Creating & Using Open Global and Local Air Quality Data at NASA GMAO

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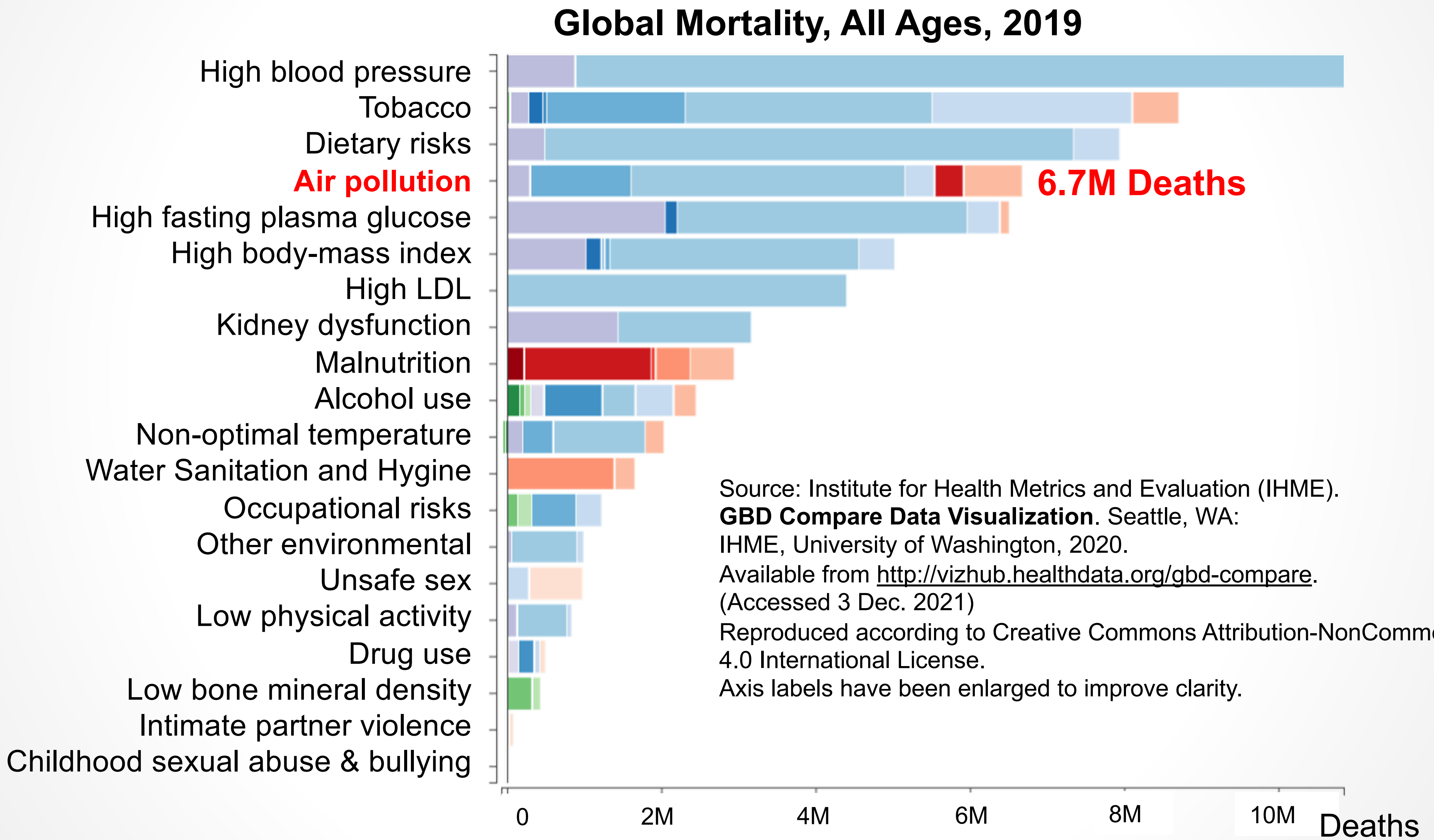
	Stephen Cohn	**Clarity:**	Sean Wihera
	Bryan Duncan	**WUSTL:**	Randall Martin
		NYU:	Noussair Lazrak

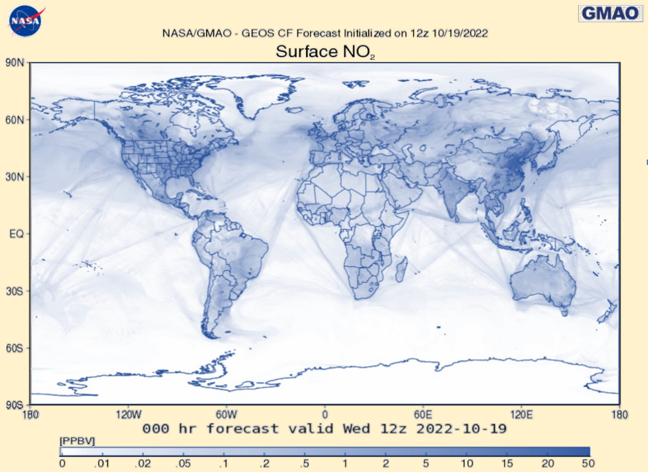
Air quality is the leading environmental health concern



Source: Institute for Health Metrics and Evaluation (IHME). **GBD Compare Data Visualization**. Seattle, WA: IHME, University of Washington, 2020. Available from http://vizhub.healthdata.org/gbd-compare. (Accessed 3 Dec. 2021)

Axis labels have been enlarged to improve clarity.

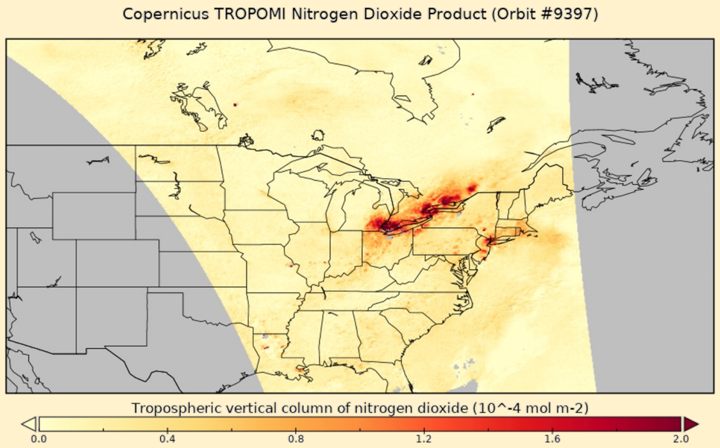
We understand air quality with both global and local data



Global Data Sources

simulation models
+ global coverage
+ forecasting
- limited resolution
? updated emissions

satellite retrievals
+ global coverage
- low time resolution
- column-integrated
? relevant to surface



