# Air quality forecasts using the NASA GEOS model

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USRA/GESTAR

NASA Global Modeling and Assimilation Office (GMAO)

**In collaboration with:**

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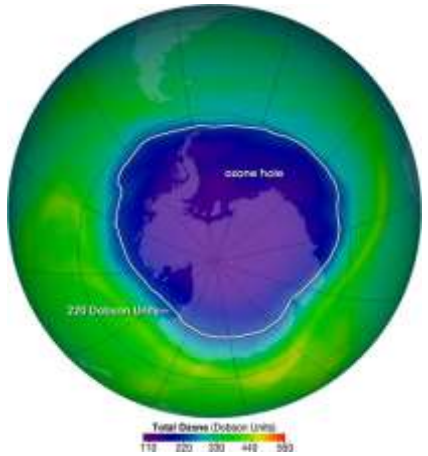
Eric J. Nielsen, Clara Orbe, Lesley Ott, Steven Pawson, Emily Saunders

5 November 2018

# Why we care about atmospheric chemistry

## 1. Climate & Dynamics




## 2. Air Quality



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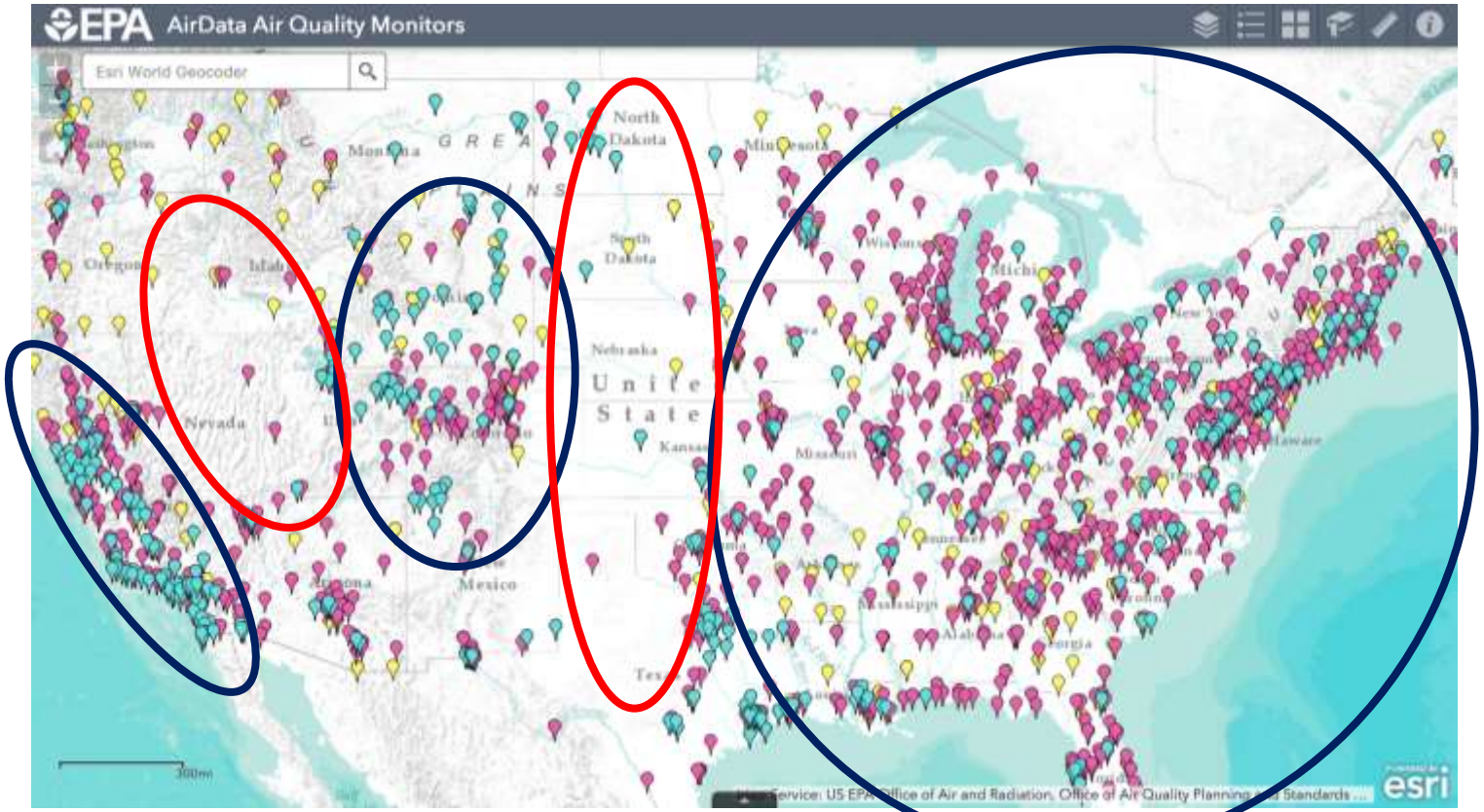
# How do we observe air quality?

Surface observations of pollutants are point source measurements which can be sparse.




$O_3$
$PM_{2.5}$
$NO_2$

https://epa.maps.arcgis.com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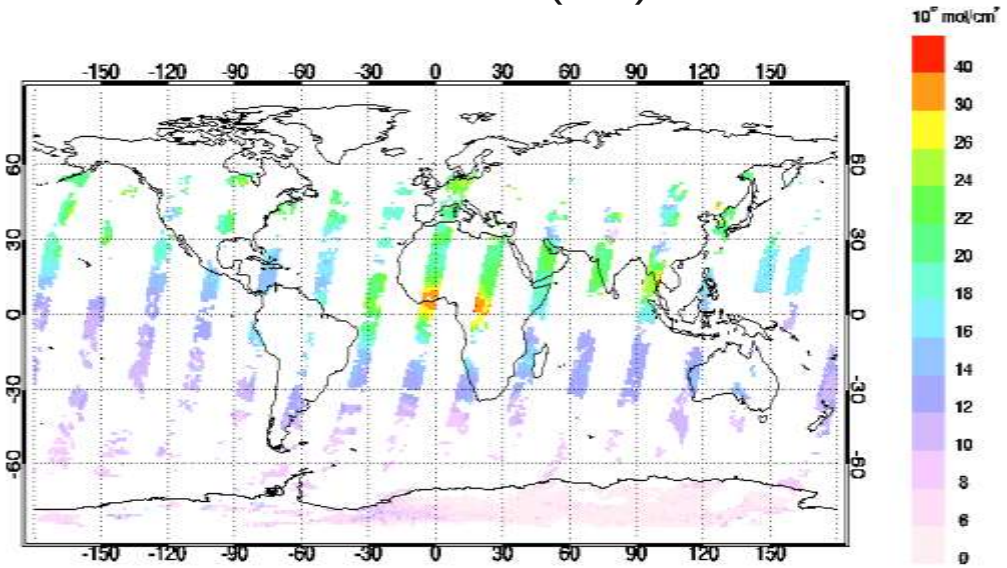
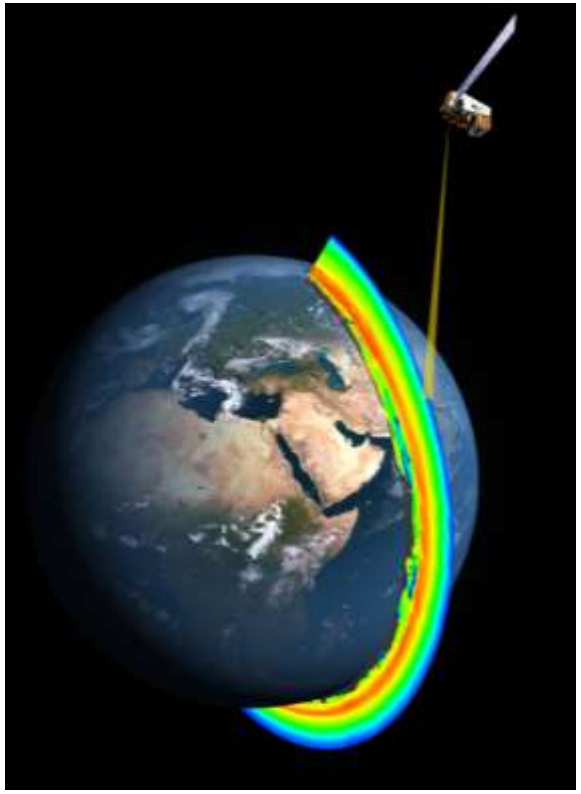
# Earth Observing Satellites

