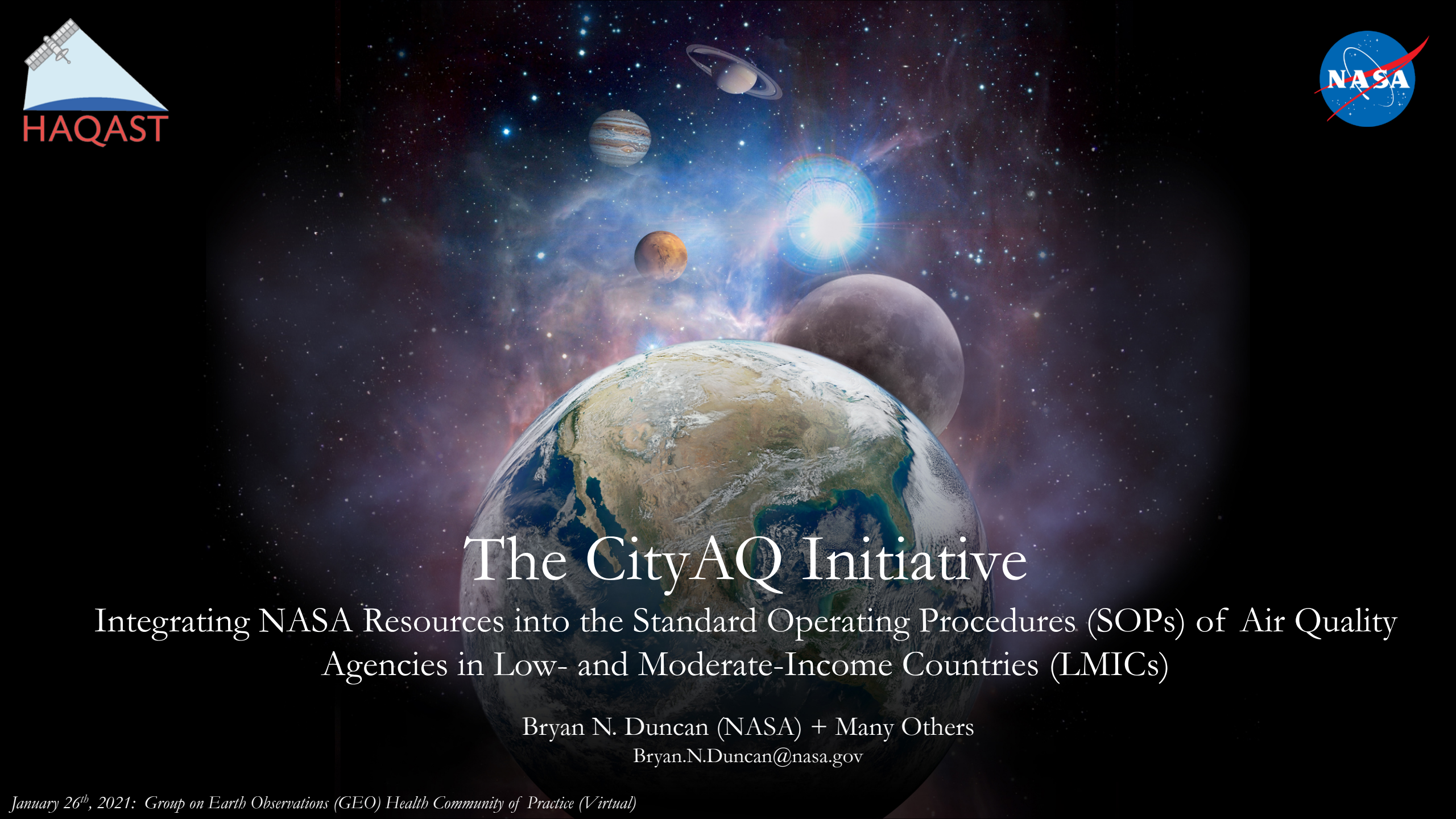


The CityAQ Initiative

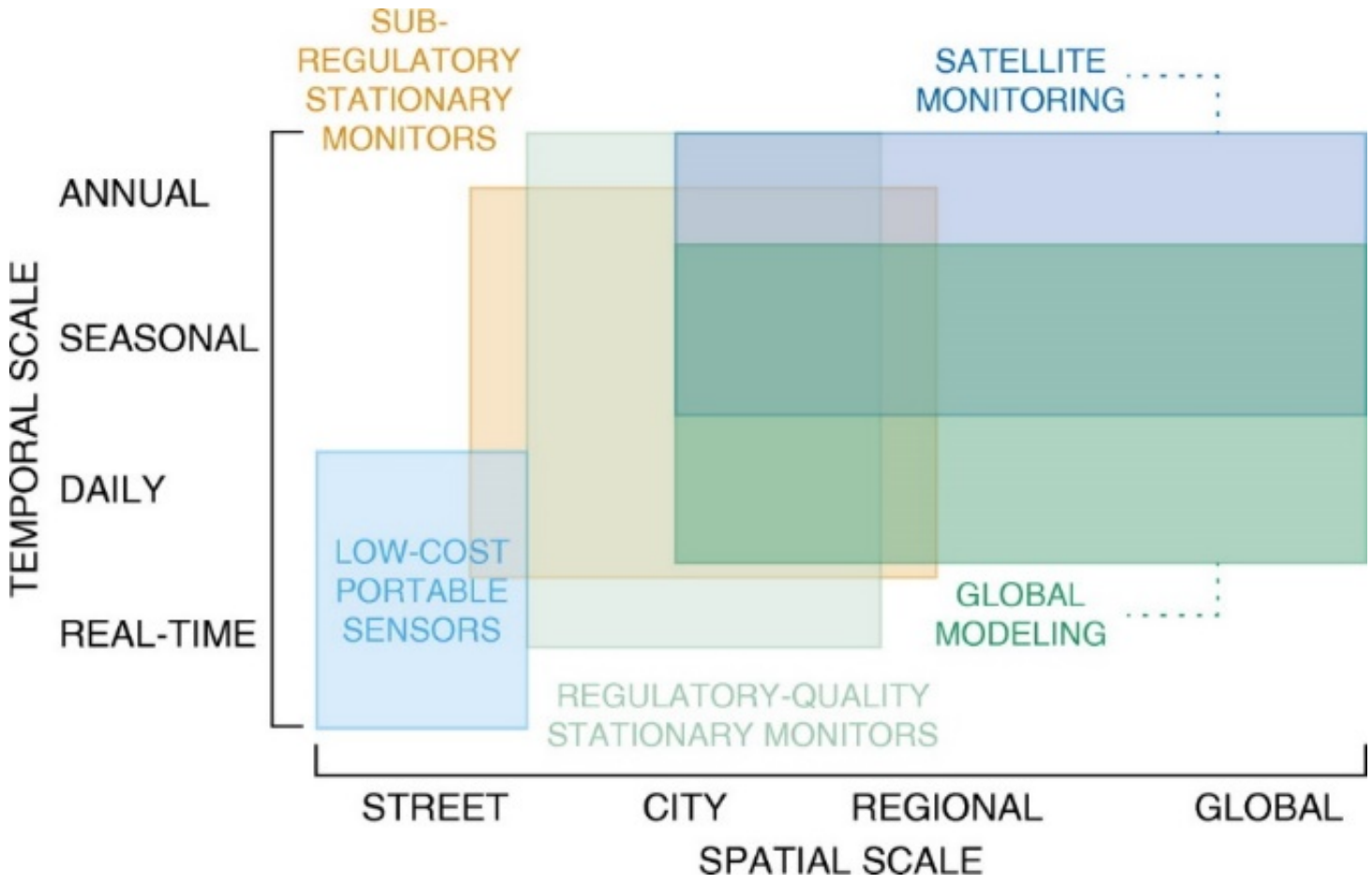
Integrating NASA Resources into the Standard Operating Procedures (SOPs) of Air Quality Agencies in Low- and Moderate-Income Countries (LMICs)

Bryan N. Duncan (NASA) + Many Others
Bryan.N.Duncan@nasa.gov

January 26th, 2021: Group on Earth Observations (GEO) Health Community of Practice (Virtual)

Motivation: American Thoracic Society Workshop (May 2017)

The ATS, EPA, NASA, and NIEHS convened a workshop [organized and led by Cromar and co-led by Duncan] in May 2017 to bring together global experts across multiple disciplines and agencies to discuss capabilities, including free and cost-effective ones, to monitor global AQ.

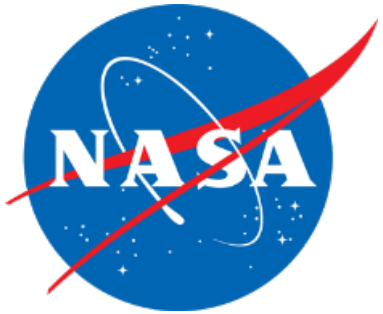


- **Integrated Approach to Air Pollution Monitoring: A New Paradigm**
- **Potential Power of Nonregulatory Data in Low & Middle Income Countries (LMIC)**

Cromar, K.R., Duncan, B.N., et al. (2019), Air Pollution Monitoring for Health Research and Patient Care: An American Thoracic Society Workshop Report. Annals of the American Thoracic Society, 16, 10, https://doi.org/10.1513/AnnalsATS.201906-477ST.

Origins: CityAQ Initiative

The **NASA Goddard Space Flight Center (GSFC)** and **World Resources Institute (WRI)** are working together to pilot a scalable model for developing tools using various technologies that provide air quality information to city health and air quality managers.



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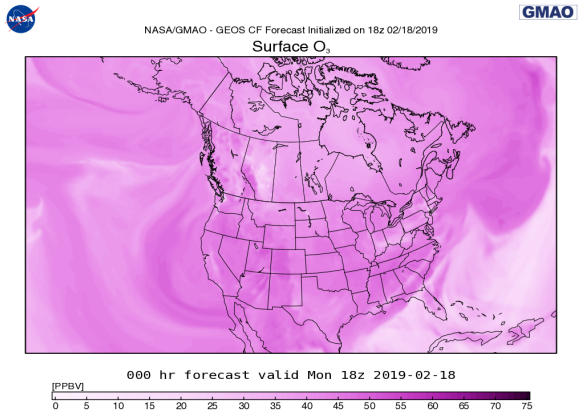
Just 5 Easy Steps to Begin Accessing NASA Data

https://www.youtube.com/watch?v=lo9X8HWqG9M&list=PLegEq6op4j3nVa7r6IKpSh22VzOZsljjM&index=3

#1: User-friendly visualization tool.
https://worldview.earthdata.nasa.gov/

#2: Overview of how satellite data aid health and air quality managers.
https://airquality.gsfc.nasa.gov/

#3: Check out AQ forecasts for your favorite world city.
https://fluid.nccs.nasa.gov/cf/



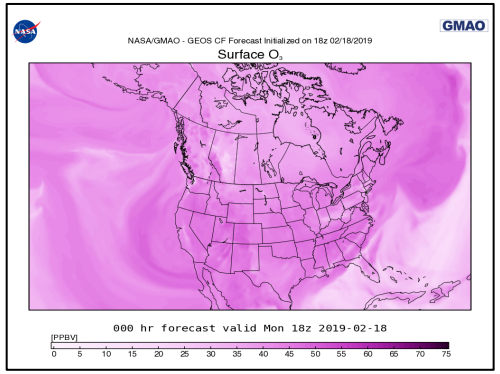
#4: On-line and in-person training on how to work with satellite data.
https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset

#5: Work with satellite data experts on your health and air quality applications.
https://haqast.org

Bryan.N.Duncan@nasa.gov

CityAQ Initiative

NASA AQ Forecast System



Forecasts via NASA Fluid & WRI Resource Watch

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Partners Decision Making

QUITO ALCALDÍA · openaq · unicef · GOVERNO DO Rio de Janeiro · GTO Secretaría de Medio Ambiente y Ordenamiento Territorial · imeplan Instituto Metropolitano de Planeación