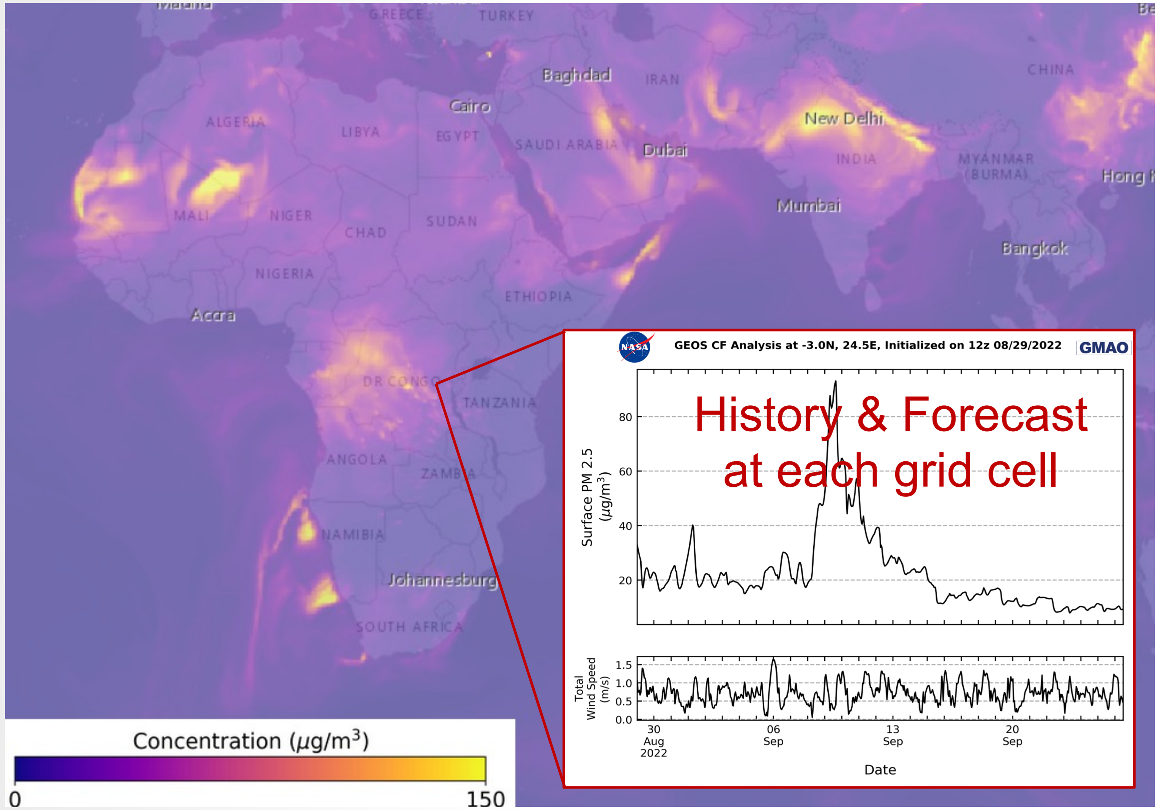
regulatory monitoring
+ accurate
- expensive
? representative

low-cost monitoring
+ relatively inexpensive
+ dense/remote deployment
- greater noise and bias
? locally calibrated

Local Data Sources

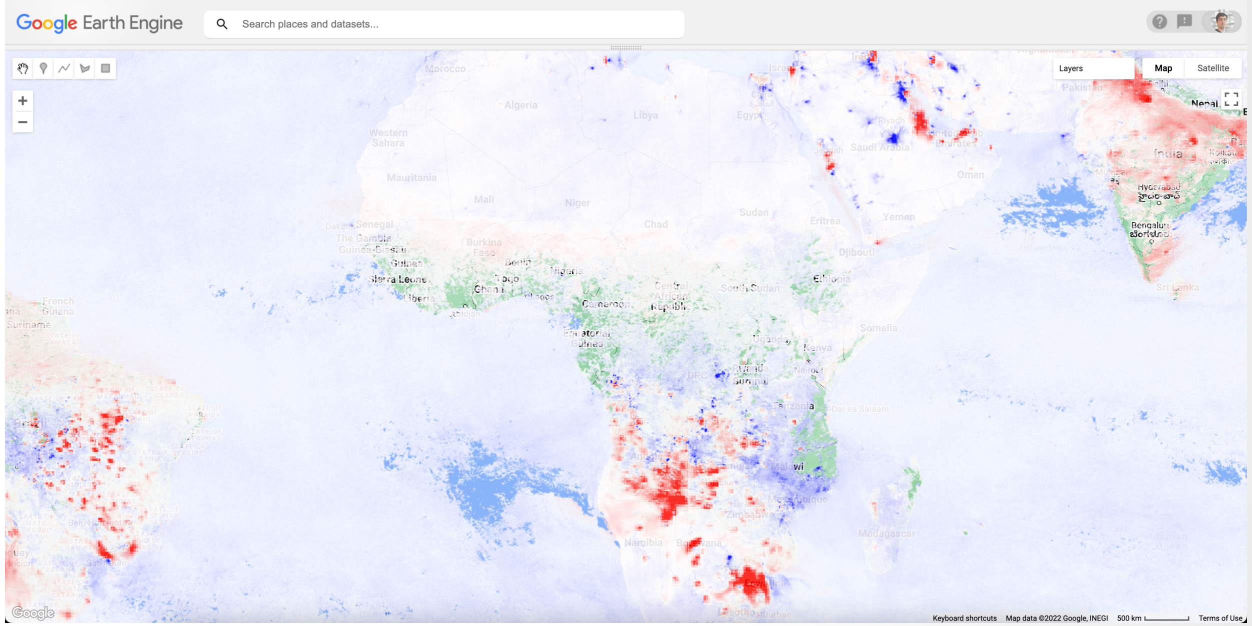
The Big Picture: global air quality with NASA GEOS-CF

Example: interactive FLUID map for GEOS-CF $PM_{2.5}$



Sources: GEOS-CF FLUID interactive map
https://fluid.nccs.nasa.gov/cf_map/index
GEOS-CF on Google Earth Engine https://code.earthengine.google.com/
ee.ImageCollection("NASA/GEOS-CF/v1/rpl/tavg1hr")

Example: comparing GEOS-CF NO_2 with satellite data (ESA TROPOMI) in Google Earth Engine



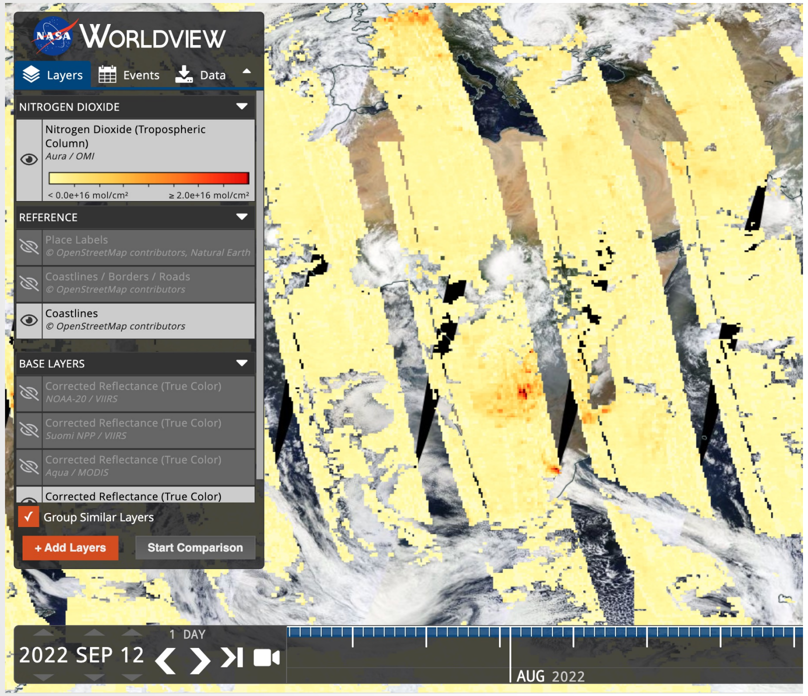
Agencies like NASA generate global air quality model analyses and forecasts & make them freely available