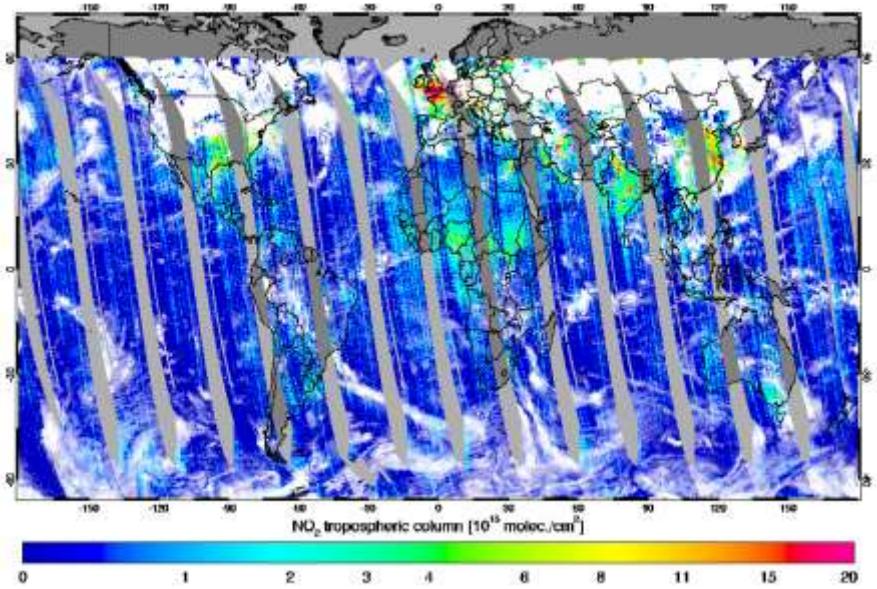
Terra MOPITT (CO)




www.acom.ucar.edu



Aura OMI ($NO_2$, $O_3$)




www.temis.nl

Global coverage from space but temporal frequency may be on the order of days not hours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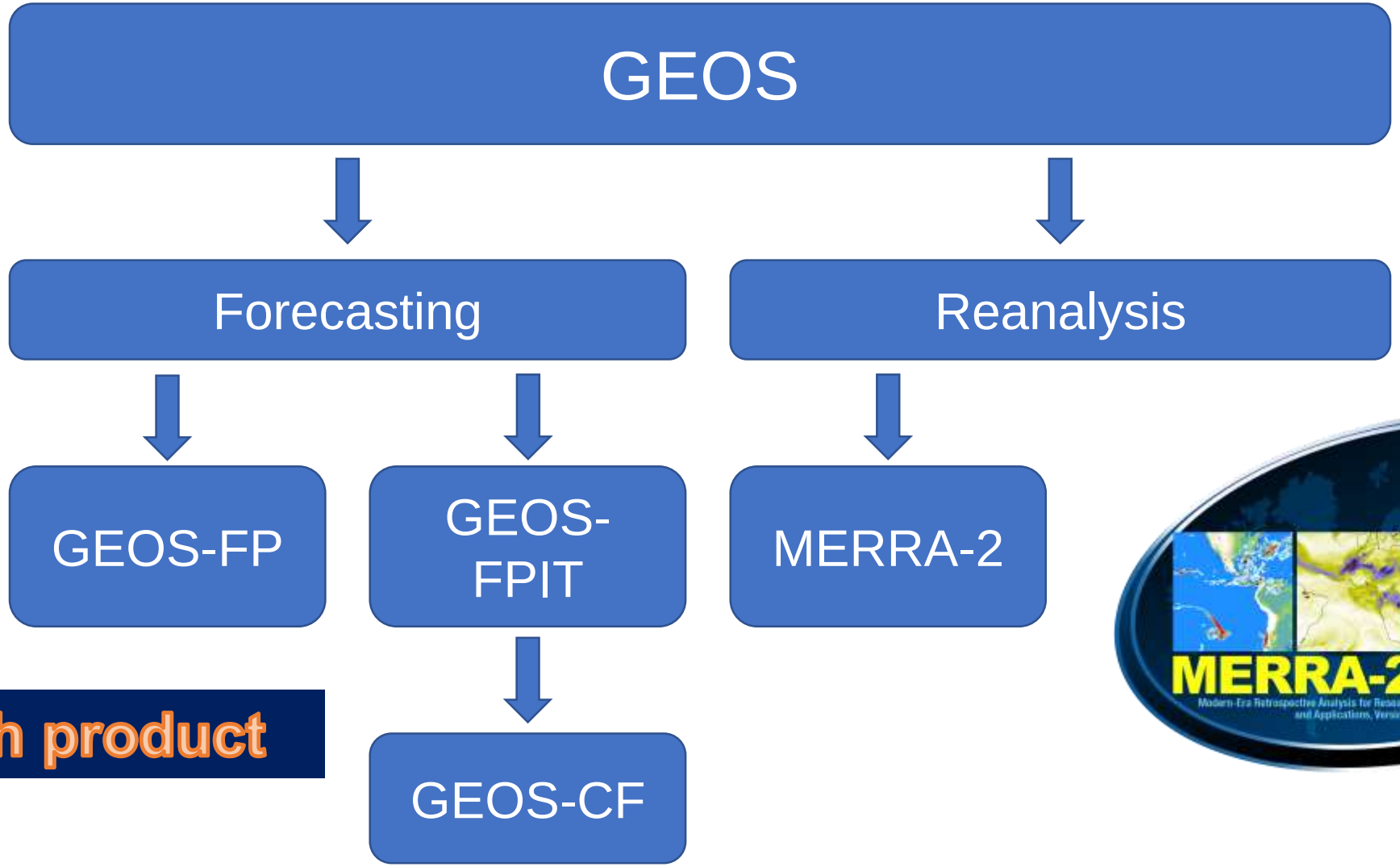
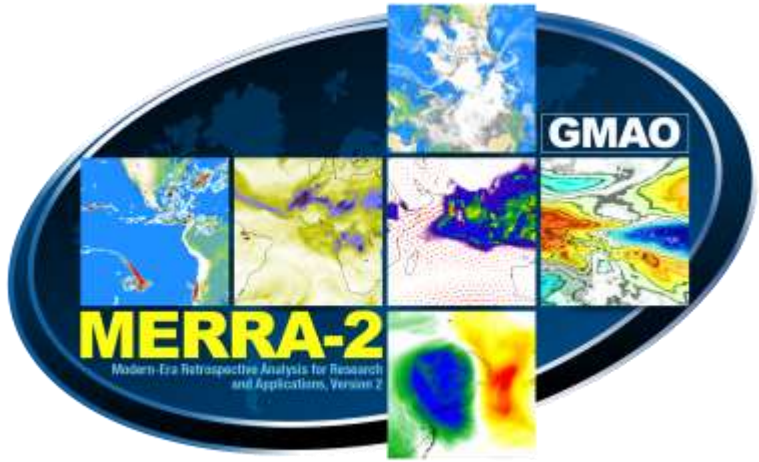
# NASA GMAO global meteorology and chemistry products