+ other cities

Satellite Data

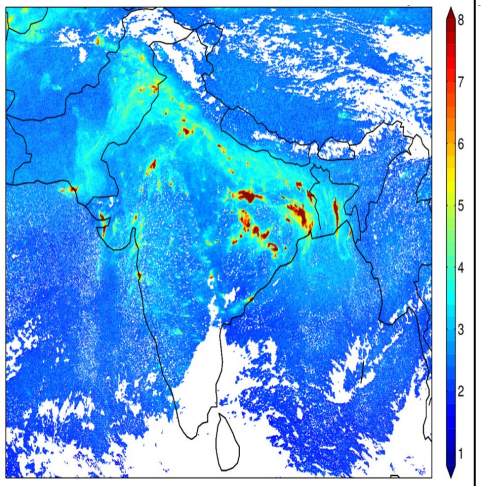
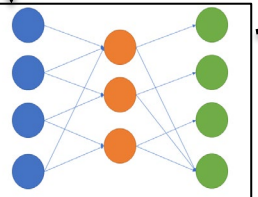


Image courtesy Lok Lamsal (NASA)

Data via WorldView

NASA

Machine Learning



Tailored Forecasts via API

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Surface AQ Data

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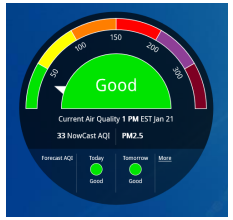
openaq

AQ Observations

© 2012 Daniele Costantini / Wikimedia Commons

Partner Applications

AQ Forecasts & Alerts



from https://www.airnow.gov

Mitigation Planning

Photo by Patrick Hendry on Unsplash

Data

Low-Cost Sensors

Photo from Clarity Movement https://www.clarity.io/

CityAQ Team Members

NASA

Bryan Duncan (*PI*)
Dan Anderson (*Postdoctoral Fellow*)

NASA Global Modeling & Assimilation Office (GMAO)

Steven Pawson (*Director*)
Christoph Keller (*GEOS-CF Lead Developer*)
K. Emma Knowland (*GEOS-CF Developer*)

NASA ARSET

Ana Prados (*Team Lead*)

New York University (NYU)

Kevin Cromar (*Director, Air Quality Program; Associate Professor of Environmental Medicine and Population Health*)

World Resources Institute (WRI)

Jessica Seddon (*Global Lead – AQ; Stakeholder Representative*)
Beatriz Cárdenas (*AQ Manager – WRI Mexico*)

UNICEF

Amy Wickham (*Programme Specialist – Climate, Energy and Environment*)

Clarity Movement Co.

Sean Wihera (*Director of Business Development*)

Pilot Cities

Through WRI we have a collaboration agreement with all the cities

City	POC	Affiliation
Kigali, Rwanda	Ms. Juliet Kabera	Rwanda Environment Management Authority
Leon-Salamanca-Celaya Metro, Mexico	Ms. Isabel Ortiz Mantilla	Secretary of Environment, Guanajuato State Government + León Mayor Office
Guadalajara Metro, Mexico	Ms. Patricia Martínez	Coordinator of Territorial Management Jalisco State
Bogota, Colombia	Ms. Carolina Urrutia	Secretary of Environment Bogota
Monterrey Metro, Mexico	Mr. Manuel Vital	Secretary of Environment, Nuevo Leon State
Rio de Janeiro, Brazil	Mr. Bruno B. Franca	Municipal Government of Rio de Janeiro
Quito, Ecuador	Ms. Maria Diaz Suarez	Secretary of Environment, Quito

Completed Tasks

- NASA GMAO global AQ forecast system, including FLUID visualization tool
- Development of multi-pollutant health AQ index (HAQI)
- Capacity building with various themes (e.g., AQ data QA/QC, experiences in using forecasts to communicate and protect human health)
- Adaptors and API developed to share real time data in different data platforms
  - Forecast visualizations in Resource Watch
  - Support to cities in QA/QC to ingest their data into CityAQ
  - API developed by WRI to ingest tailored forecasts

Capacity building with participating cities

TheCityFix Learn

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EN

SOLUTIONS | CATALOG | EVENTS | BLOGS | ABOUT

WEBINAR

AQ TECH TALK: DEVELOPING CITY-LEVEL AIR QUALITY FORECASTING, THE MEXICO CITY EXPERIENCE

Speakers

Beatriz Cárdenas
Air Quality Manager
WRI Mexico

Armando Retama
Former Air Quality Monitoring Director; Consultant
Mexico City; WRI Mexico

Monica Jaimes-Palomera
Deputy Director of Modelling and Analysis
Mexico City Secretary of Environment

Valeria Diaz-Suarez
Coordinator
Metropolitan Atmospheric Monitoring Network of Quito

Edison Yesid Ortiz Duran
Leader of Integrated Air Quality Modeling System
Bogota's District Secretary of Environment

WEBINAR

AQ TECH TALK: FORECAST AND IMPACTS OF SAHARAN DUST

Speakers

Beatriz Cárdenas
Air Quality Manager
WRI Mexico

Ken Wakabayashi
Research Analyst
NUMO Alliance

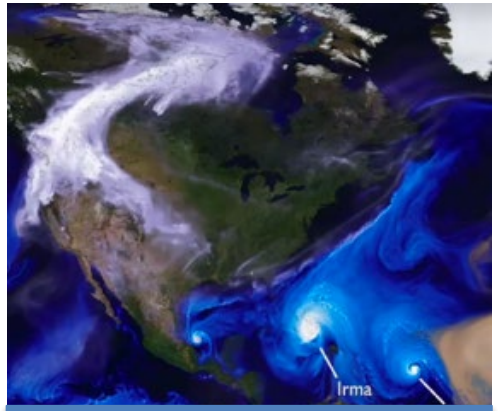
Dr. Peter Colarco
Research Physical Scientist, NASA Goddard Space Flight Center
Co-Chair, International Cooperative for Aerosol Prediction (ICAP)

Dr. Graciela B. Raga
Professor, National Autonomous University of Mexico
Senior Scientist, Micro-Mesoscale Interactions Research Group

About the series

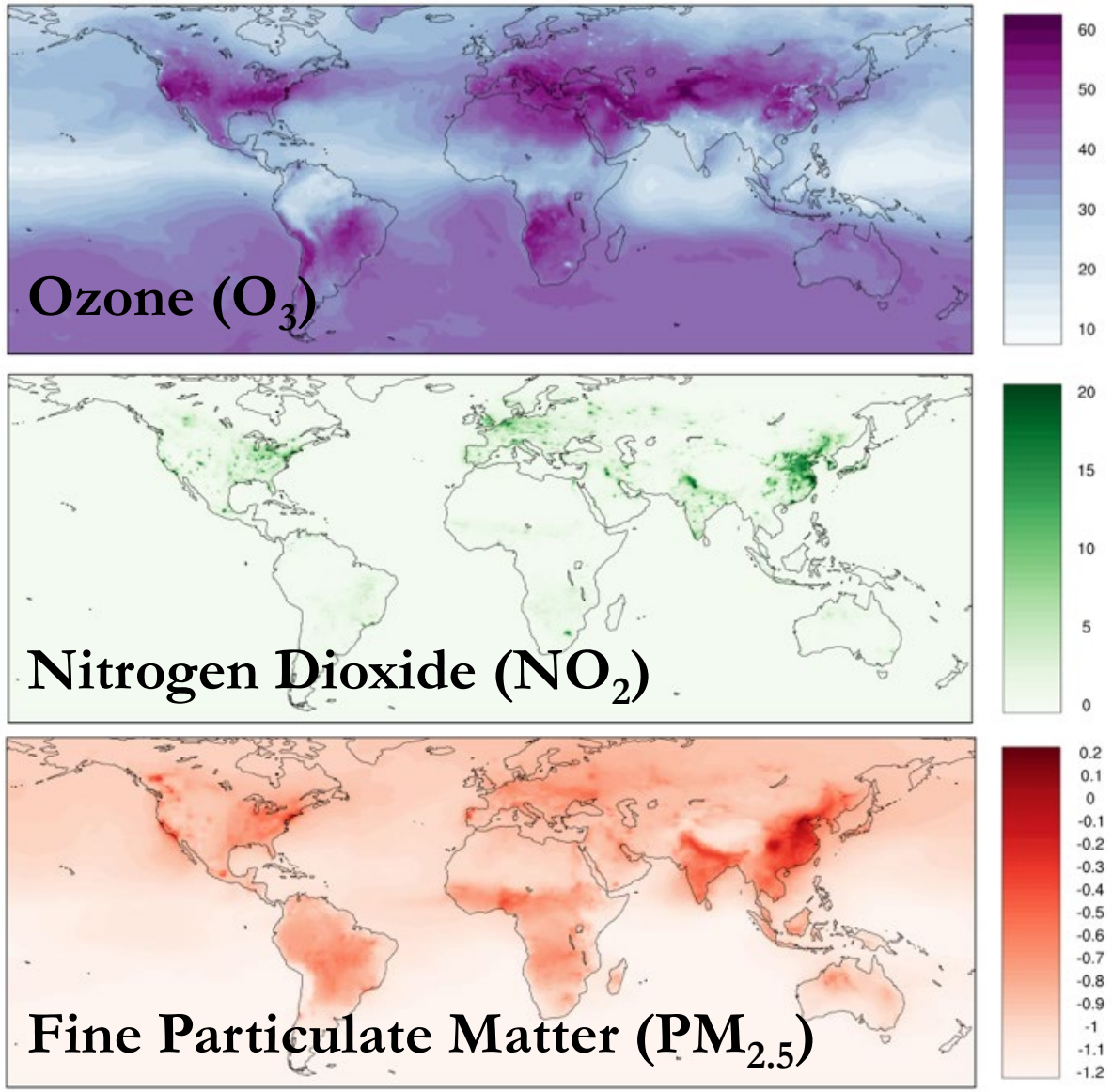
The Air Quality Tech Talk series covers key topics around technology and science in air quality, with an emphasis on learning from experiences and projects happening around WRI's global offices.