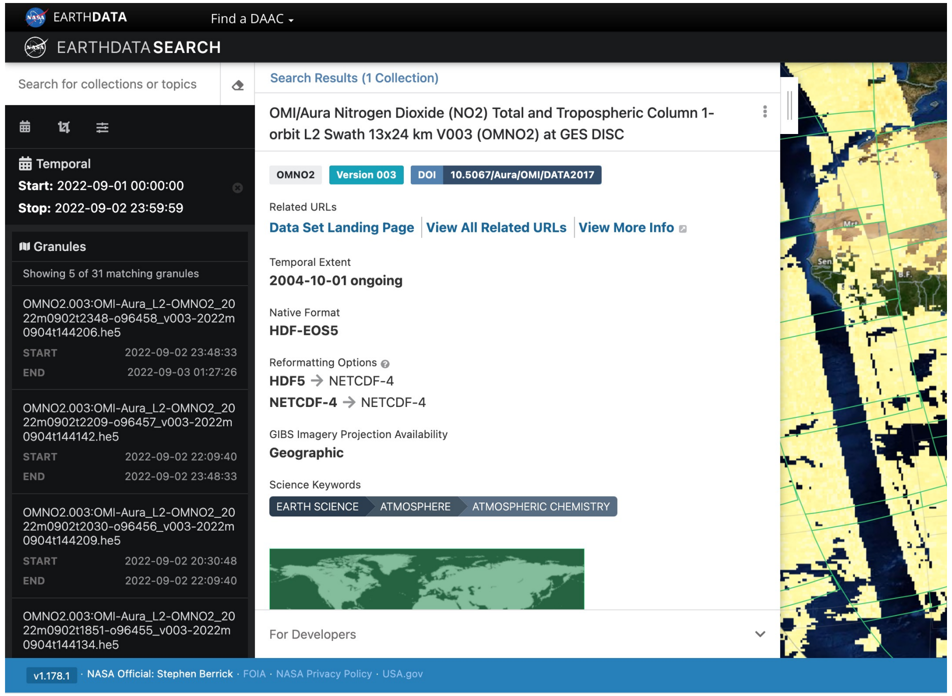
Top-Down View: satellite air quality data from NASA & others

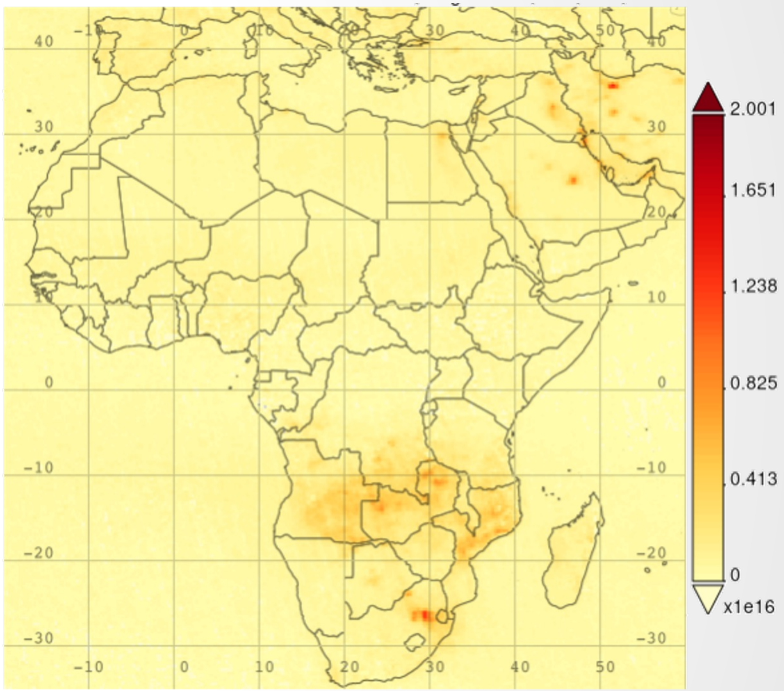
Worldview
simplified data visualization

Earthdata
explore, subset, download data

Giovanni
simple online data analysis







Example: OMI Satellite Tropospheric Column NO_2

Satellites are expensive, but provide valuable “top down” insight into air quality as they orbit above the Earth

Sources:
NASA Worldview. https://worldview.earthdata.nasa.gov/
NASA Earthdata. https://www.earthdata.nasa.gov/
NASA Giovanni. https://giovanni.gsfc.nasa.gov/giovanni/

The Ground Truth: regulatory air quality monitors and LCS

Regulatory Monitoring


metone.com

twobtech.com

These form the “backbone” of the monitoring system, but are relatively sparse (especially when taking a global view).

+ accurate
- expensive
? representativity

Low-Cost Sensors (LCS)