**Research product**





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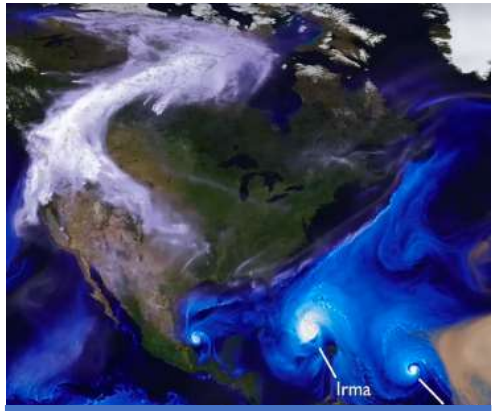
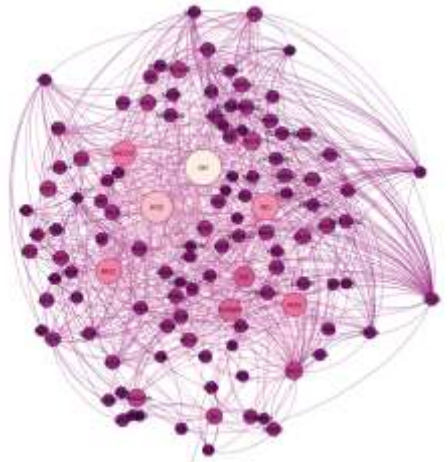
# NASA's composition forecast

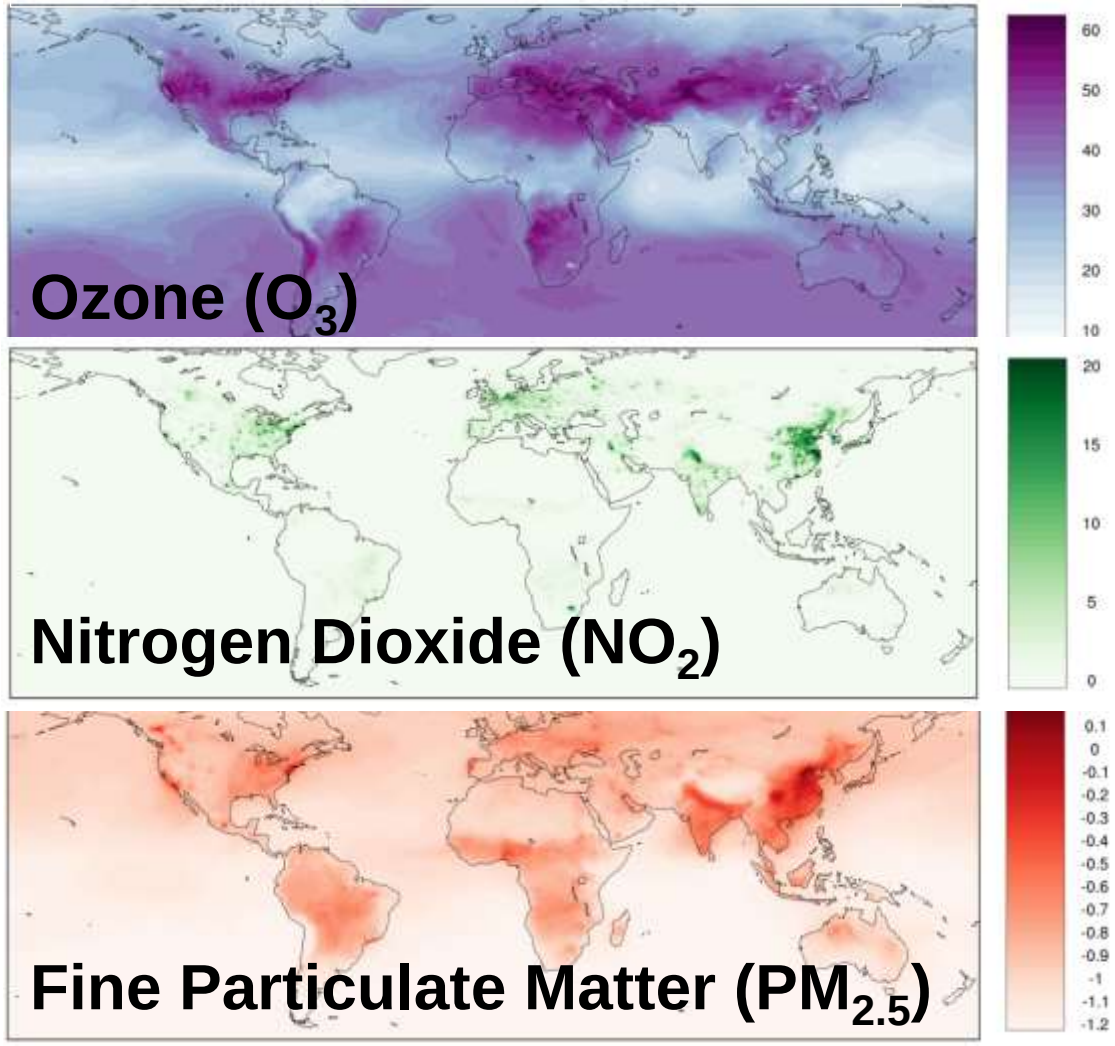



GEOS - FPIT



GEOS - Chem

## GEOS - CF





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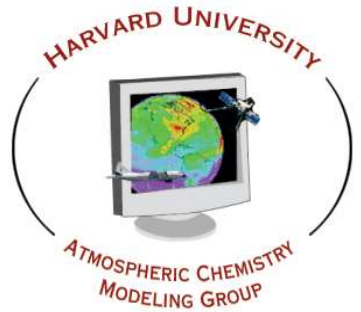
# GEOS-Chem is a state-of-the science chemistry model