NASA GEOS Composition Forecast (GEOS-CF) System

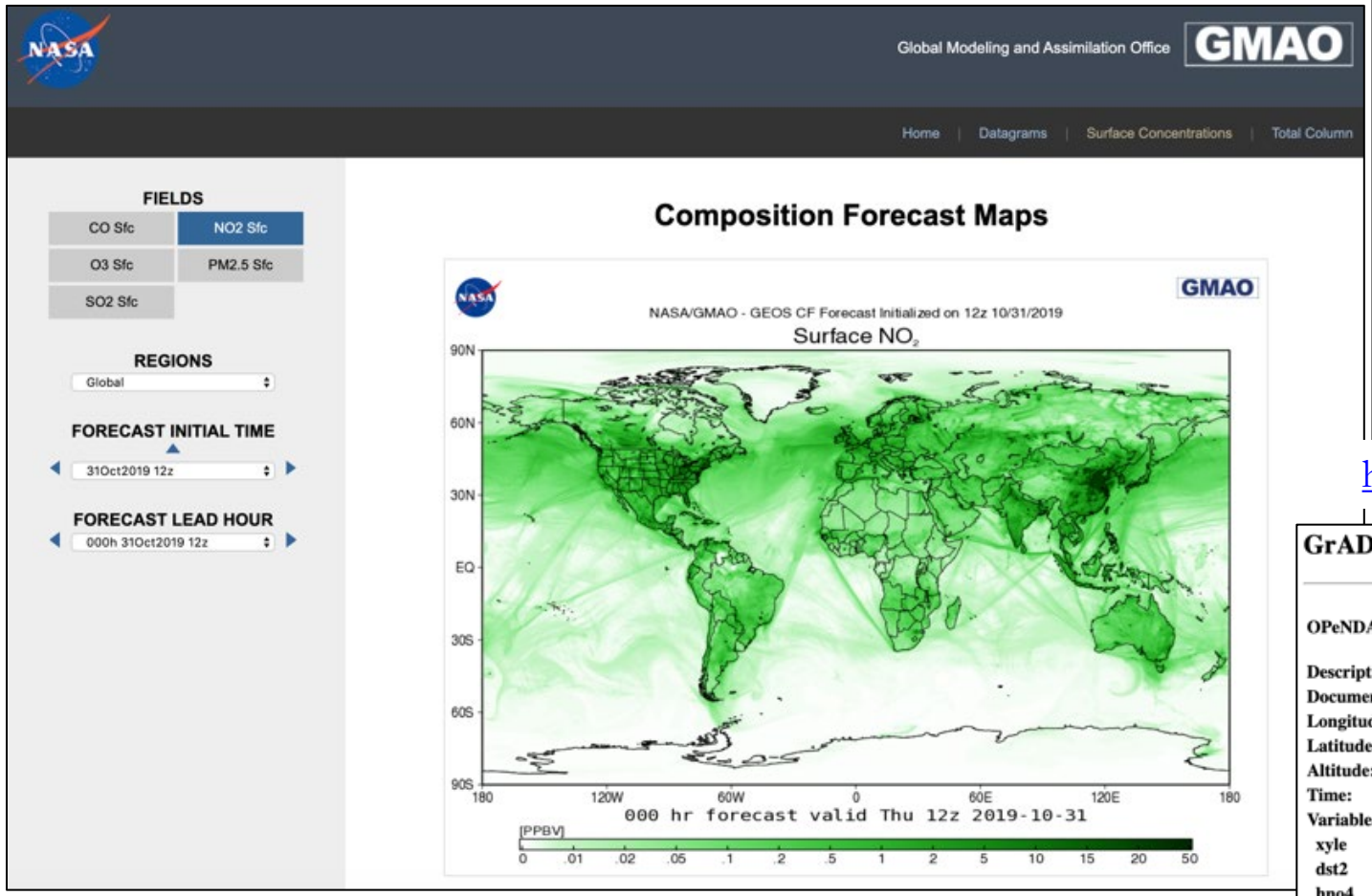


GEOS Weather

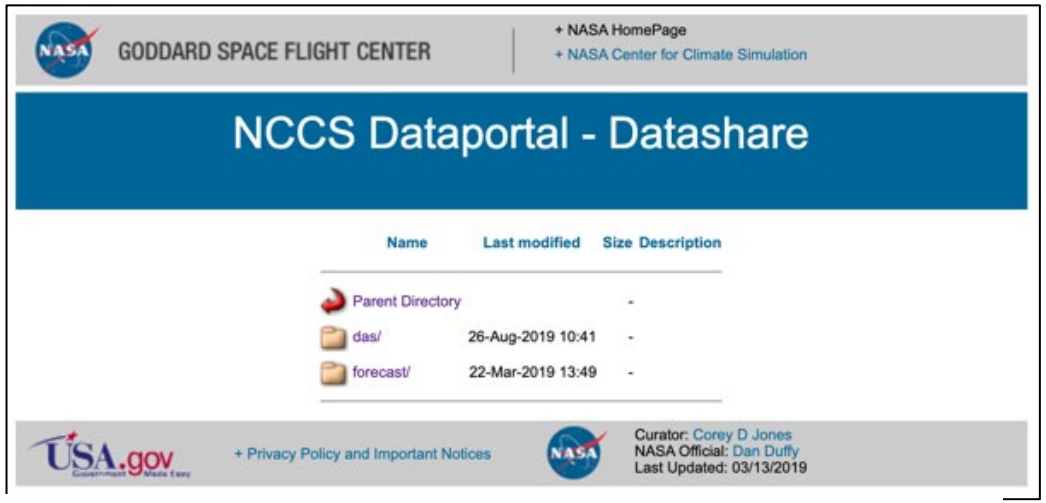
GEOS Chemistry



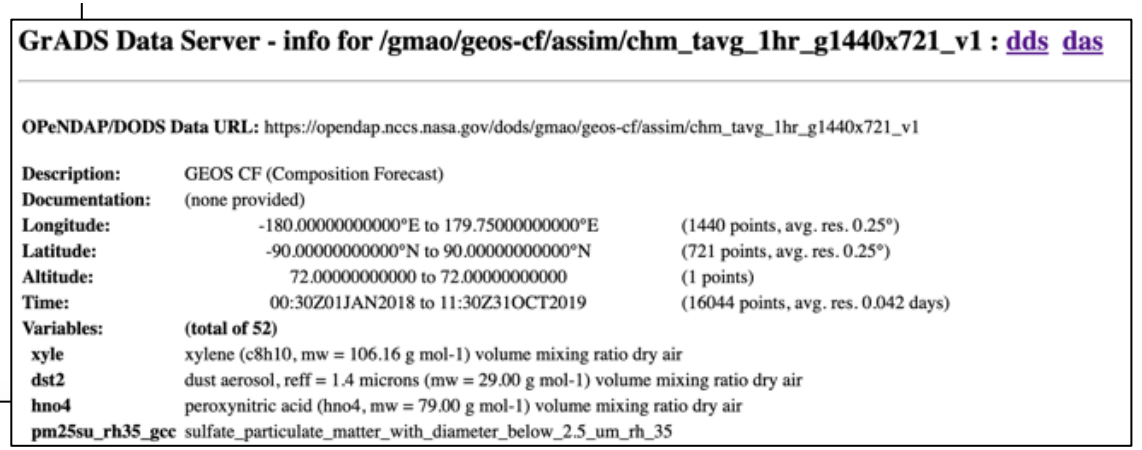
GEOS-CF model output available to the public in near real-time



https://fluid.nccs.nasa.gov/cf/

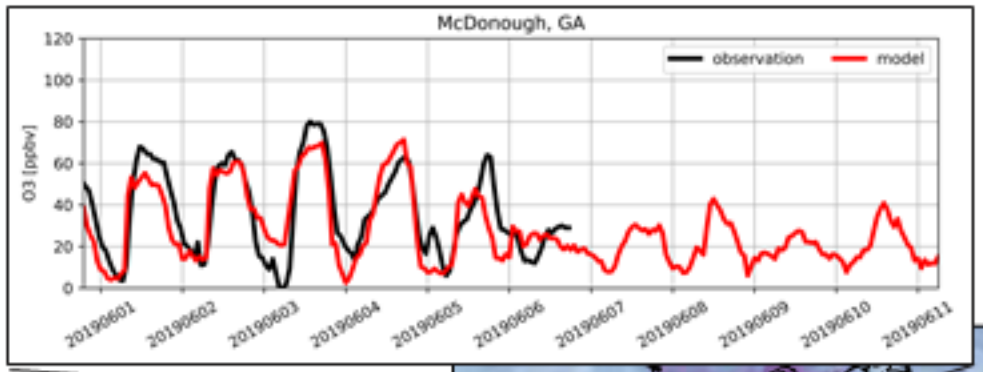


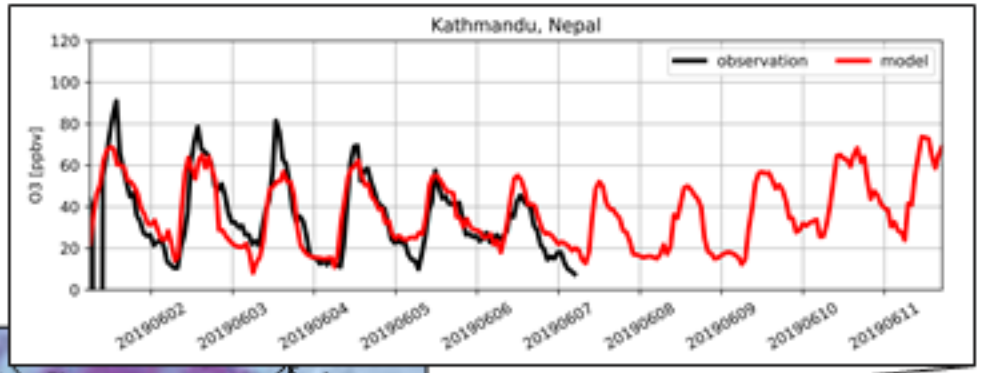
https://portal.nccs.nasa.gov/datashare/gmao/geos-cf/v1/

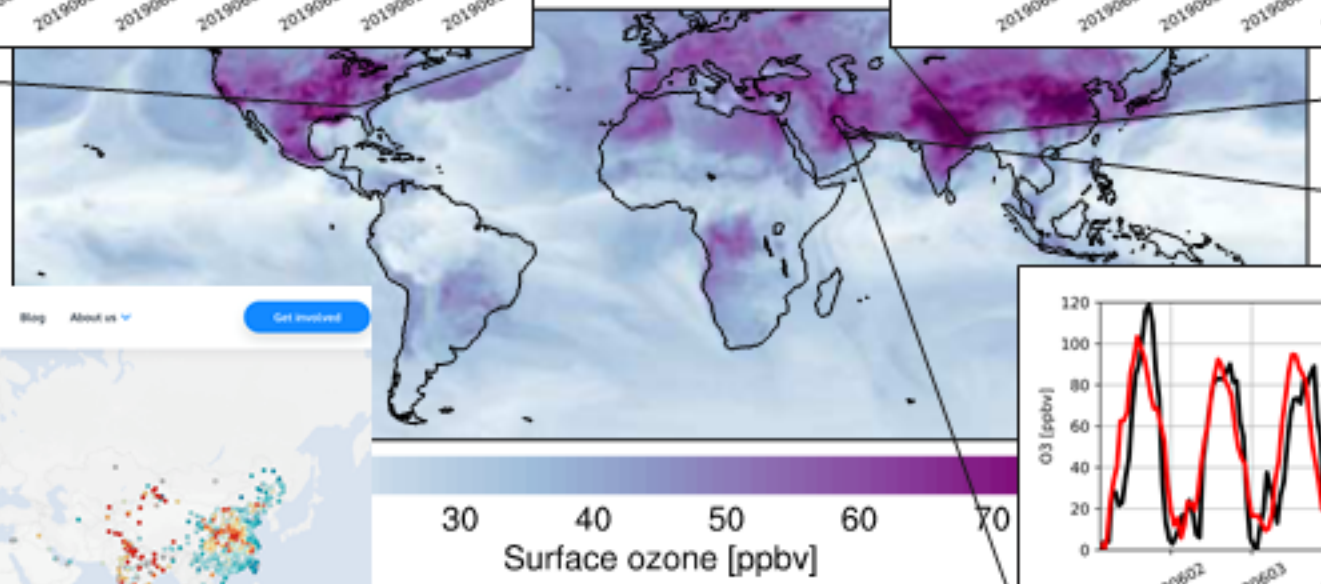


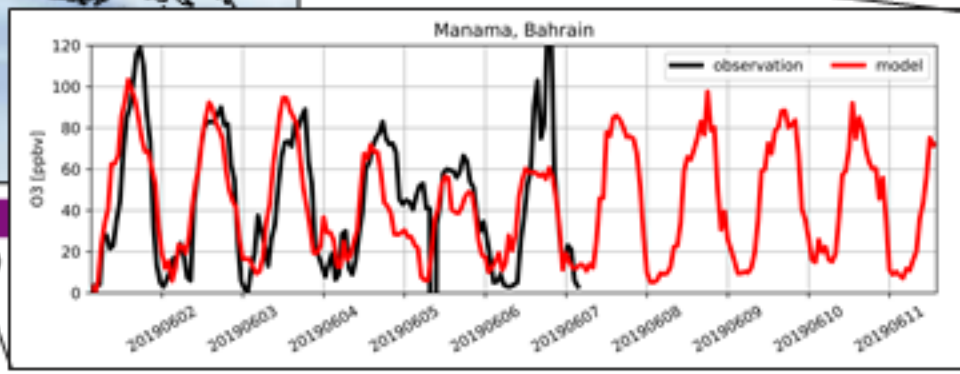
https://opendap.nccs.nasa.gov/dods/gmao/geos-cf/