purpleair.com


clarity.io

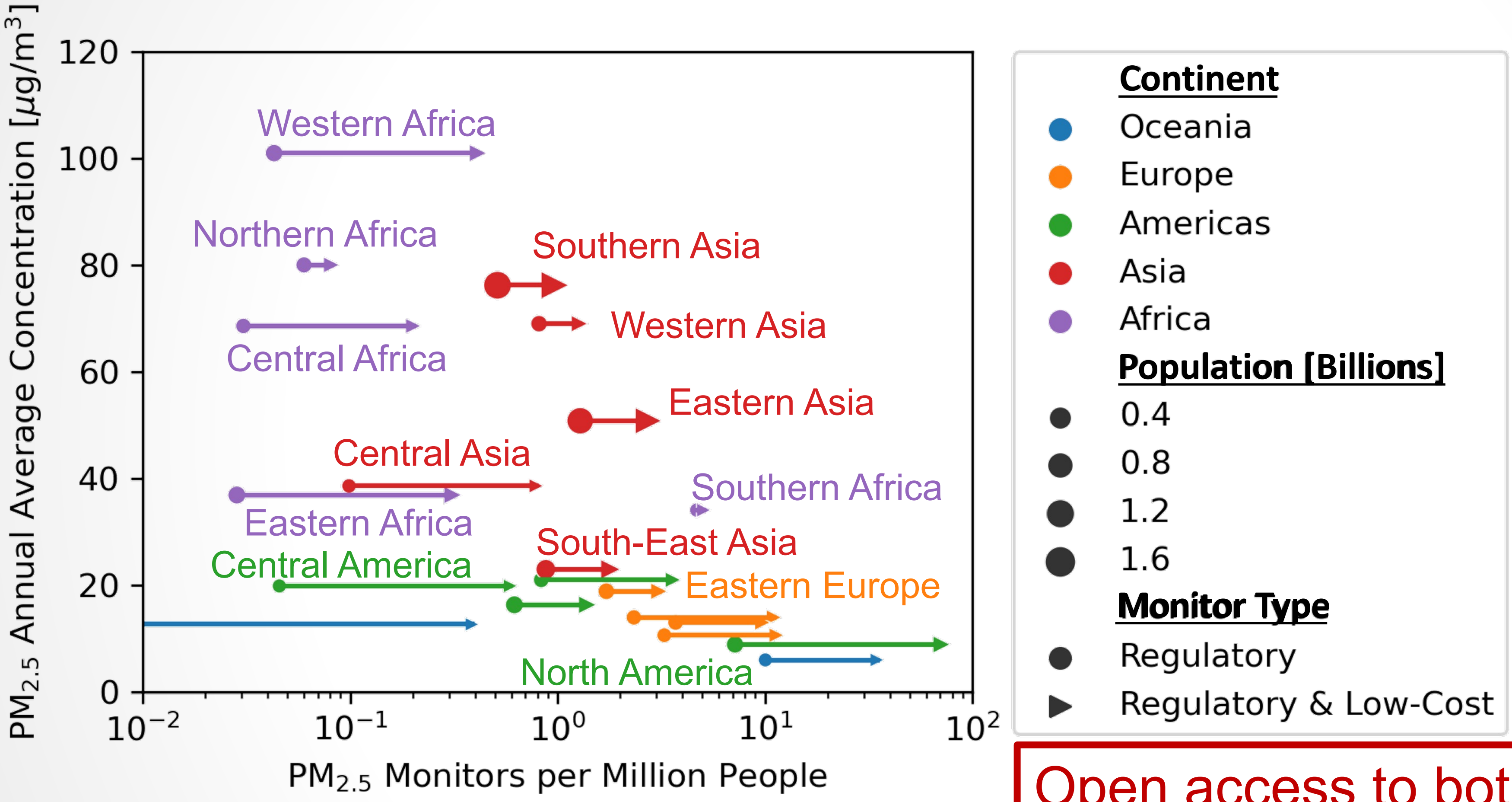
gasleaksensors.com

calibration is an open issue, but leveraging network density can offset some of these shortcomings, and allows greater access to air quality monitoring technologies

+ relatively inexpensive
+ dense and/or remote deployment
- greater noise and bias

Accurate but expensive regulatory monitors plus cheaper but more uncertain LCS give the “ground truth”

Global inequalities in air quality data: every datapoint counts



Source: Malings et al. (2020). "Application of low-cost fine particulate mass monitors to convert satellite AOD to surface concentrations in North America and Africa." *Atmospheric Measurement Techniques.* DOI: 10.5194/amt-13-3873-2020.
Updated analysis based on open air quality data available from openAQ.org

Many regions (especially Africa & Asia) feature high $PM_{2.5}$ concentration but low per-capita $PM_{2.5}$ monitor density, leading to poor AQ data coverage.

Including low-cost sensors increases per-capita AQ monitor density by up to an order of magnitude in some regions.

Open access to both regulatory and low-cost sensor datasets are key to filling in global air quality data gaps

Evaluating GEOS-CF model with Open Surface Data

NASA GMAO GEOS Composition Forecasts (GEOS-CF)

Evaluation of daily forecasts

Date

31 July 2022

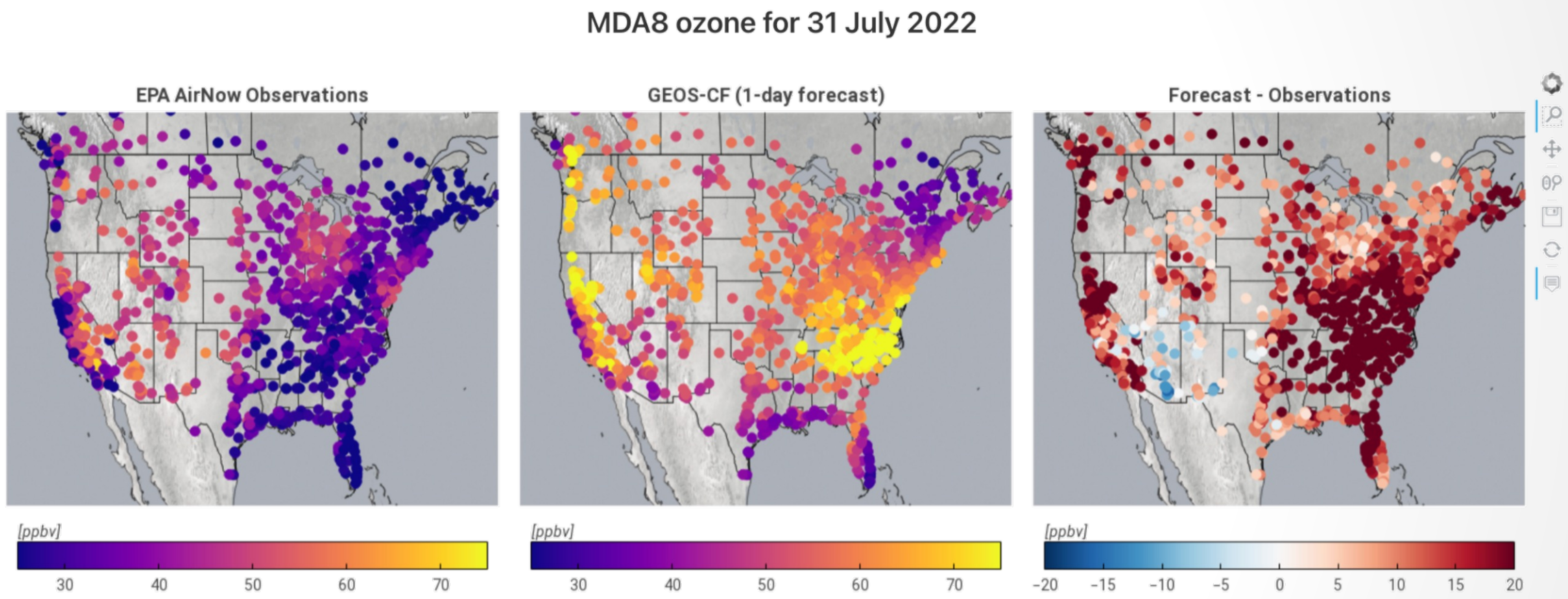
Region

U.S.

Parameter

MDA8 ozone

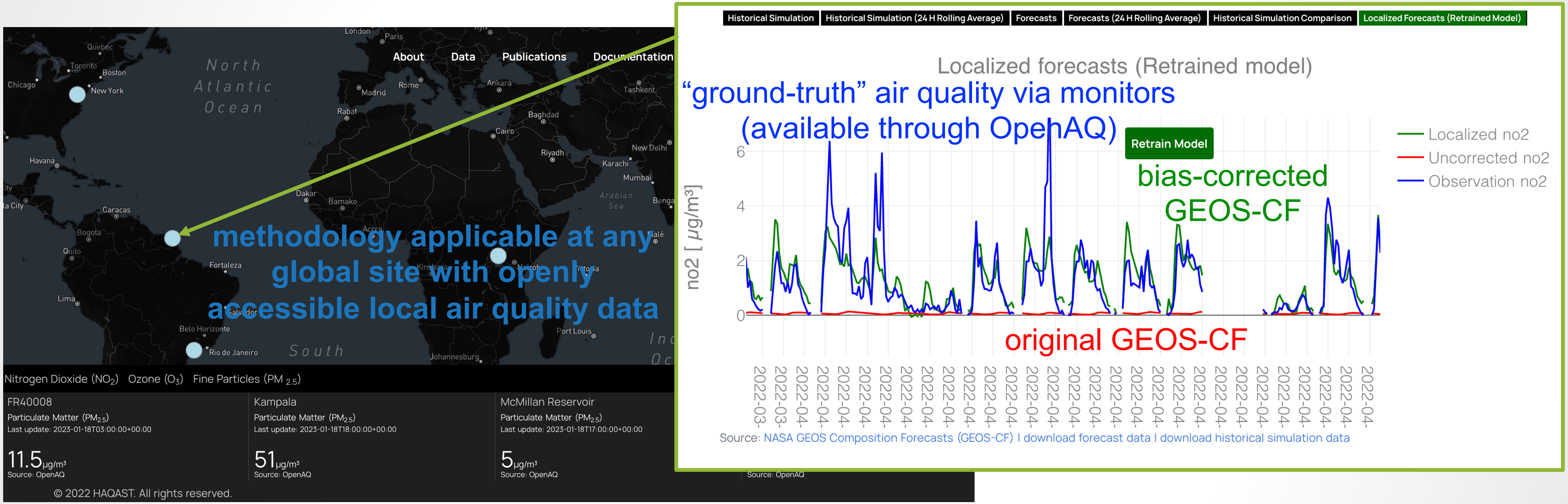
Submit



Tool developed by Viral Shah, NASA GMAO (SSAI)

Notes and data sources: The observations are from the EPA AirNow program and were made by over 120 federal, state, local, and tribal air quality agencies. The AirNow observations are preliminary and subject to change. The GEOS-CF system is a product of the NASA Global Monitoring and Analysis Office (GMAO). It provides daily, global forecasts of atmospheric composition at a spatial resolution of 25 km, using meteorological analyses from other GEOS systems. These forecasts are intended as research datasets for use by NASA researchers and the broader community.