Tropospheric and Stratospheric full chemistry

- 220 reactive species, 720 reactions
- 100+ user/developer groups worldwide
- Updated version is released about every year





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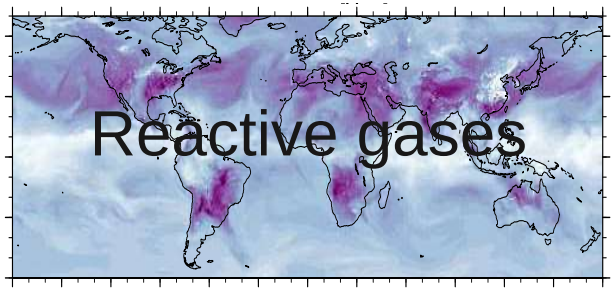
# Contributors to Air Pollution


- Particulate matter (PM):
  - Organic Carbon
  - Black Carbon
  - Sea salt
  - Nitrate
  - Sulfate
  - Dust

- Ozone ($O_3$)
- Nitrogen dioxide ($NO_2$)
- Sulfur dioxide ($SO_2$)
- Volatile organic compounds (VOCs):
  e.g., Formaldehyde, Benzene, Toluene, and many more…

GOCART

GEOS-Chem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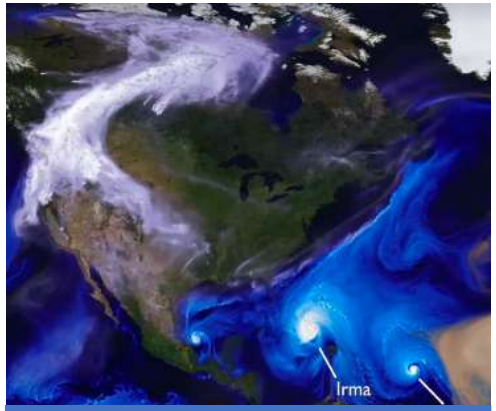
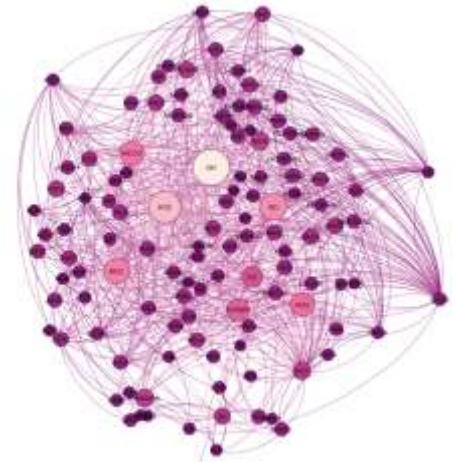
# Chemistry is *not* cheap!




GEOS - FPIT



GEOS - Chem

GEOS - CF

One **5-day forecast** per day

- 1-day analysis
- 5-day forecast
- c360 (0.25°, ~**25x25 km²**) resolution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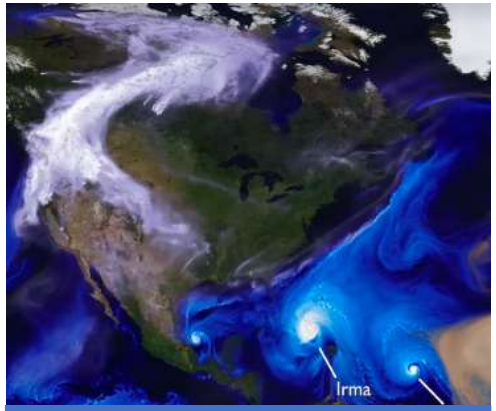
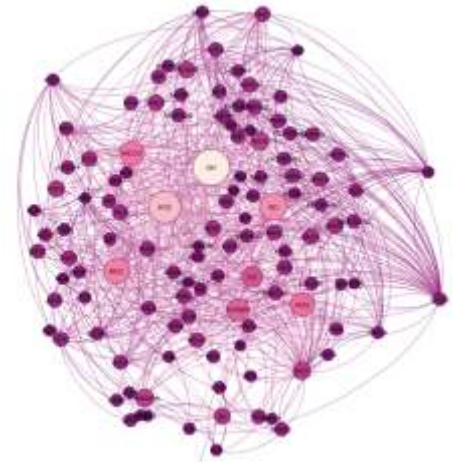
# Chemistry is *not* cheap!




GEOS - FPIT



GEOS - Chem

GEOS - CF

Run on **NASA's** Center for Climate Simulation **supercomputer**

- using the computing power equivalent to **3500** personal **computers**.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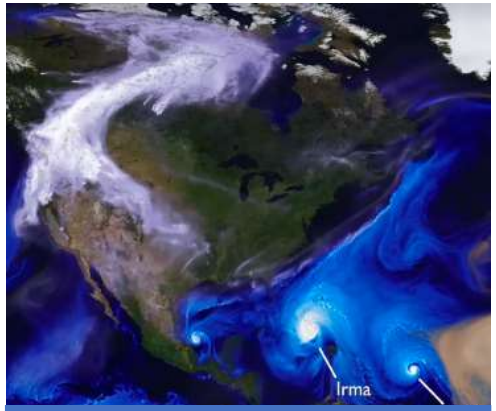
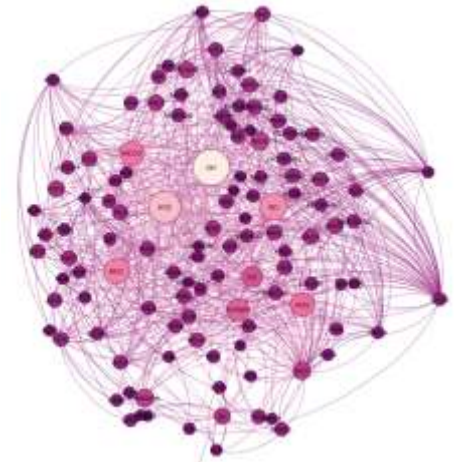
# But are we alone?




