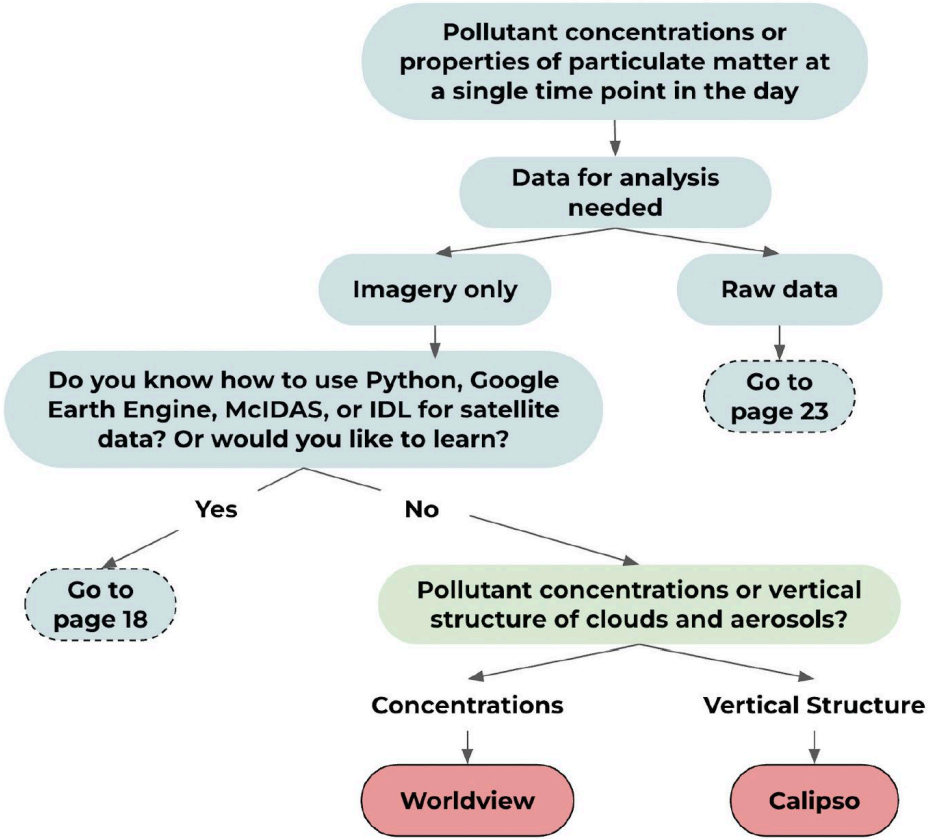
Nathan Pavlovic
Sonoma Technology

Pat Reddy
University of Wisconsin-Madison

Mary Tran
University of Chicago – EPIC Air Quality Fund

Mary Uhl
WESTAR

https://haqast.org/ambassadors/



HAQAST.org

Figure 5. Excerpt from the McGinnis, Holloway, and Bratburd (2023) flowchart, where blue represents steps along the path connecting need to outcome, green represents final criteria in the matching process, and red represents data, tutorial, or research paper end-points.

Something in the Air Reports

A series of reports highlighting the promising potential of satellite data to complement and enhance the United States' existing air quality monitoring network.

As a nation, we make great strides cleaning up air pollution—but not all communities benefit equally.

National Ambient Air Quality Standards (NAAQS)

The Clean Air Act directs EPA to periodically review the National Ambient Air Quality Standards. Together with our Tribal, state, and local air agency partners, we have successfully implemented those standards to bring Americans cleaner air and lower risks of adverse health effects.

Play background video of NASA 2005 - 2023 NO_2 satellite imagery

ladco.org/pm2-5-urban-increment-calculator-updated/

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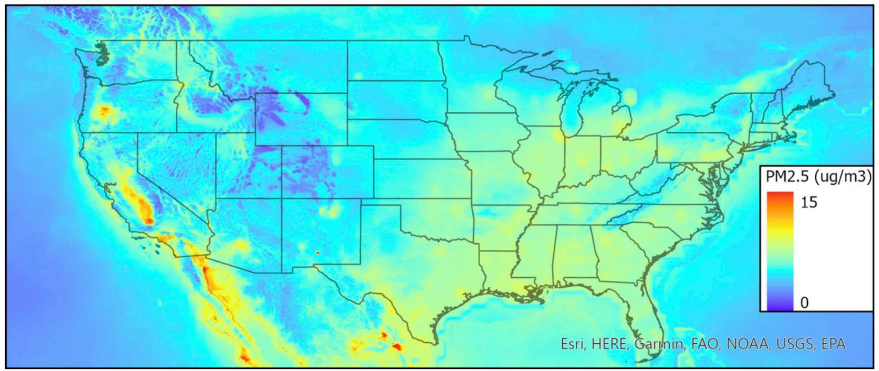


Figure 1. Washington University 0.01 degree 2022 average $PM_{2.5}$.