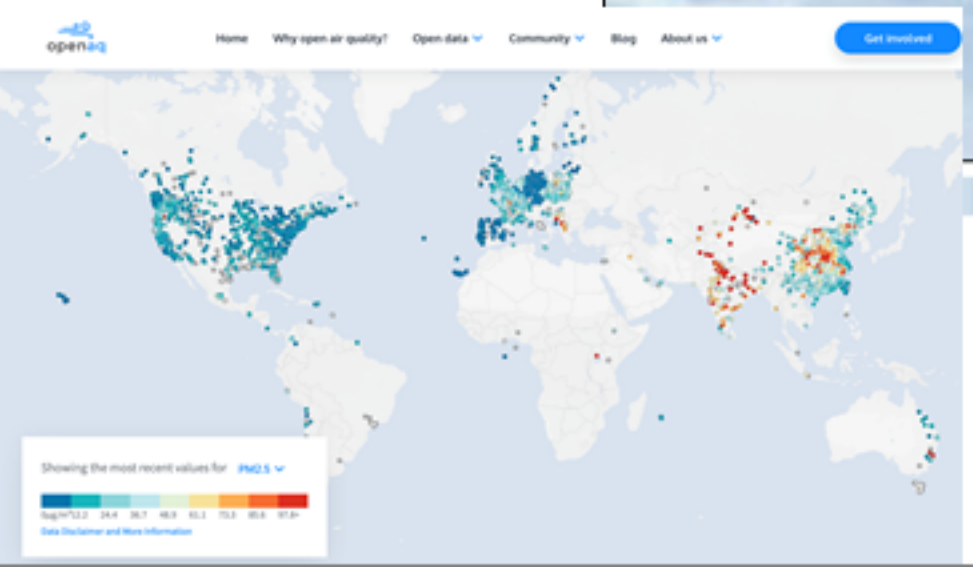
Observe ozone levels around the world







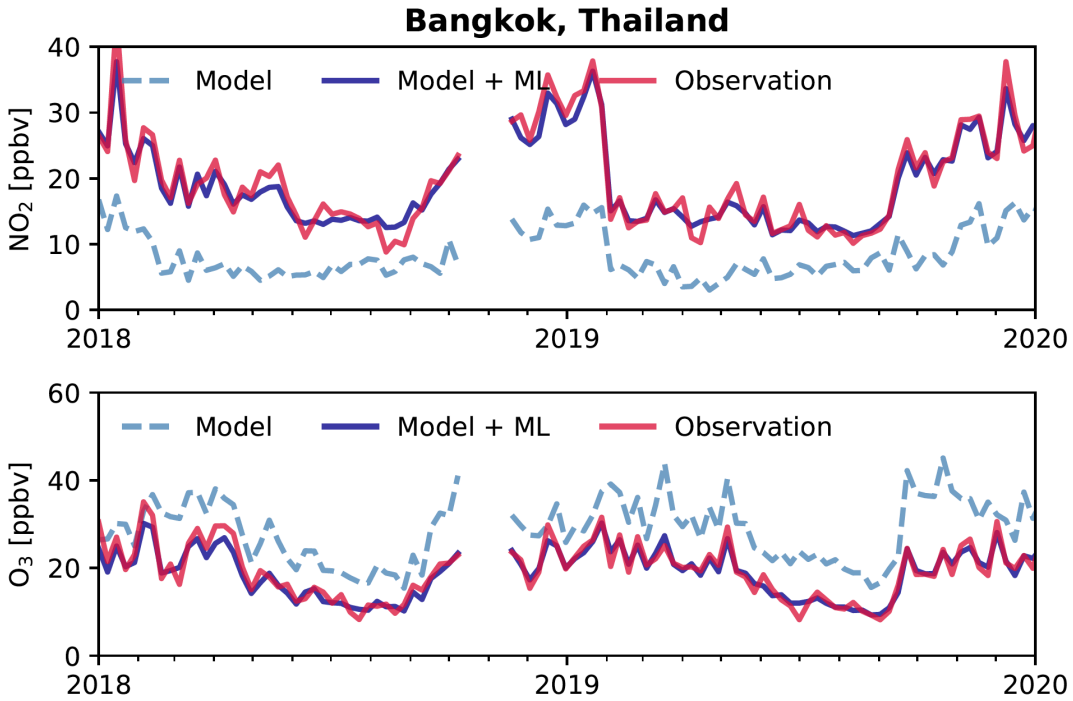




k.e.knowland@nasa.gov
christoph.a.keller@nasa.gov

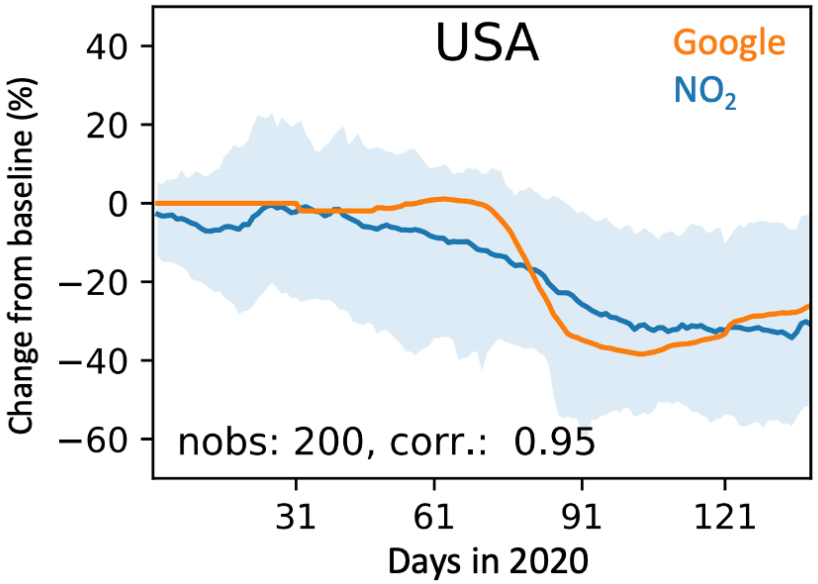
Potential applications involving GEOS-CF

Tailored forecasts & downscaling



→ Global, high-resolution air quality maps

Incorporate real-time activity data



→ Improved air quality forecasts

Air Pollution Messaging using HAQI

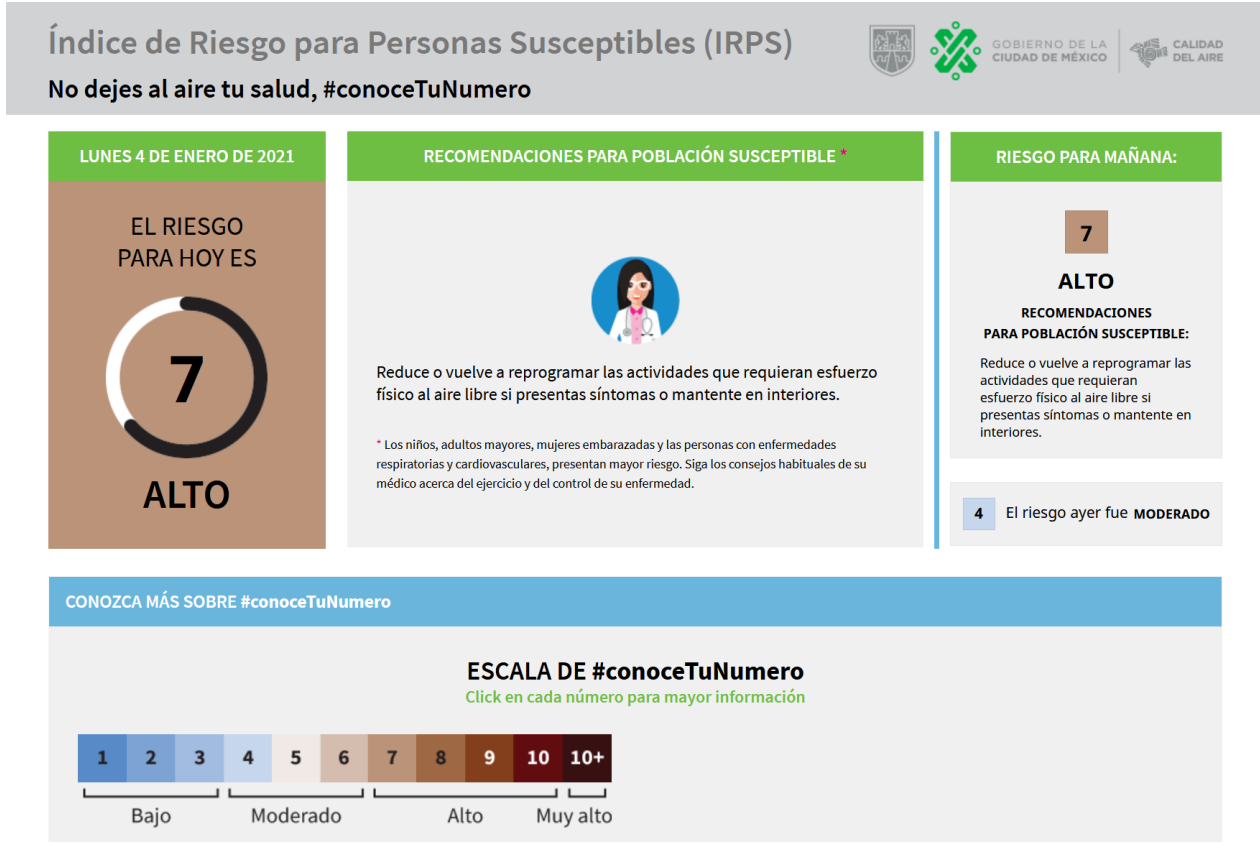
Global Multi-Pollutant Health Air Quality Index (HAQI)

HAQI = f($PM_{2.5}$, O_3, NO_2)

HAQI data can be used directly in air quality messaging campaigns developed and distributed by local air quality and health agencies.

> *"Health agencies and others responsible for information on air pollution should provide reliable information that is useful to individuals for modifying their behaviour on the basis of the physical levels at which they begin to experience adverse impacts, symptoms or discomfort (...) "*

Personal interventions and risk communication on air pollution. Geneva: World Health Organization; 2020. Licence : CC BY-NC-SA 3.0 IGO. See "Risk Communication with Air Pollution Indices" led by Kevin Cromar, NYU.



Mexico City's version of HAQI communicated to the public using the #conoceTuNumero campaign.
http://www.aire.cdmx.gob.mx/conoce-tu-numero-iner/

Developed in partnership with SEDEMA and Kevin Cromar at Marron Institute, NYU.