GEOS - FPIT



GEOS - Chem

GEOS - CF

25 km x 25 km (16 miles)

- **Highest** horizontal resolution of a global atmospheric composition forecast
- **10 x higher** than conventional global atmospheric chemistry simulations.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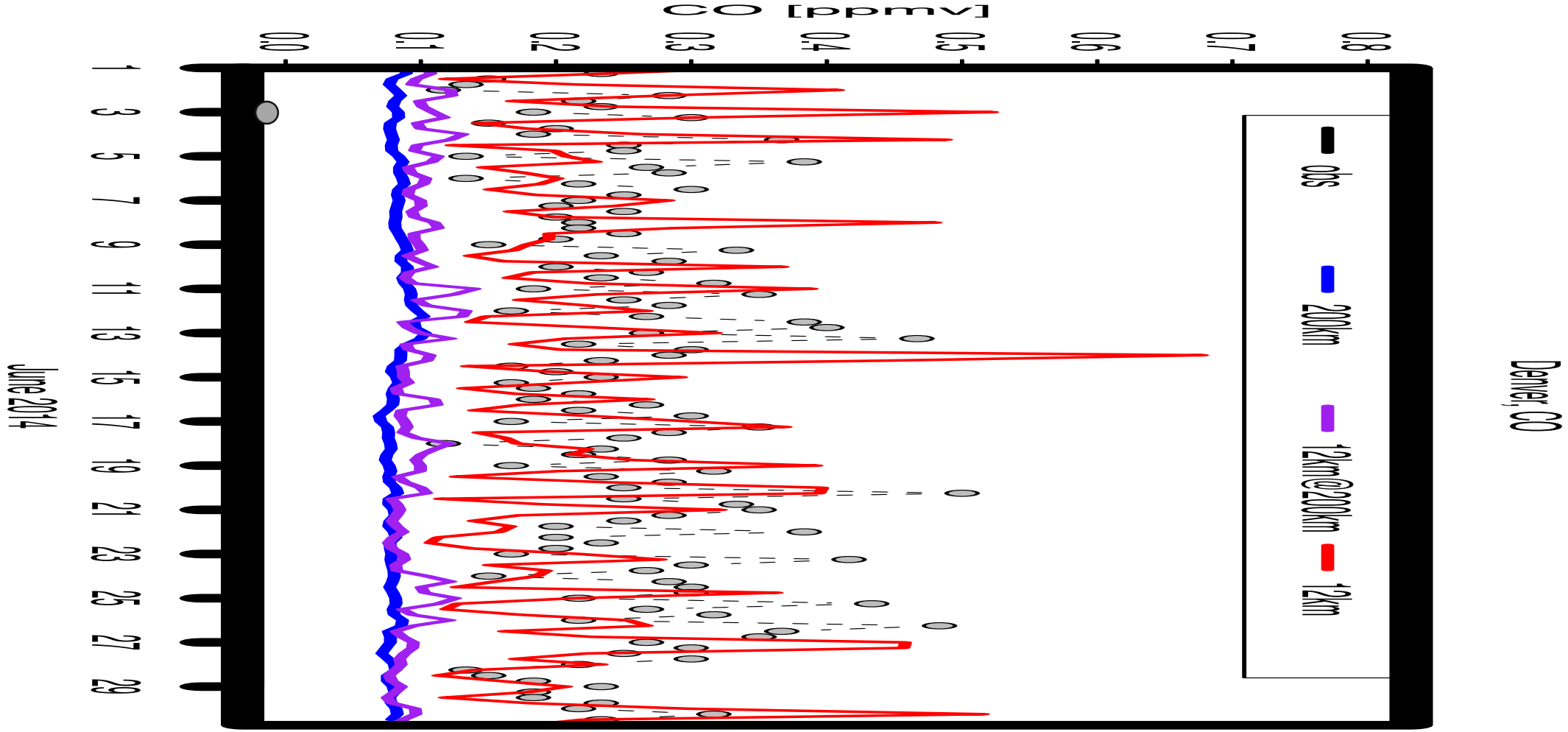
# High resolution critical to resolve features relevant to air quality





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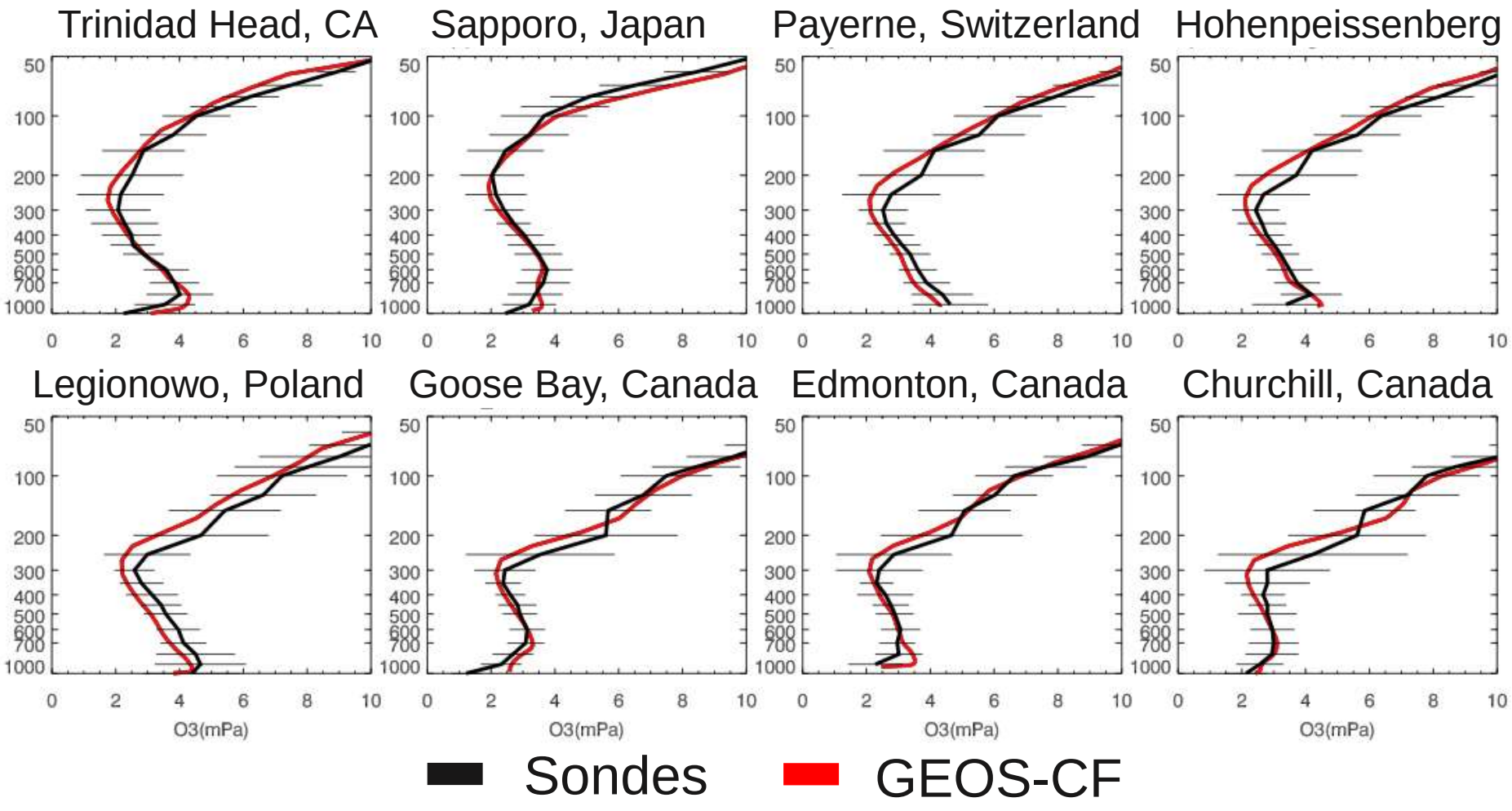
# Comparison of GEOS-CF $O_3$ against ozone sondes