Localized bias-corrected GEOS-CF forecasts with CityAQ



Sources: **Project overview:** https://www.wri.org/initiatives/cityaq

Methodology description: Keller et al. (2021). "Global impact of COVID-19 restrictions on the surface concentrations of nitrogen dioxide and ozone." *Atmospheric Chemistry and Physics.* DOI: 10.5194/acp-21-3555-2021.

Web-based tool: https://noussairlazrak.github.io/localized_forecasts/#

Visualizations provided by Noussair Lazrak, NYU

Bias-correcting global air quality forecasts with local data from OpenAQ monitor stations in the CityAQ project

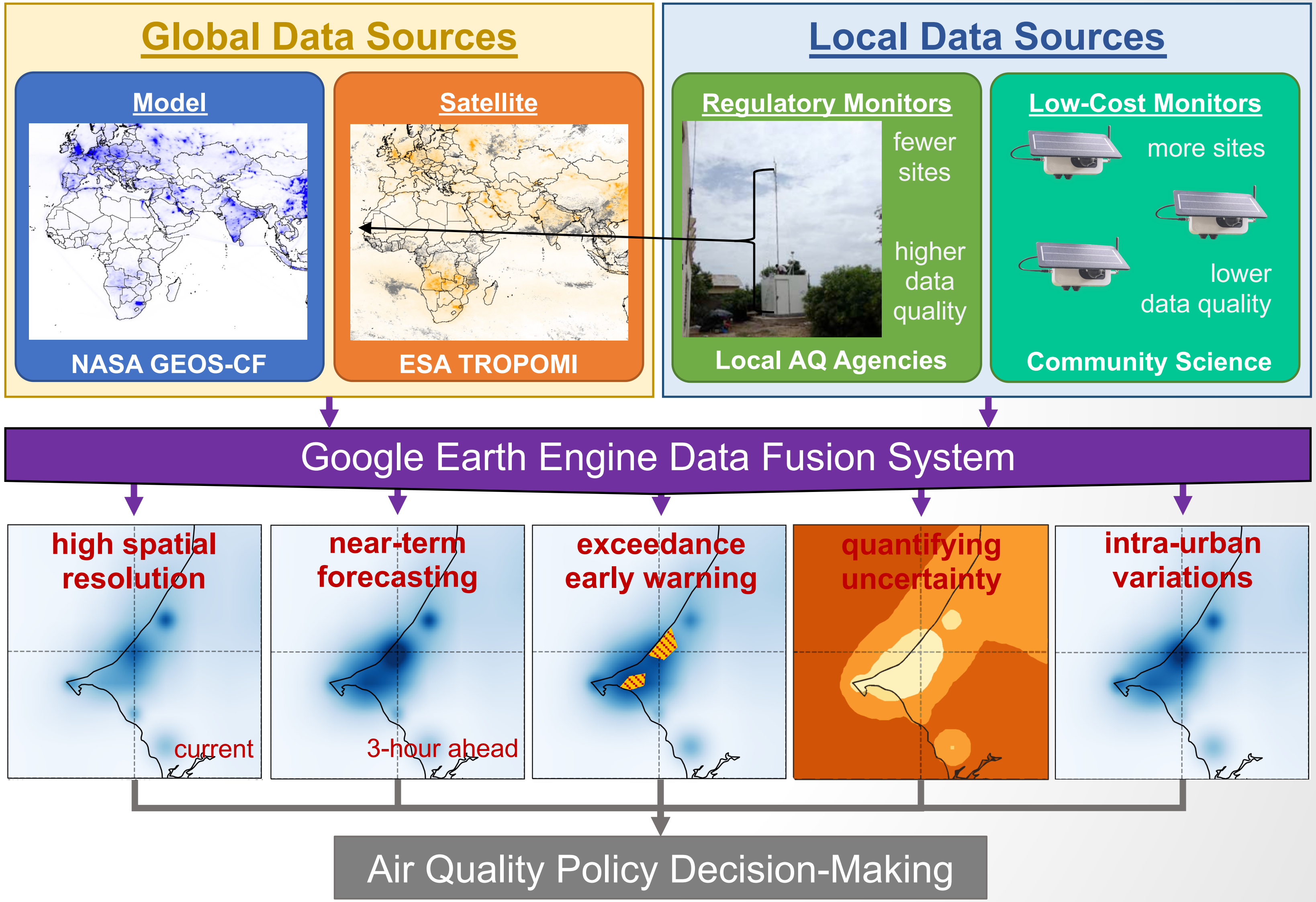
Our ongoing NASA-funded project's objective is to…

…integrate diverse **global** and **local** air quality data sources…

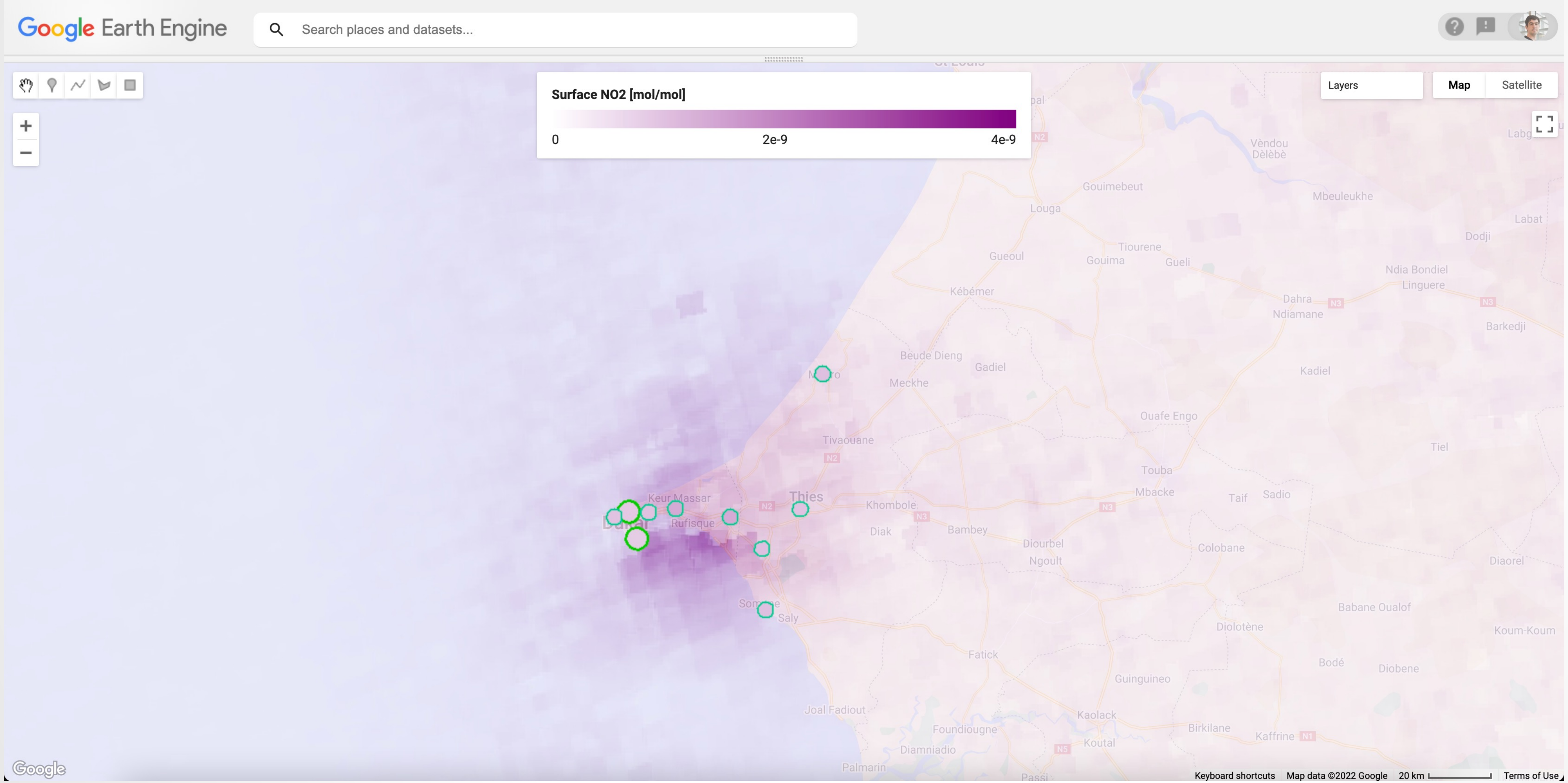
…using the cloud computing platform of **Google Earth Engine**…