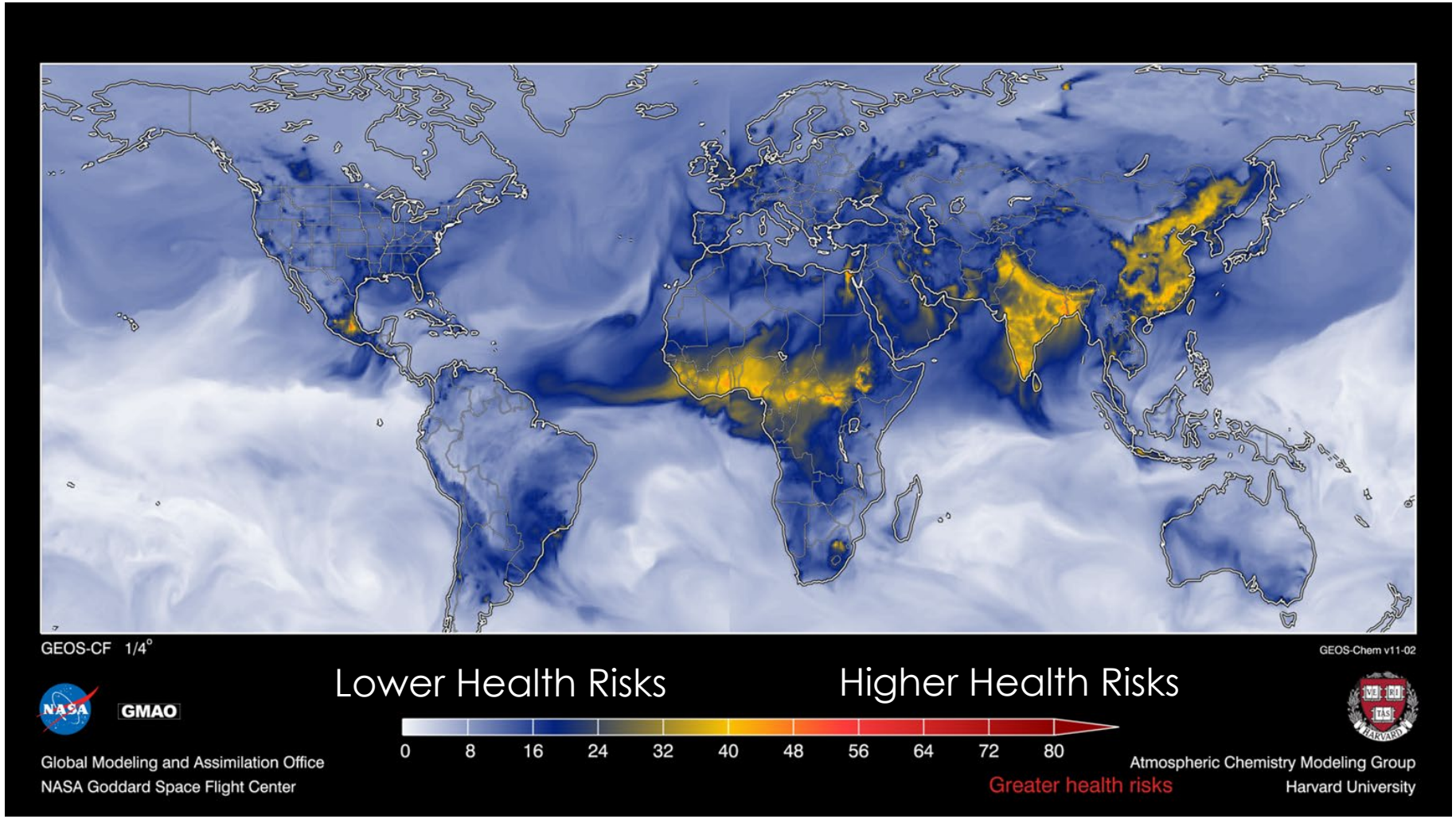
GEOS-CF Air Pollution Forecasts

HAQI

24-h average $PM_{2.5}$ & NO_2

daily max 8-h O_3

Health Air Quality Index: *January 1st, 2017*



GEOS-CF Air Pollution Forecasts

HAQI

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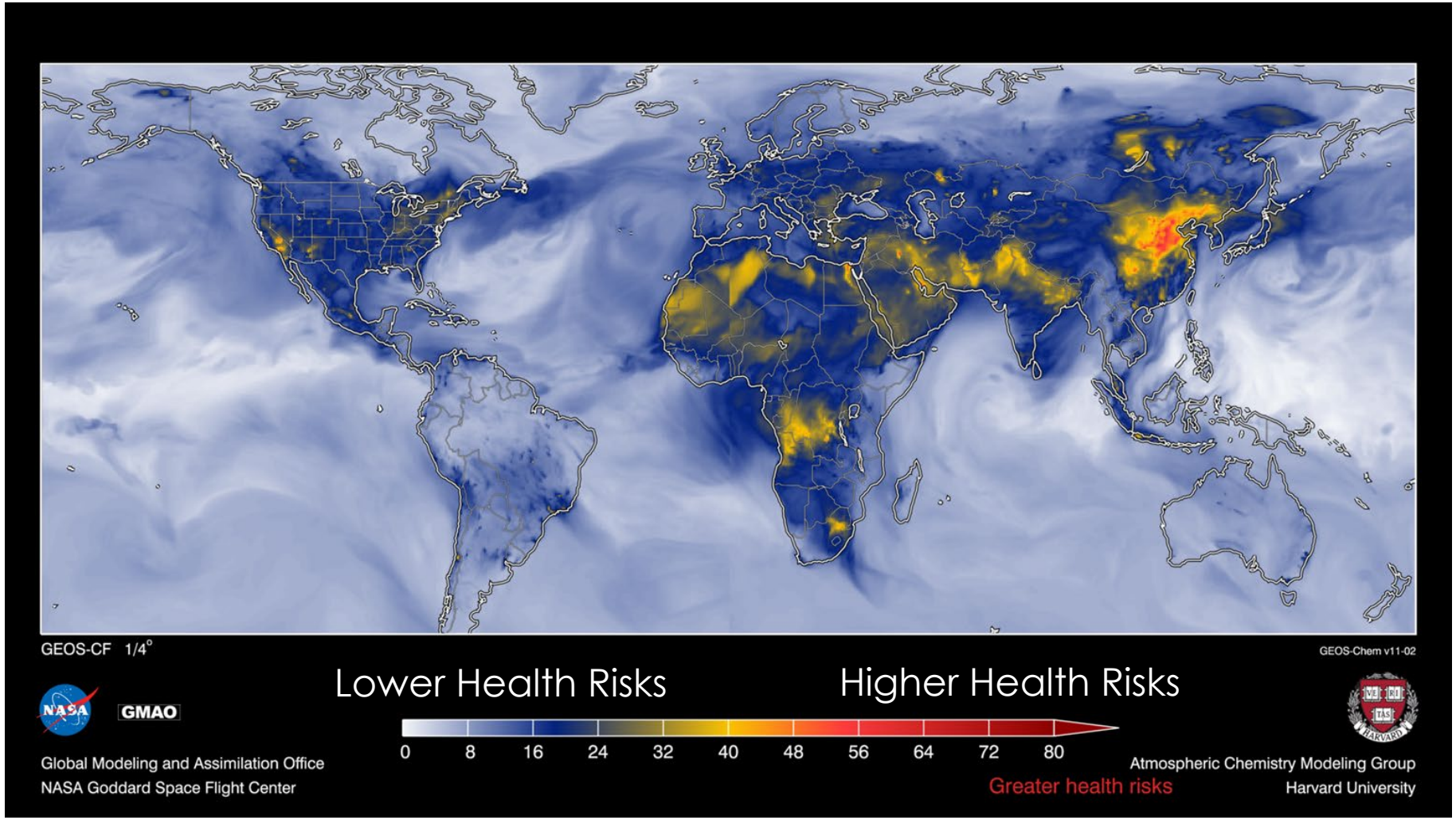
daily max 8-h O_3

Health Air Quality Index: *July 1st, 2017*



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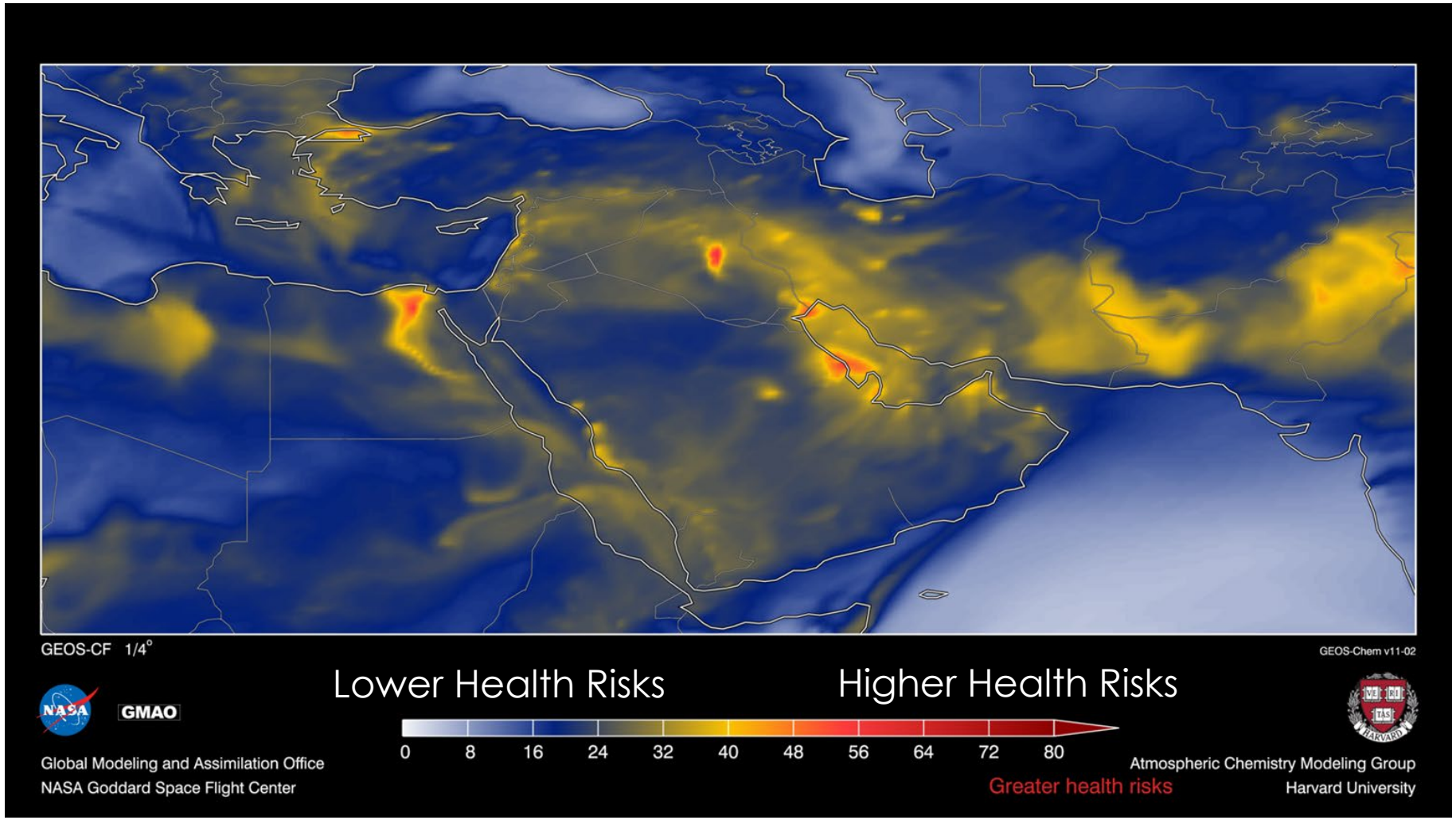


Ongoing & Upcoming Tasks

Incorporating NASA Resources into City Standard Operating Procedures (SOPs)

- We will develop illustrative case studies for our Pilot Cities.
- We will troubleshoot incorporation of NASA resources.

"Scaling Up" CityAQ from Pilot Cities to Any World City

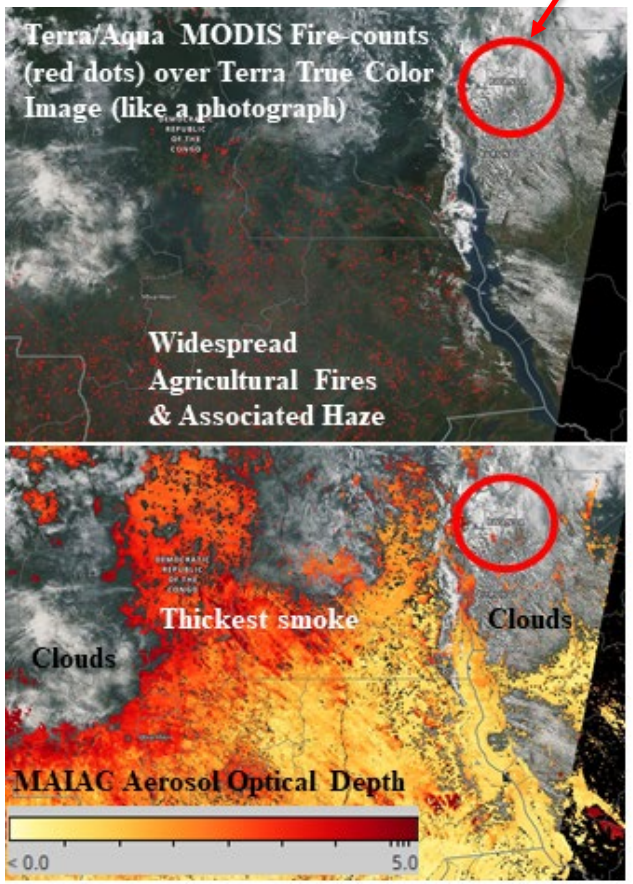
- With lessons learned, we will work to refine tools (e.g., FLUID, NASA WorldView; GEOS-CF) to make them more user-friendly and comprehensive.
- We will create documentation (e.g., website, journal article) to aid new cities to incorporate NASA resources into their SOPs.
- Continue support and capacity building with cities.
- Integrate local high resolution emissions inventories.