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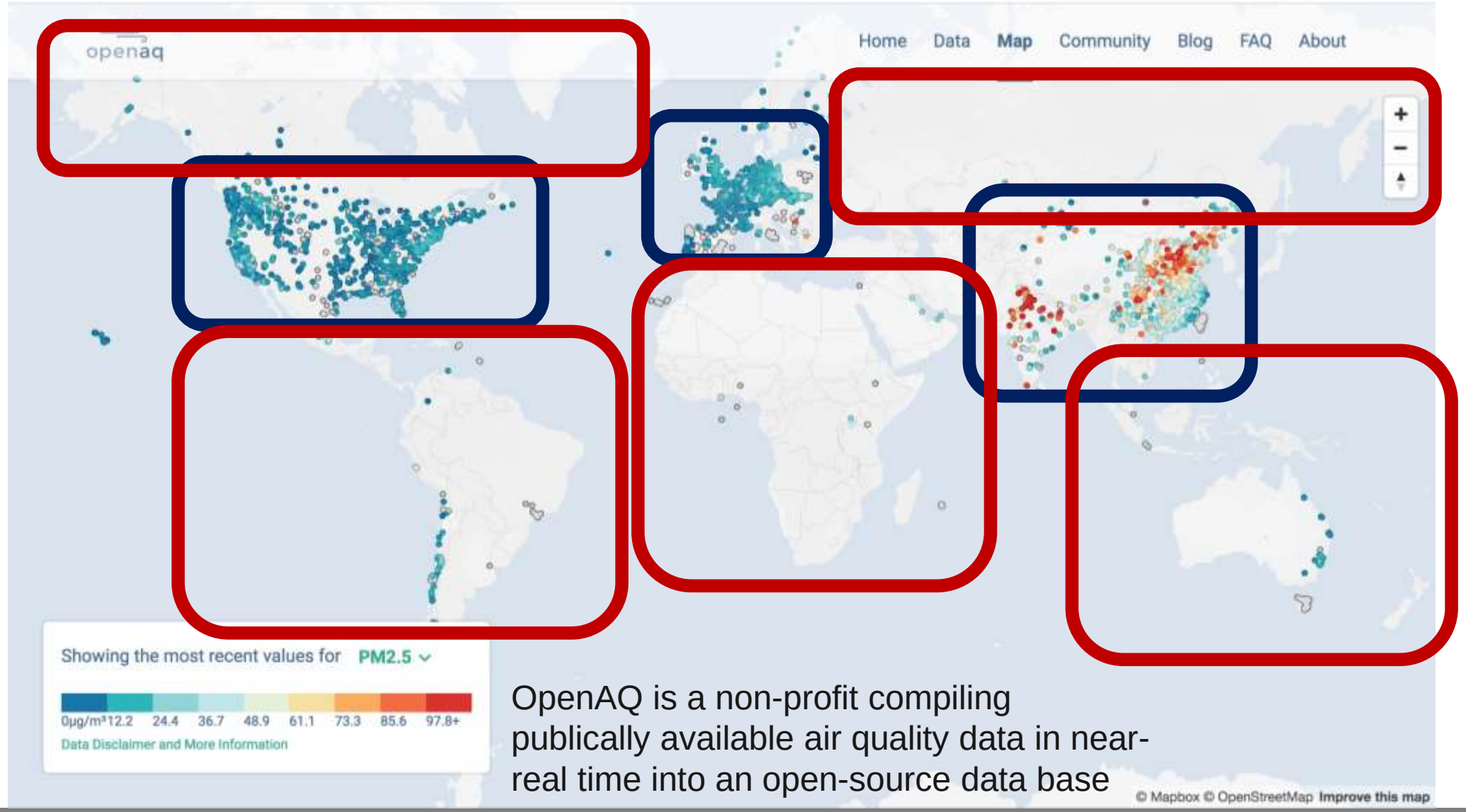
# OpenAQ surface observation data base