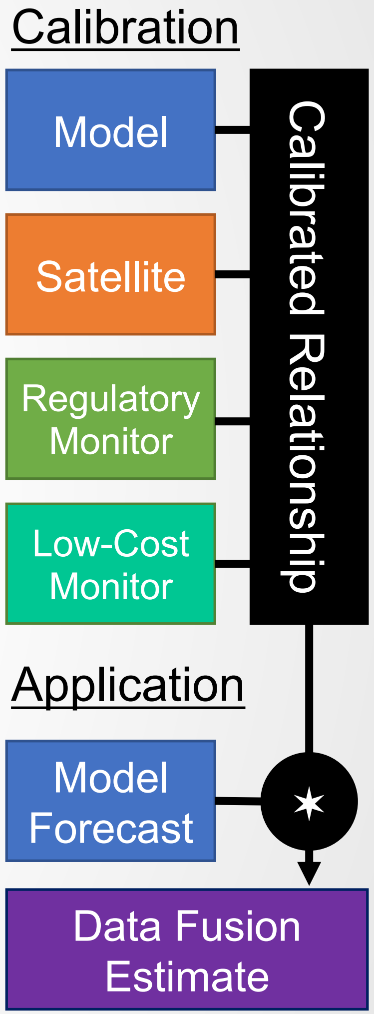
…to provide synthesized **estimates** and **forecasts** of air quality at a **local scale** but with a **global scope**…

…which will be freely accessible by air quality managers worldwide, facilitating their **decision-making** processes.



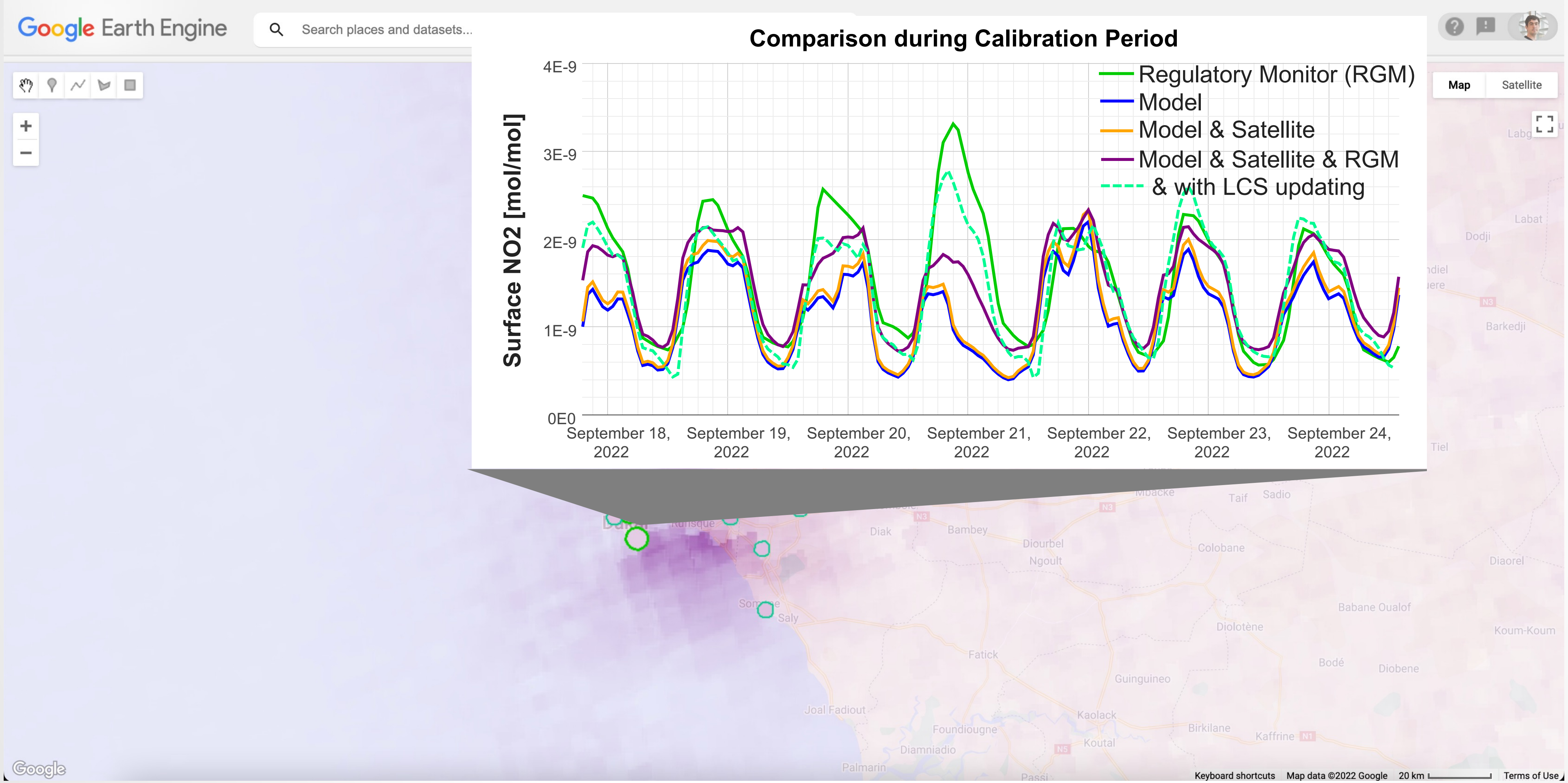
Data Fusion in GEE (preliminary demonstration)