Coordinate with Other Efforts (e.g., SERVIR, AfriqAir)

Incorporating NASA Resources into City SOPs

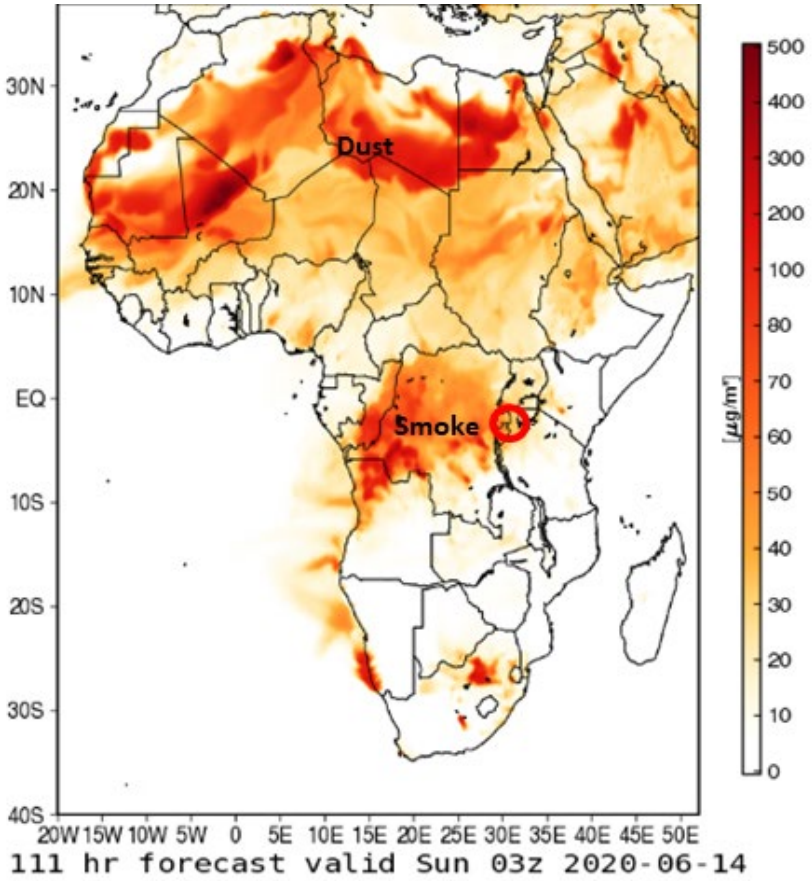
Example Illustrative Case Study: **Kigali, Rwanda**

Satellite Data
(June 9, 2020)



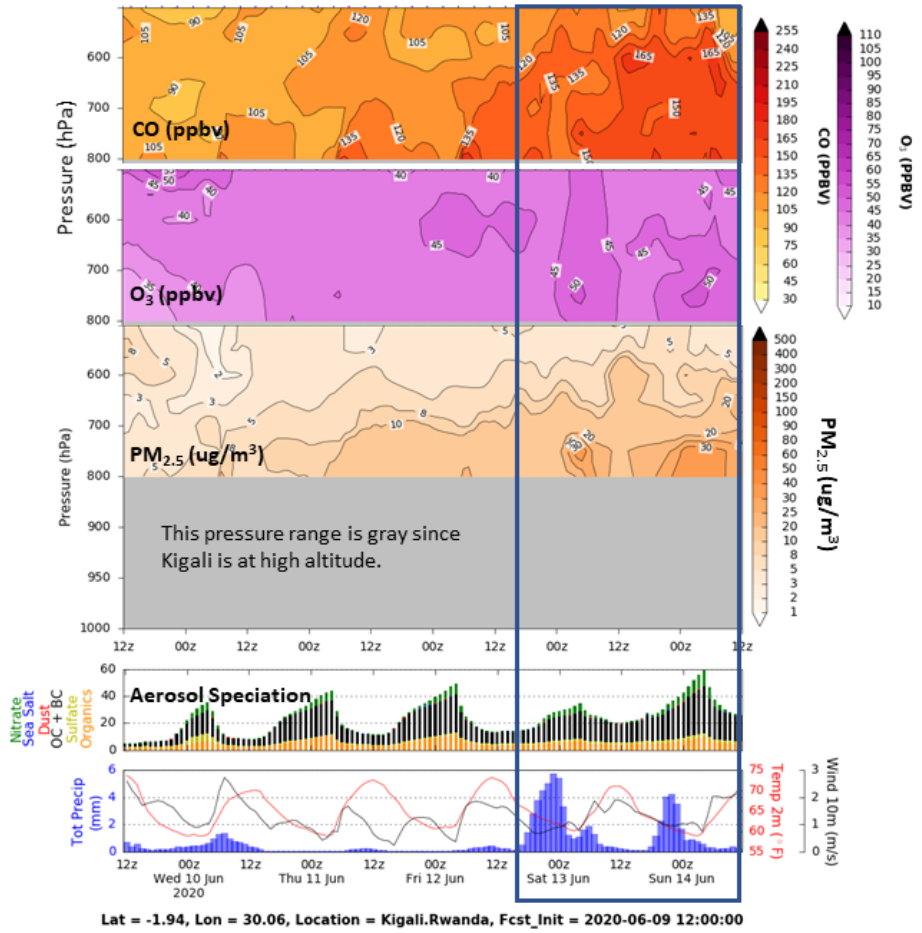
Accessed via NASA WorldView

AQ Forecasts
(June 14, 2020)



Accessed via FLUID

AQ Forecasts
(June 10-14, 2020)



Accessed via FLUID

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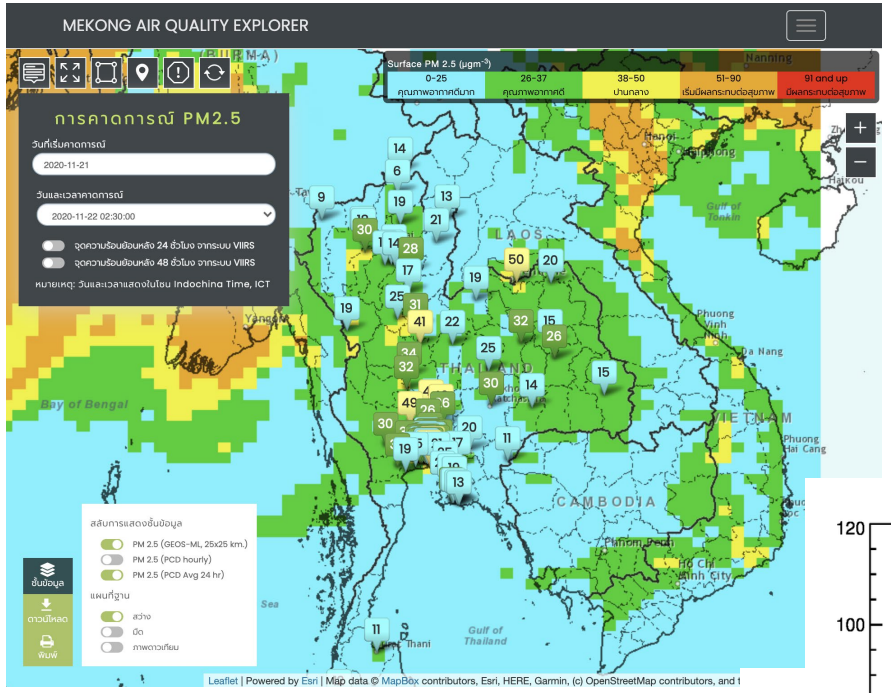
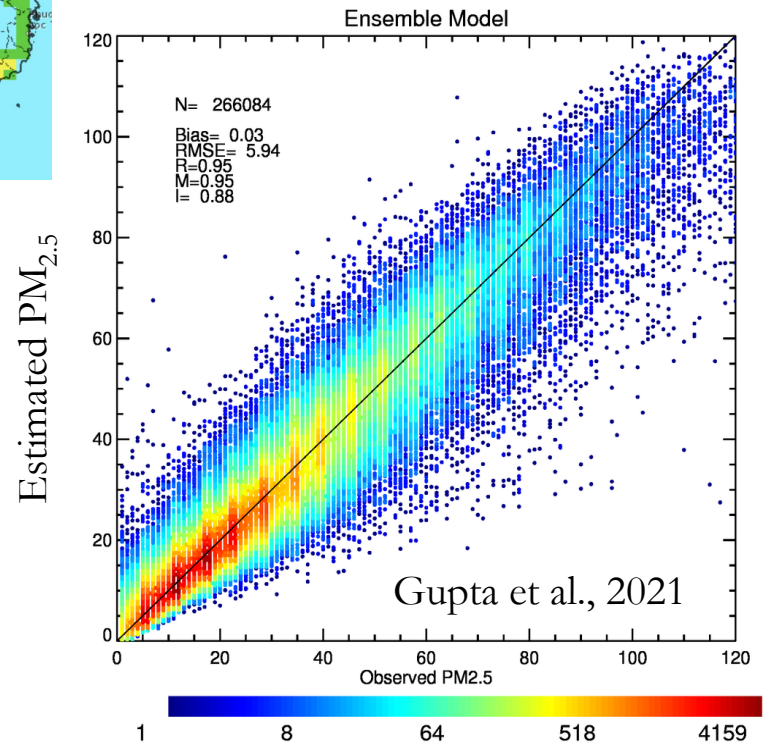
Air Quality Explorer Overview