OpenAQ is a non-profit compiling publically available air quality data in near-real time into an open-source data base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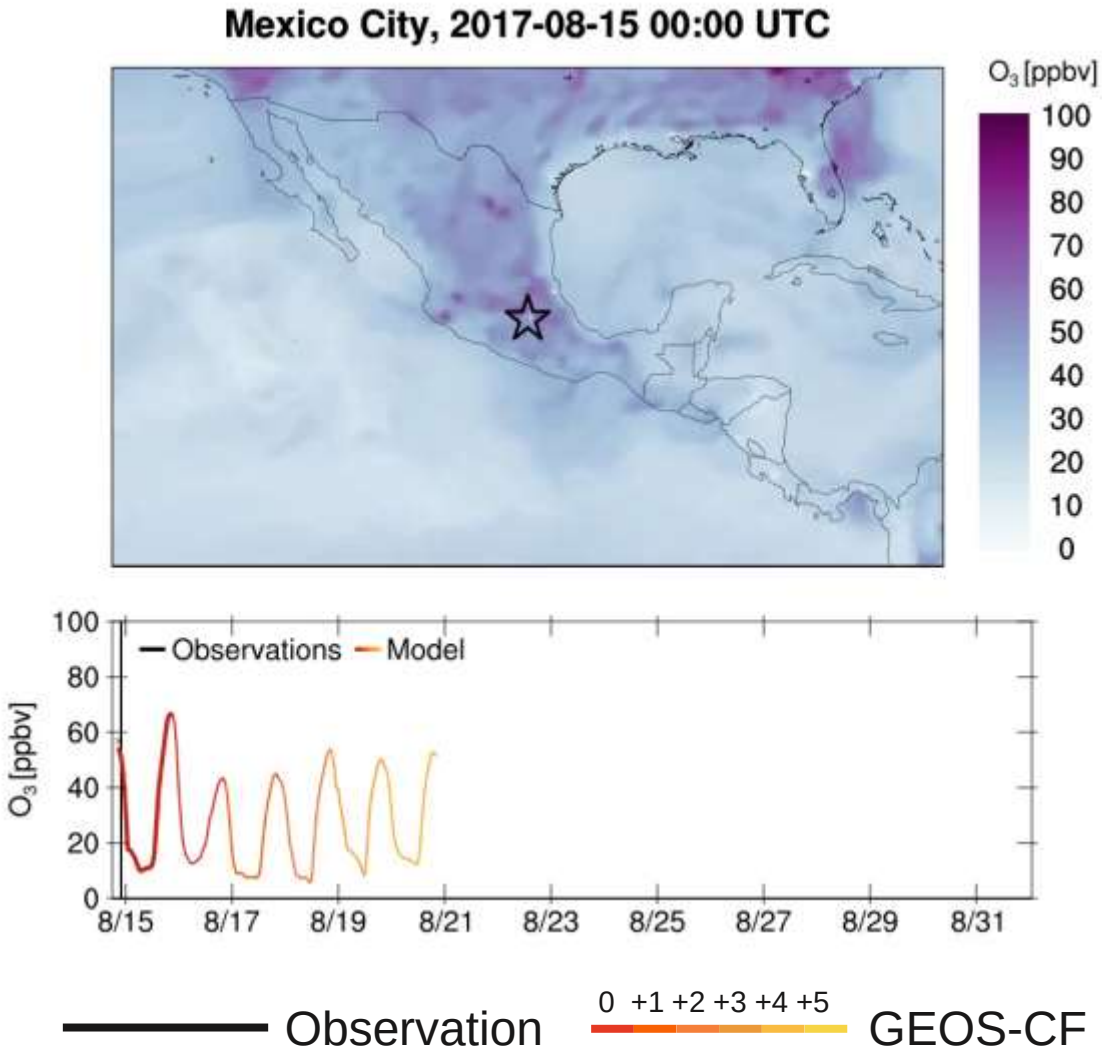
# Ozone forecast against surface observations for Mexico City





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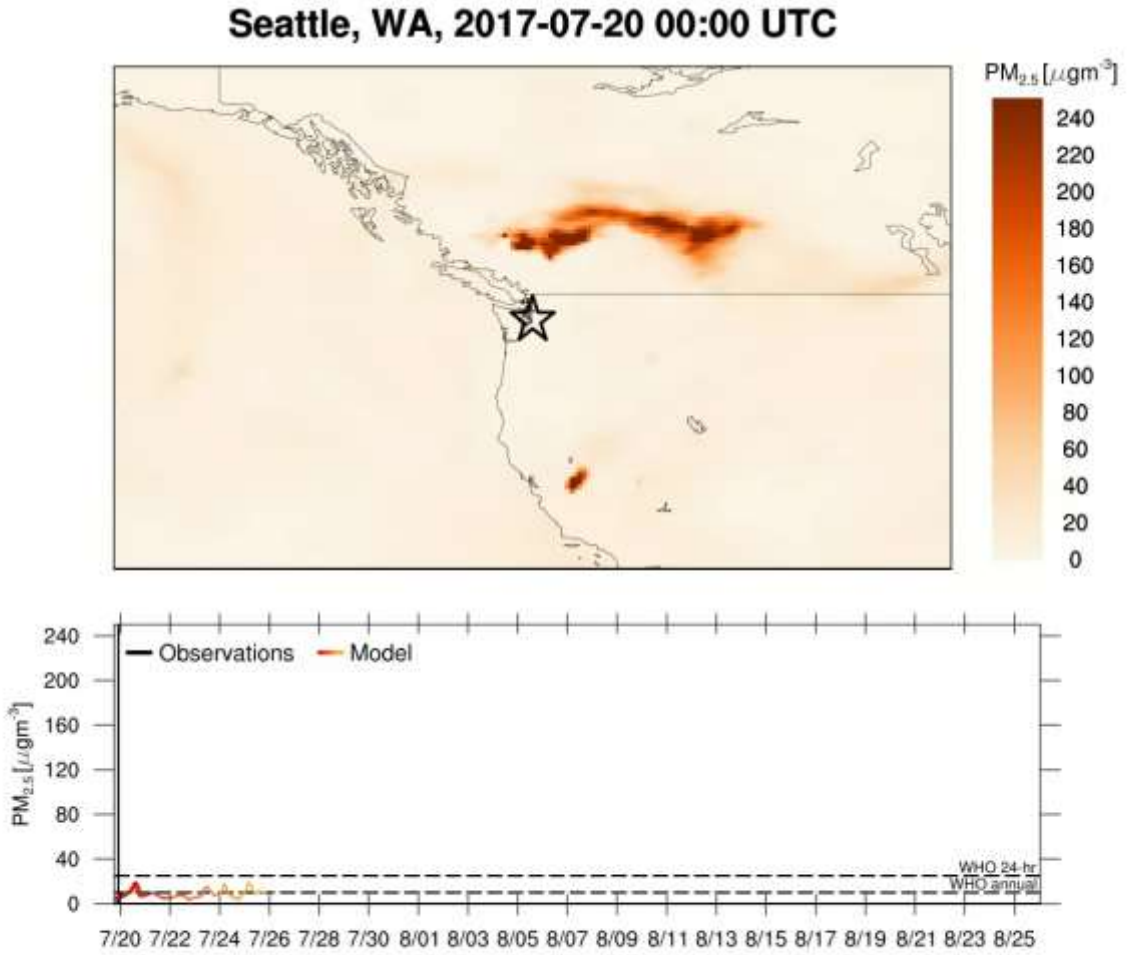
# Local evaluation of $PM_{2.5}$ from wildfires