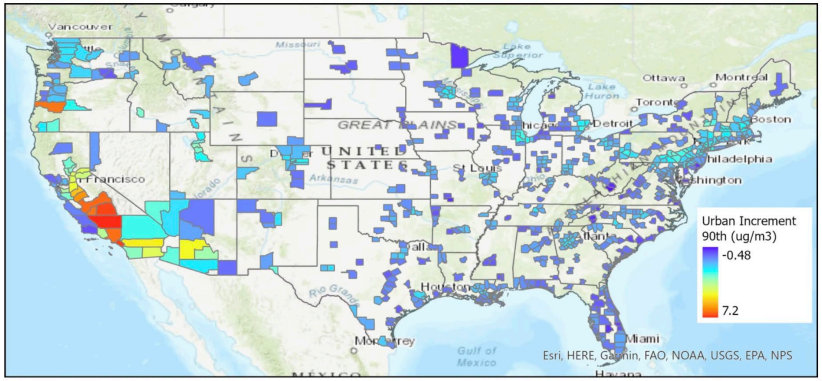
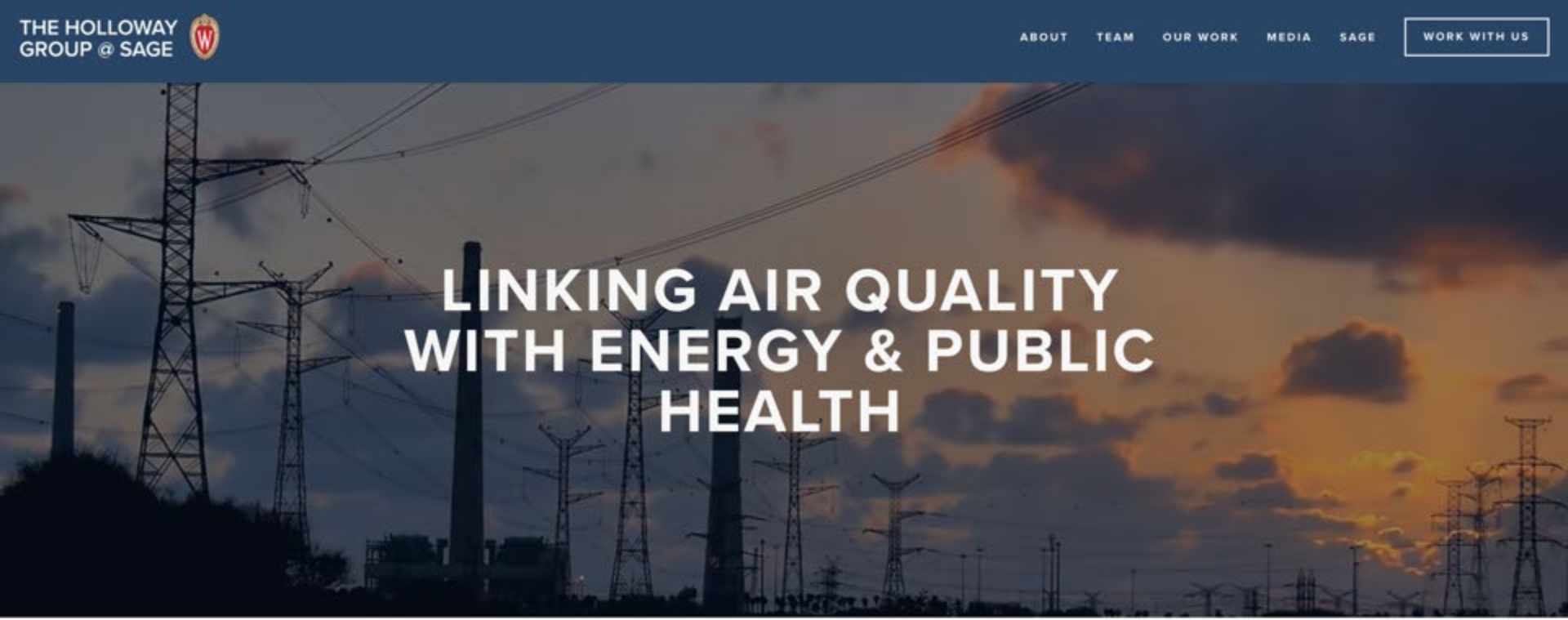


Figure 7. Urban increment based on the 90th percentile concentration for urban counties, determined as the difference between the 90th percentile urban and mean rural $PM_{2.5}$ concentrations.



The Holloway Group Advances Air Quality Research To Inform Science And Policy. We Partner With Organizations To Ensure The Relevance Of Our Work To Real-World Needs.

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