SERVIR
NASA+USAID

- Three hourly $PM_{2.5}$ Forecasts for next 3 days in the region
- Ground-based $PM_{2.5}$ and AQ measurements from the government's ground measurements
- AQE includes real- time & historical RGBs, Aerosol Optical Depth (AOD), & Fires from NASA MODIS and VIIRS-SNPP and $PM_{2.5}$ forecasts



http://aqatmekong-servir.adpc.net/en/mapviewer/

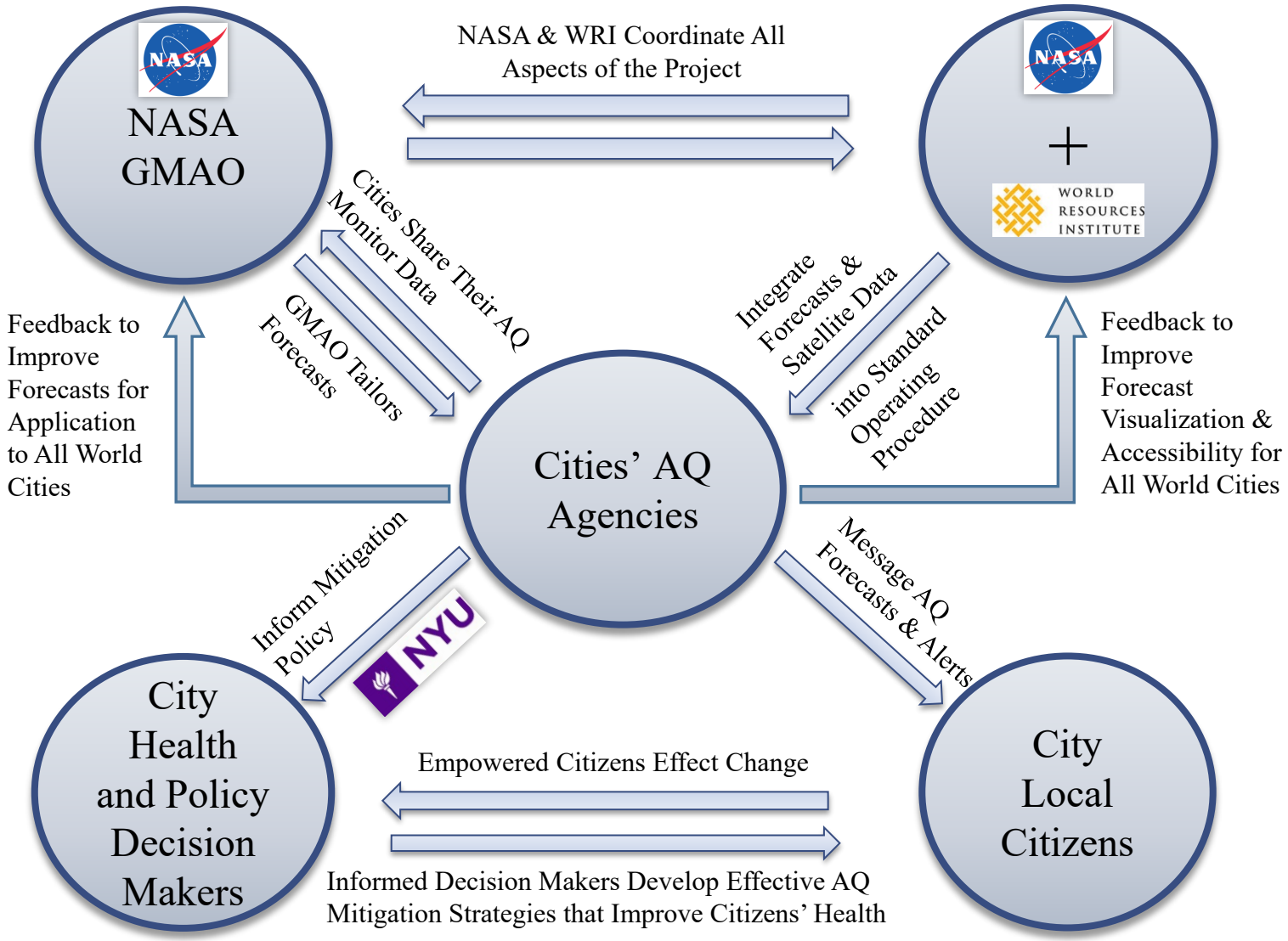


- NASA's GEOS global aerosols and meteorological forecasts
- Advanced Machine Learning to calibrate global data for local conditions
- The AQE is now being used by Thai Pollution Department

https://earthobservatory.nasa.gov/blogs/fromthefield/2020/12/16/using-space-to-monitor-air-quality-at-the-surface/

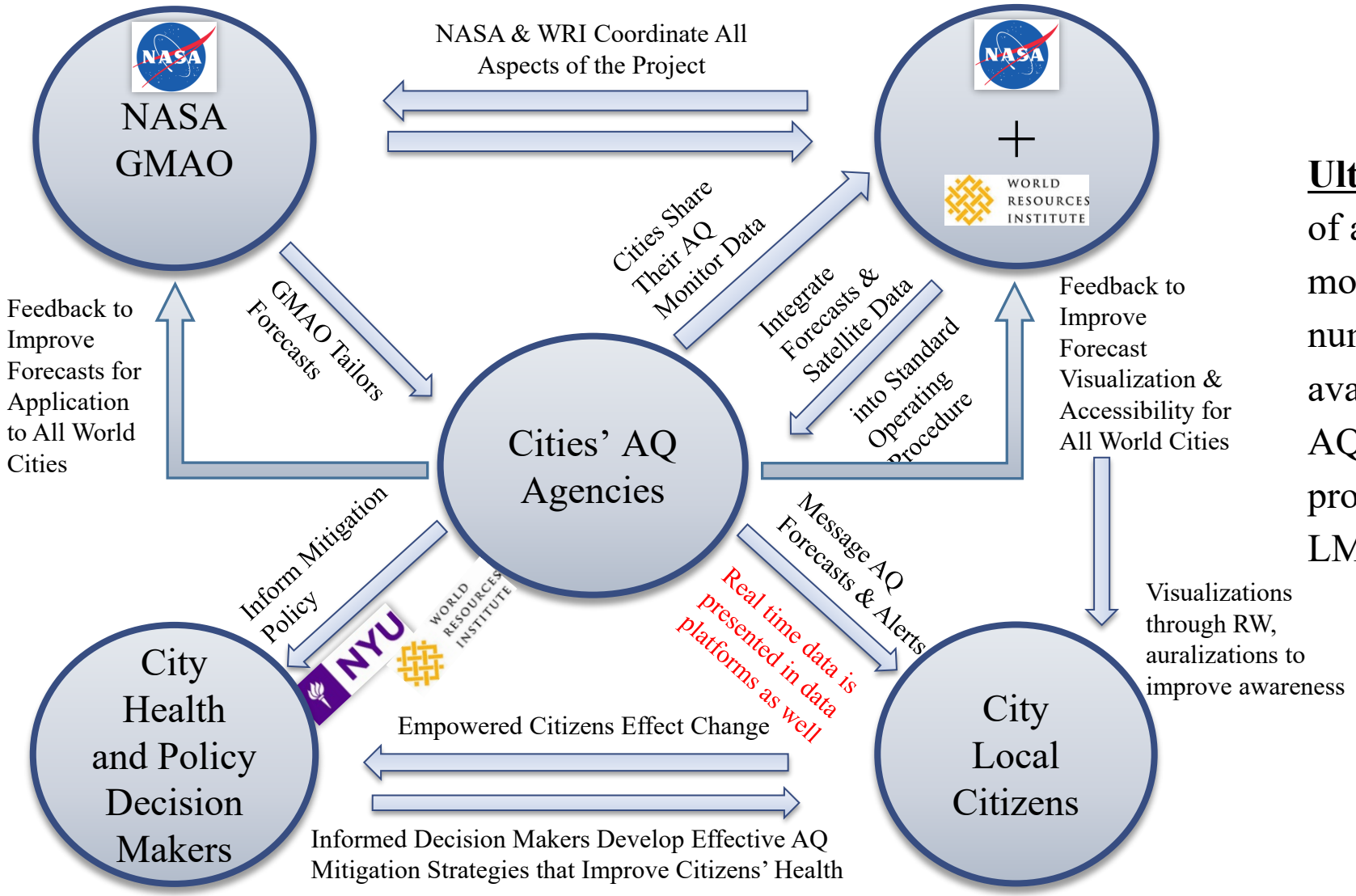
Extra Slides

CityAQ Initiative



Ultimate Goal: Advance the development of an integrated approach to a global AQ monitoring system that takes advantage of numerous technologies to ensure the availability of cost-effective and reliable AQ information to AQ and health professionals around the world, including LMICs.

CityAQ Initiative (modified)



<u>Ultimate Goal</u>: Advance the development of an integrated approach to a global AQ monitoring system that takes advantage of numerous technologies to ensure the availability of cost-effective and reliable AQ information to AQ and health professionals around the world, including LMICs.

Potentially Useful Space-based Observations

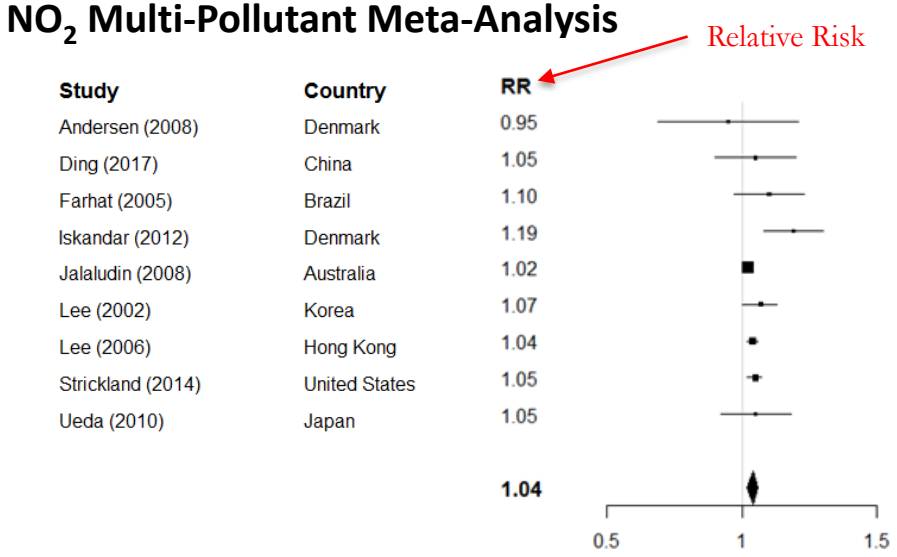
- Aerosols (AOD, fire detection) → can be used to infer "nose-level" $PM_{2.5}$ with atmospheric models
- Ozone (O_3) → no information on "nose-level" concentrations
- Nitrogen dioxide (NO_2) → most straightforward to observe & excellent tracer of combustion
- Carbon monoxide (CO) → another tracer of combustion
- Sulfur dioxide (SO_2)
- Ammonia (NH_3)
- Formaldehyde (HCHO)

precision and accuracy not suitable for most health studies

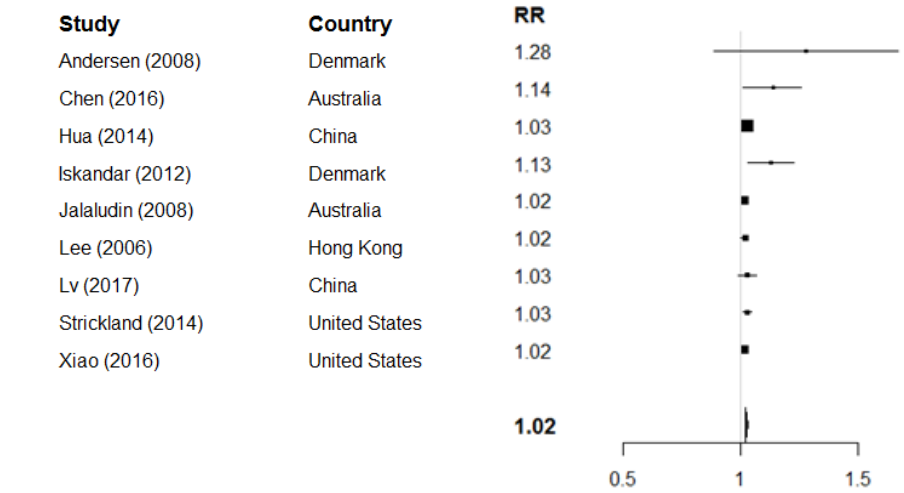
- Surface UV → not a pollutant, but …

Air Pollution Messaging using HAQI

NO_2 Multi-Pollutant Meta-Analysis



$PM_{2.5}$ Multi-Pollutant Meta-Analysis



Adverse health impacts are attributable to multi-pollutant exposures. A well designed index needs to accurately account for these mixtures.