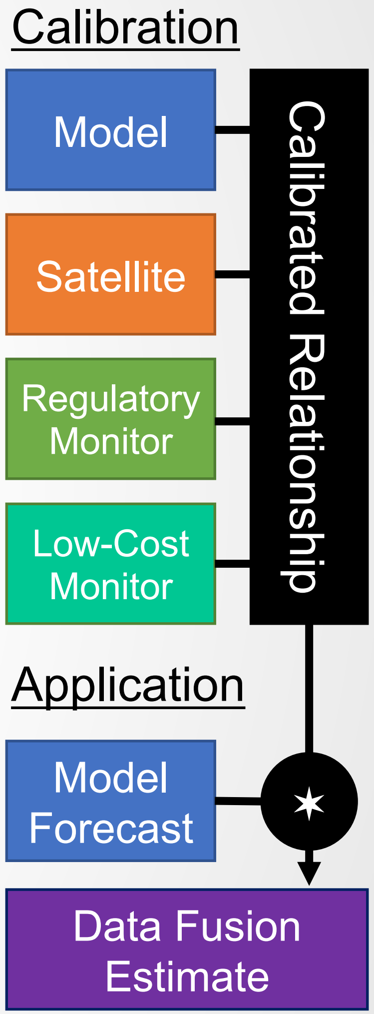


Screenshot of https://code.earthengine.google.com/ (code by presenter)

Data Fusion in GEE (preliminary demonstration)



Screenshot of https://code.earthengine.google.com/ (code by presenter)



Open data key to address the global air quality problem

Sources of Open Data

- National & International agencies (e.g., NASA): satellites & models, regulatory monitoring
- Community science and activism: local insight & data (especially low-cost sensors)

Dissemination of Open Data

- Data can't just be available, it must be accessible (e.g., API access, web tools like NASA Worldview)
- Aggregators (e.g., OpenAQ) have a big role to play here (quality filtering, data systematization, etc.)

Uses of Open Data

- Comparing different data sources boosts confidence in our air quality assessments
- Synthesizing from all available (open) data sources will give the most robust insights

Integration of Open Data

- Open geospatial data analysis platforms (e.g., Google Earth Engine) bring together many type of data with computing power to answer questions and test solutions.

Thank You!

Questions & Comments?

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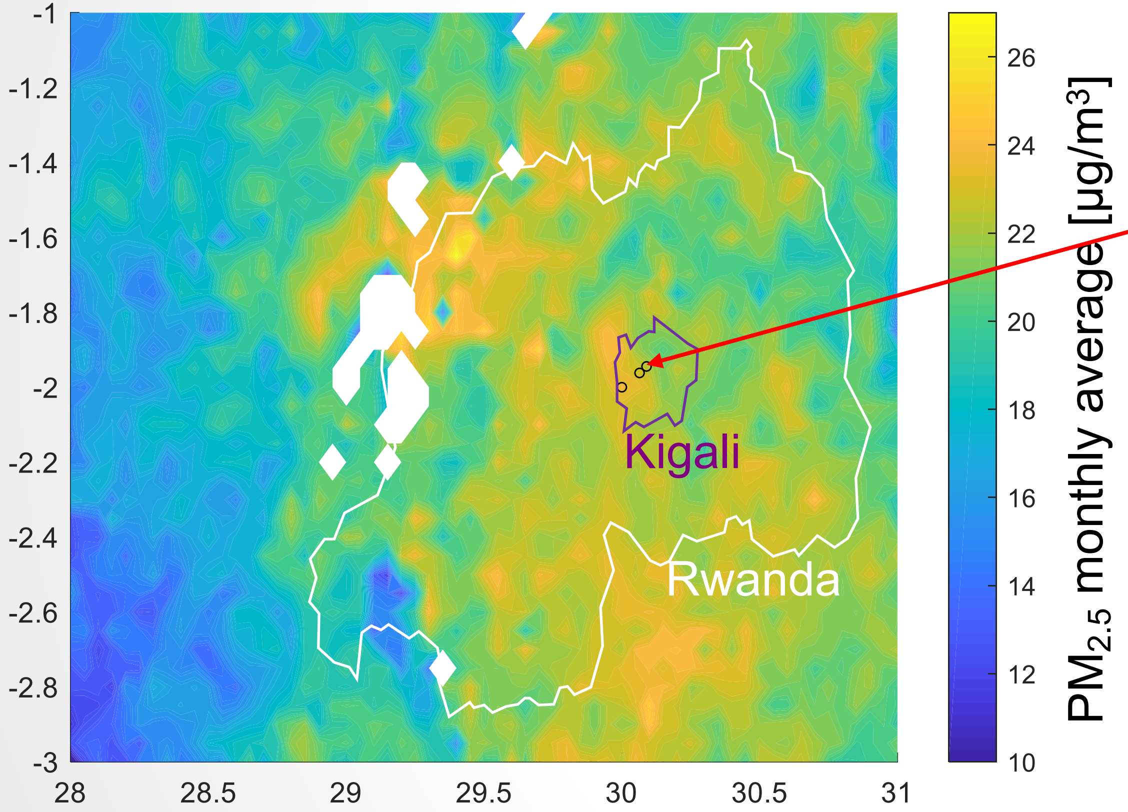
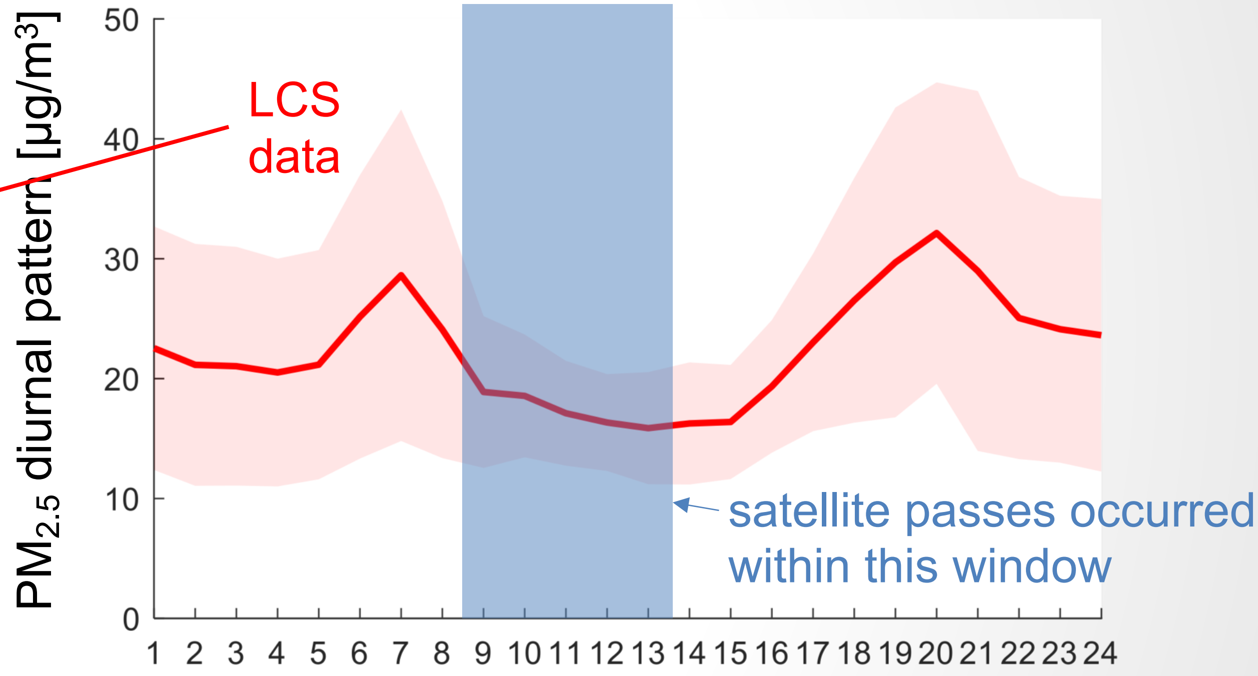
Backup Slides