Calculating Children's Respiratory Health-based Index Values

Calculate individual pollutant values using the following equations:

$$O_3 \text{ index} = \ln\left[100\left(e^{(0.002 * X_{O3})} - 1\right)\right]$$

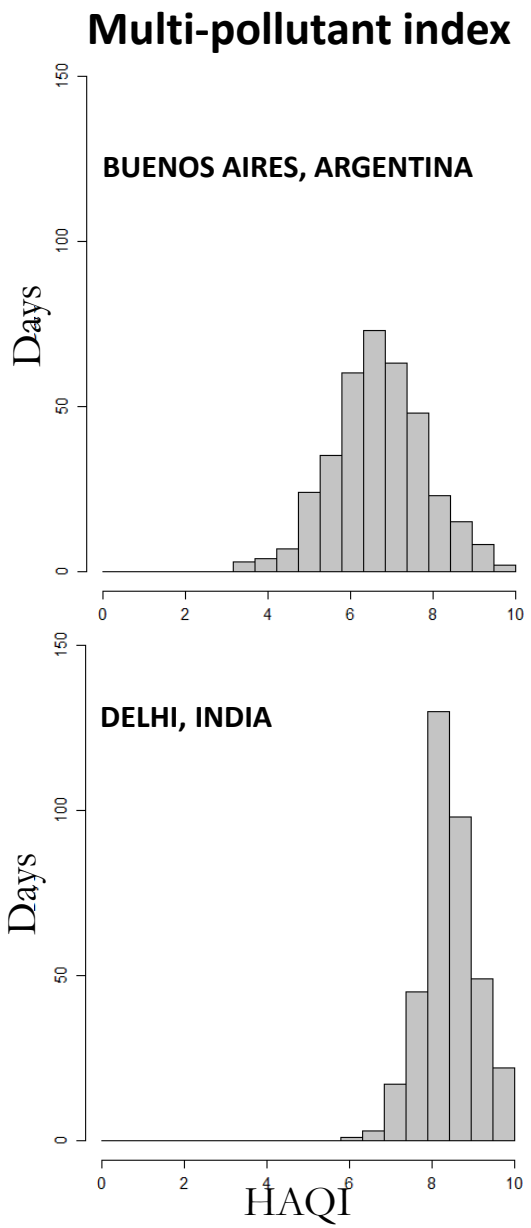
$$NO_2 \text{ index} = \ln\left[100\left(e^{(0.004 * X_{NO2})} - 1\right)\right]$$

$$PM_{2.5} \text{ index} = \ln\left[100\left(e^{(0.002 * X_{PM2.5})} - 1\right)\right]$$

Sum the individual pollutant index values for the overall daily index value:

$$Overall\ Index\ Value = O_3 \text{ index} + NO_2 \text{ index} + PM_{2.5} \text{ index}$$

Air Pollution Messaging using HAQI



"The best solution is to indicate as specifically as possible how a local [air quality index] has been tailored to local needs, which may differ according to local air quality, types of pollutants, geographical and climatic conditions and population characteristics.

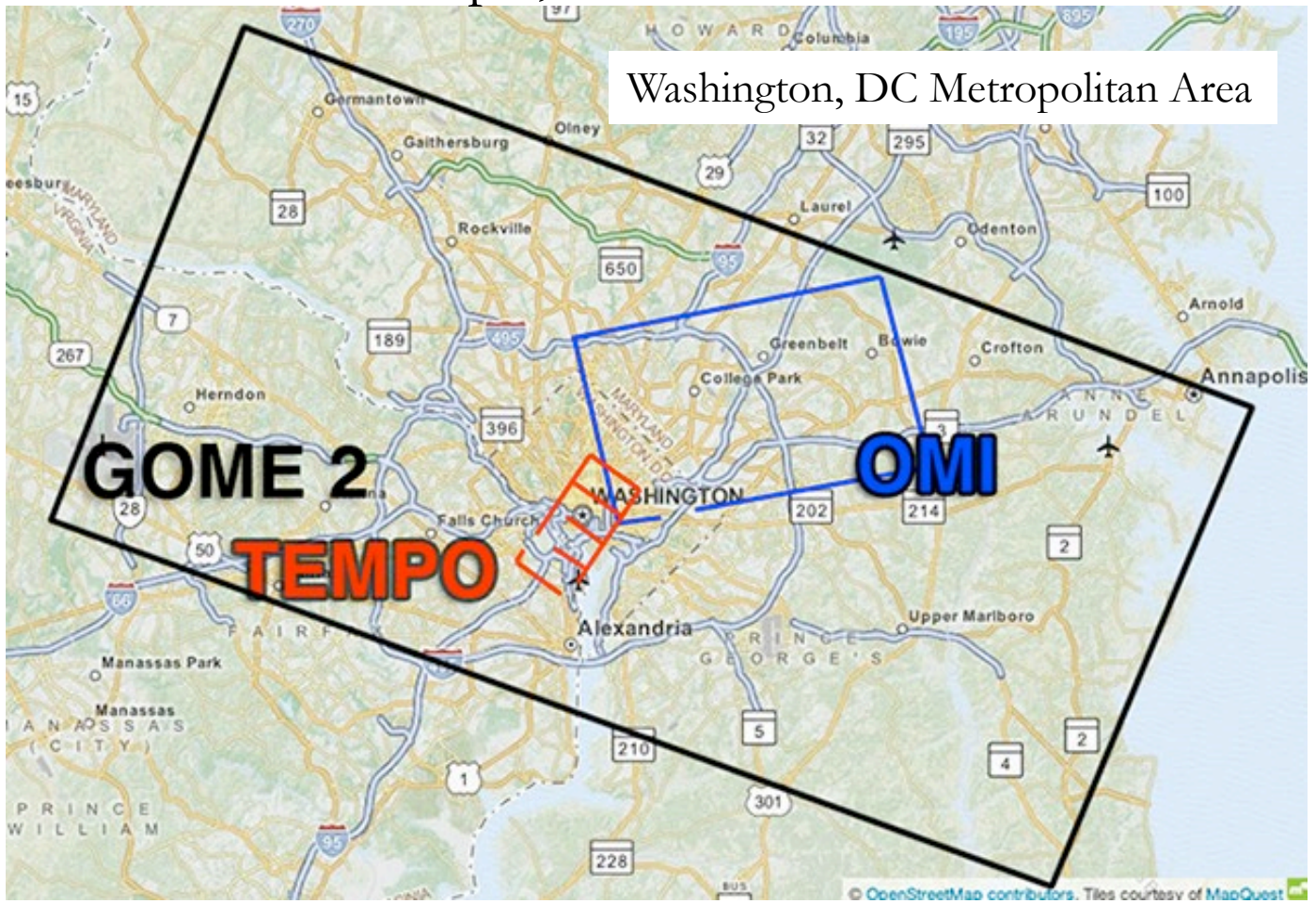
"The most important function of an [air quality index] is reliable communication of day-to-day changes in the health risks of outdoor air pollution in a given location, rather than providing information to compare risks among geographical locations."

World Health Organization

Personal interventions and risk communication on air pollution. Geneva: World Health Organization; 2020. Licence : CC BY-NC-SA 3.0 IGO. See "Risk Communication with Air Pollution Indices" led by Kevin Cromar, NYU.

An Exciting Time:
Evolving Technology & New Satellites

For example, horizontal resolution.



GOME (1996)
40 x 40 km^2 & greater

↓

OMI (2004)
13 x 24 km^2 & greater

↓

TROPOMI (2017)
~3.5 x 5.5 km^2

↓

TEMPO (2022)
2 x 5 km^2 & greater

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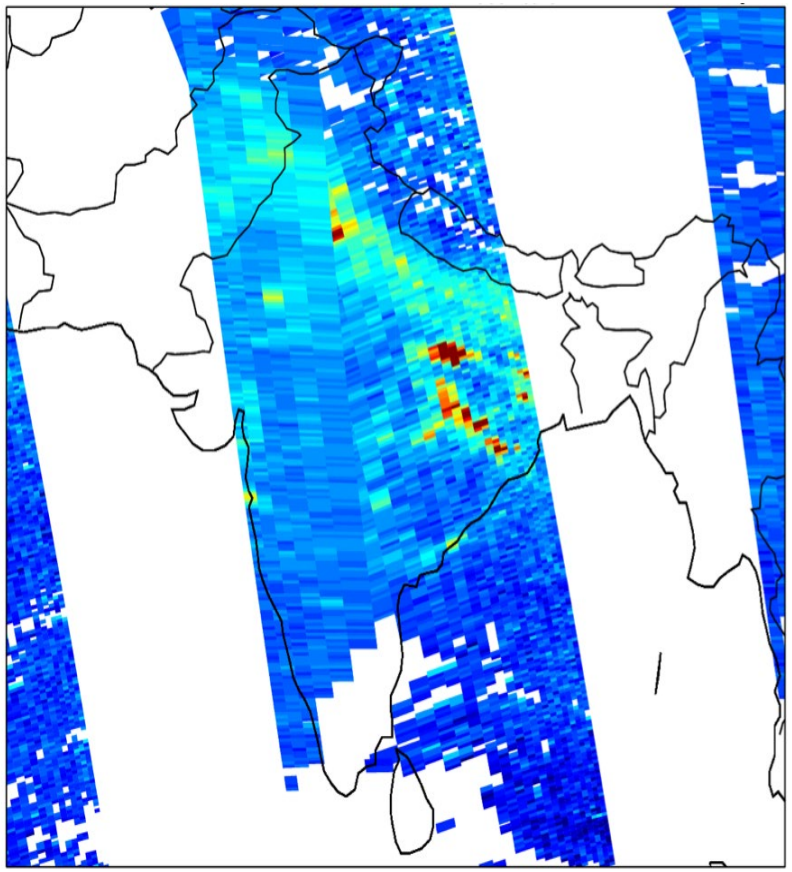
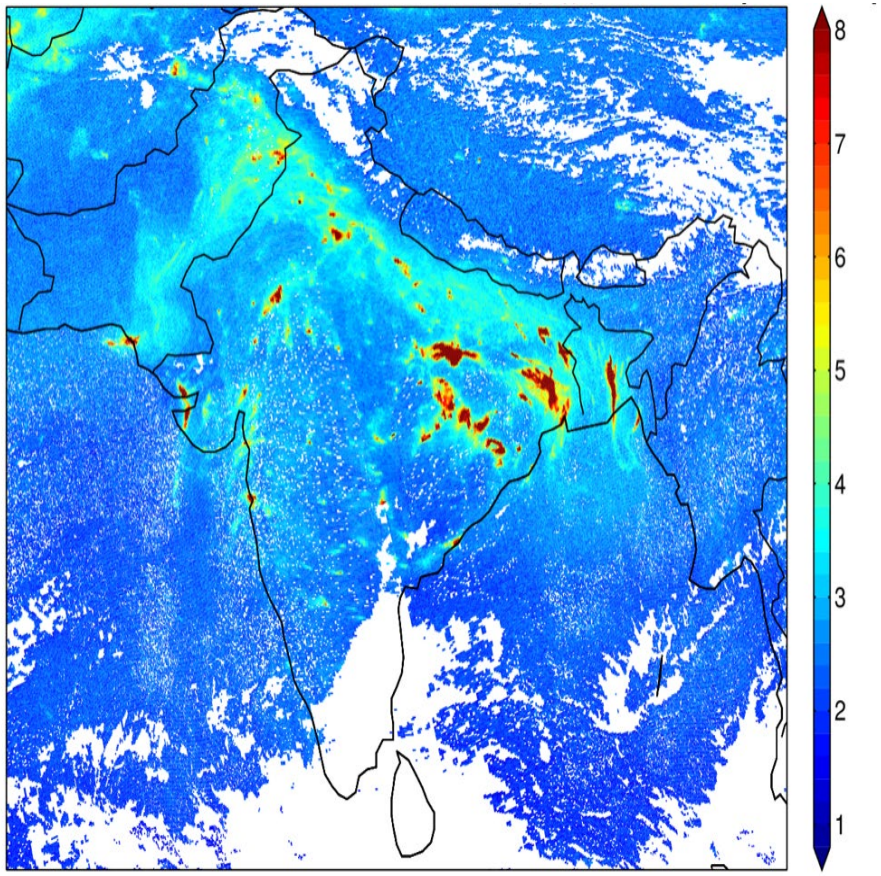
OMI NO_2



November 28, 2017

TROPOMI NO_2



Spatial Resolution = 3.5 x 7.0 km^2

Images courtesy Lok Lamsal (NASA)