Global (Satellites) and Local (LCS) are complementary

Spatial Coverage (satellite)



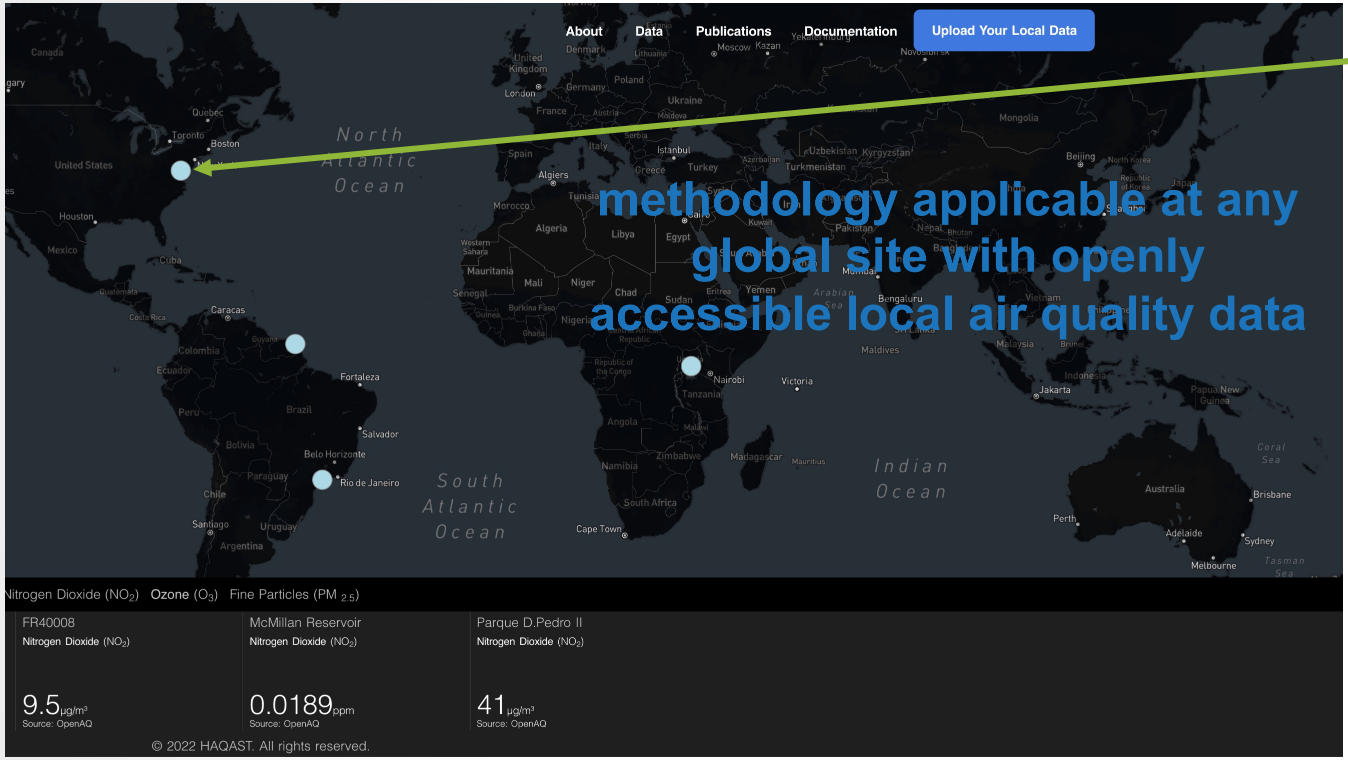
Temporal Coverage (LCS)

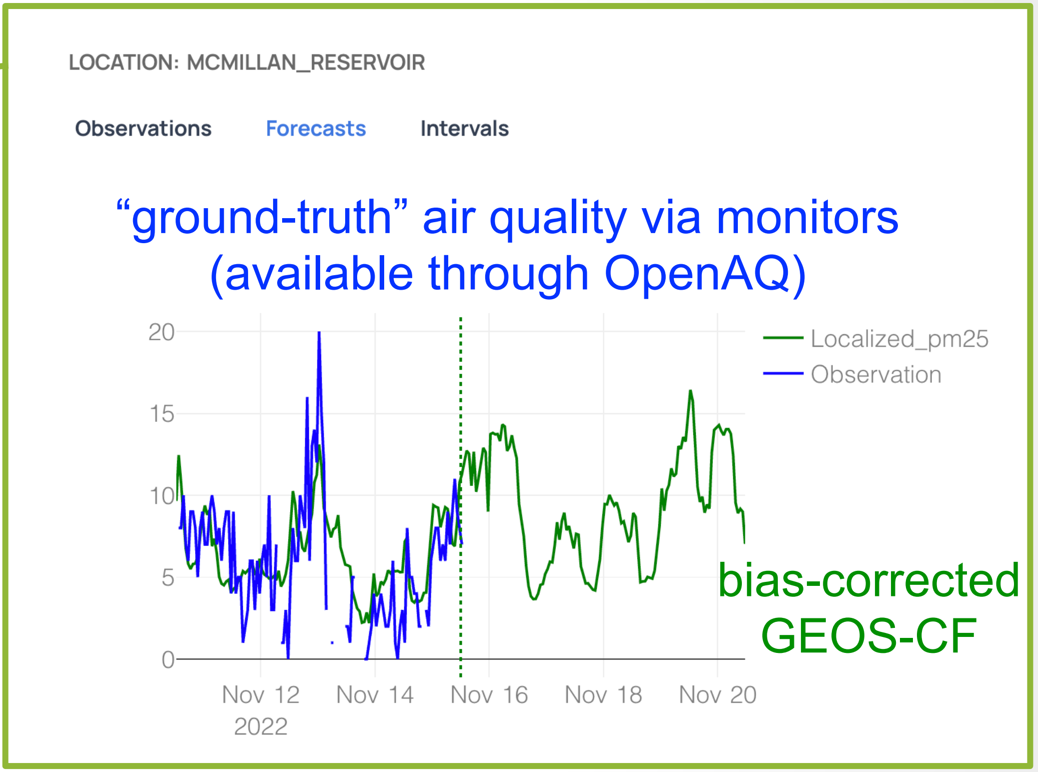


Source: Malings et al. (2020), "Application of low-cost fine particulate mass monitors to convert satellite AOD to surface concentrations in North America and Africa" *Atmospheric Measurement Techniques.* DOI: 10.5194/amt-13-3873-2020

Satellite gives wide-area map
Satellite only observed near mid-day
LCS measures daily cycle (and peaks)

Localized bias-corrected global forecasts with CityAQ





Sources: **Project overview:** https://www.wri.org/initiatives/cityaq
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Bias-correcting global air quality forecasts with local data from OpenAQ monitor stations in the CityAQ project

Challenges to be Confronted

Surface/Column Mismatch

Column quantities derived from satellite data may poorly reflect surface conditions for certain pollutants.

Different Local Data Availability

Many nations worldwide lack regulatory AQ monitoring; low-cost sensors can fill this gap, but with lower data quality.

Quantifying Uncertainty

Many sources of uncertainty (model bias, scale differences, local sensor miscalibration) confound data fusion.

User Acceptance and Adoption

End-users need to have confidence in the utility, accuracy, and transparency of the tool and underlying methods.