Observation 0 +1 +2 +3 +4 +5 GEOS-CF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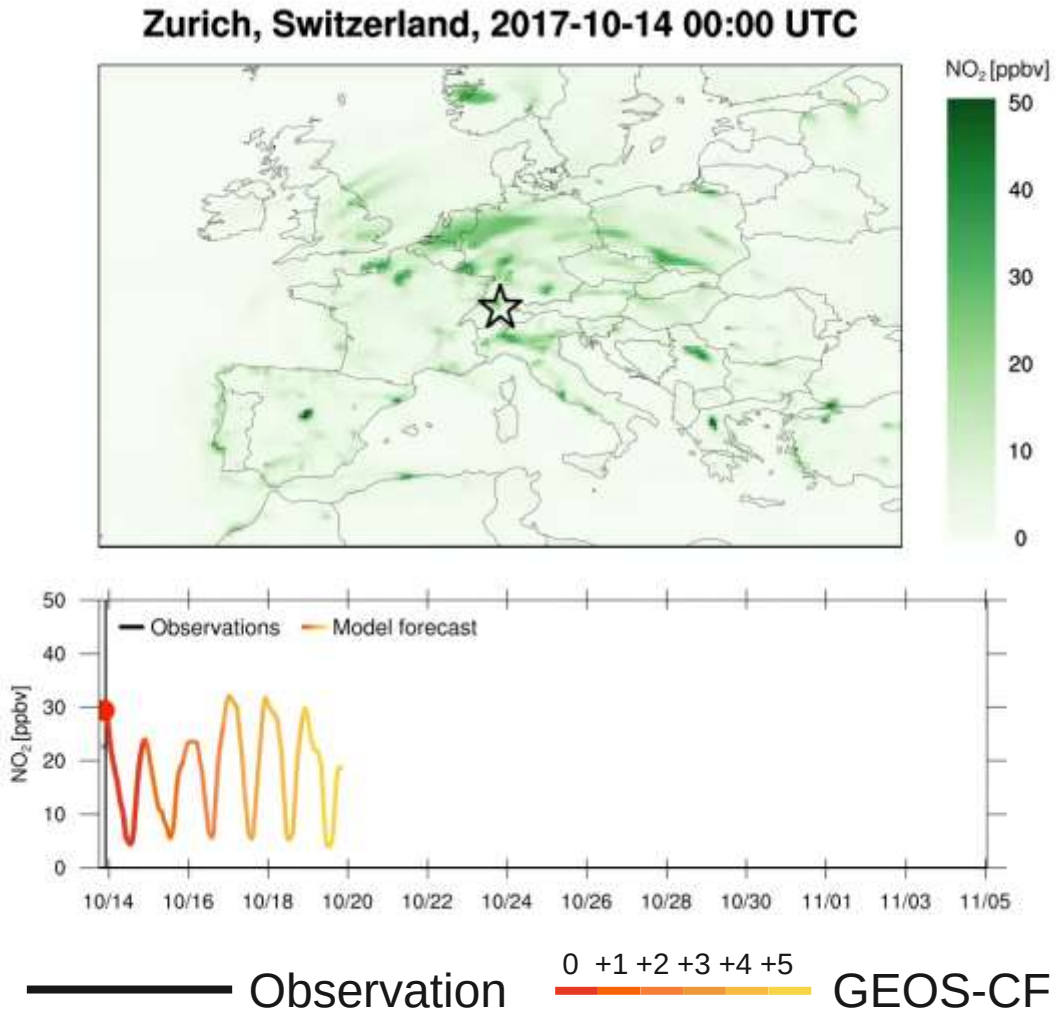
# Local evaluation of $NO_2$: model captures diurnal and weekly variations





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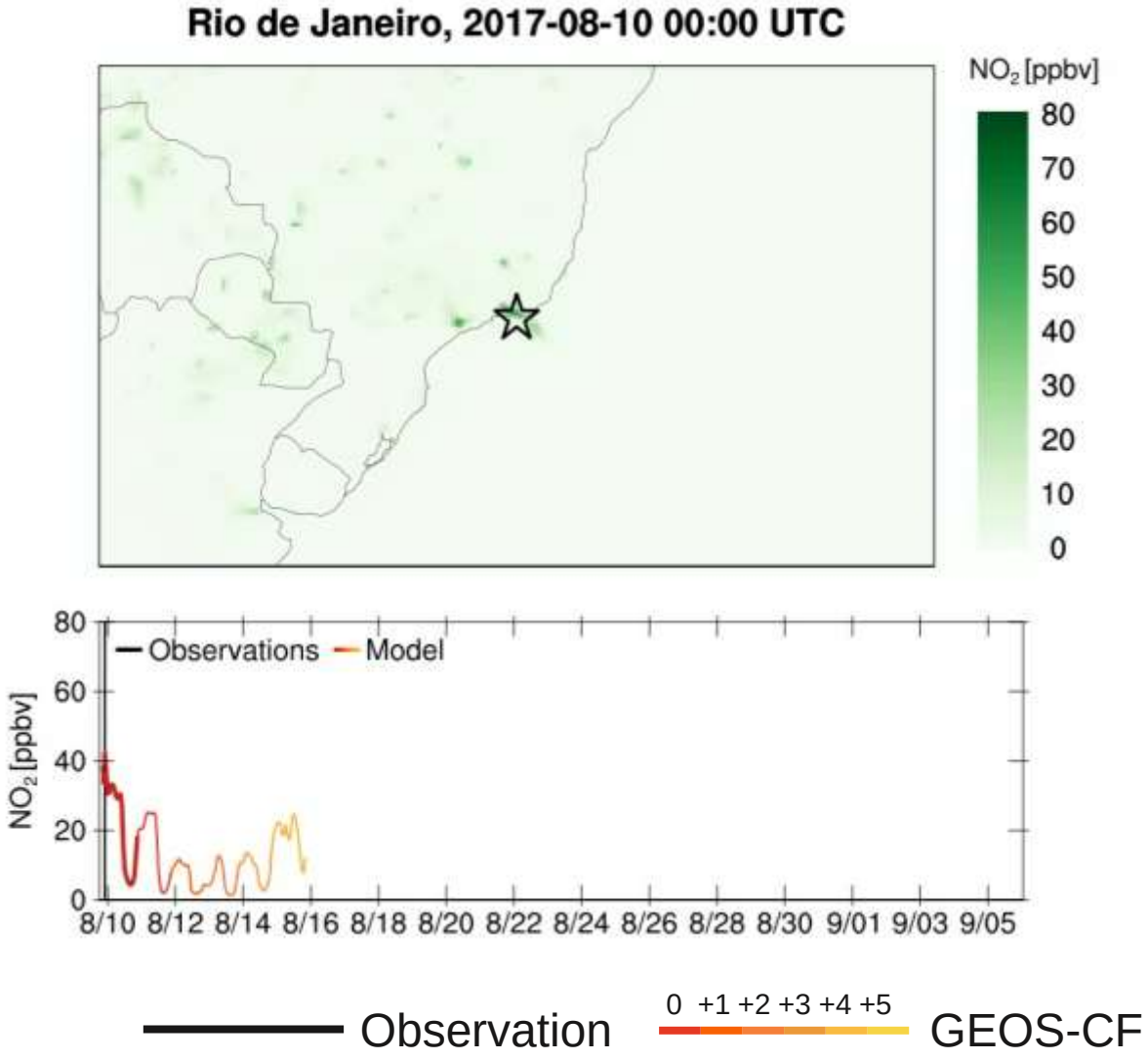
# Partnerships with local governments




Working with local governments

- Rio De Janeiro
- Jakarta

to improve emissions in the model to *hopefully* improve forecasts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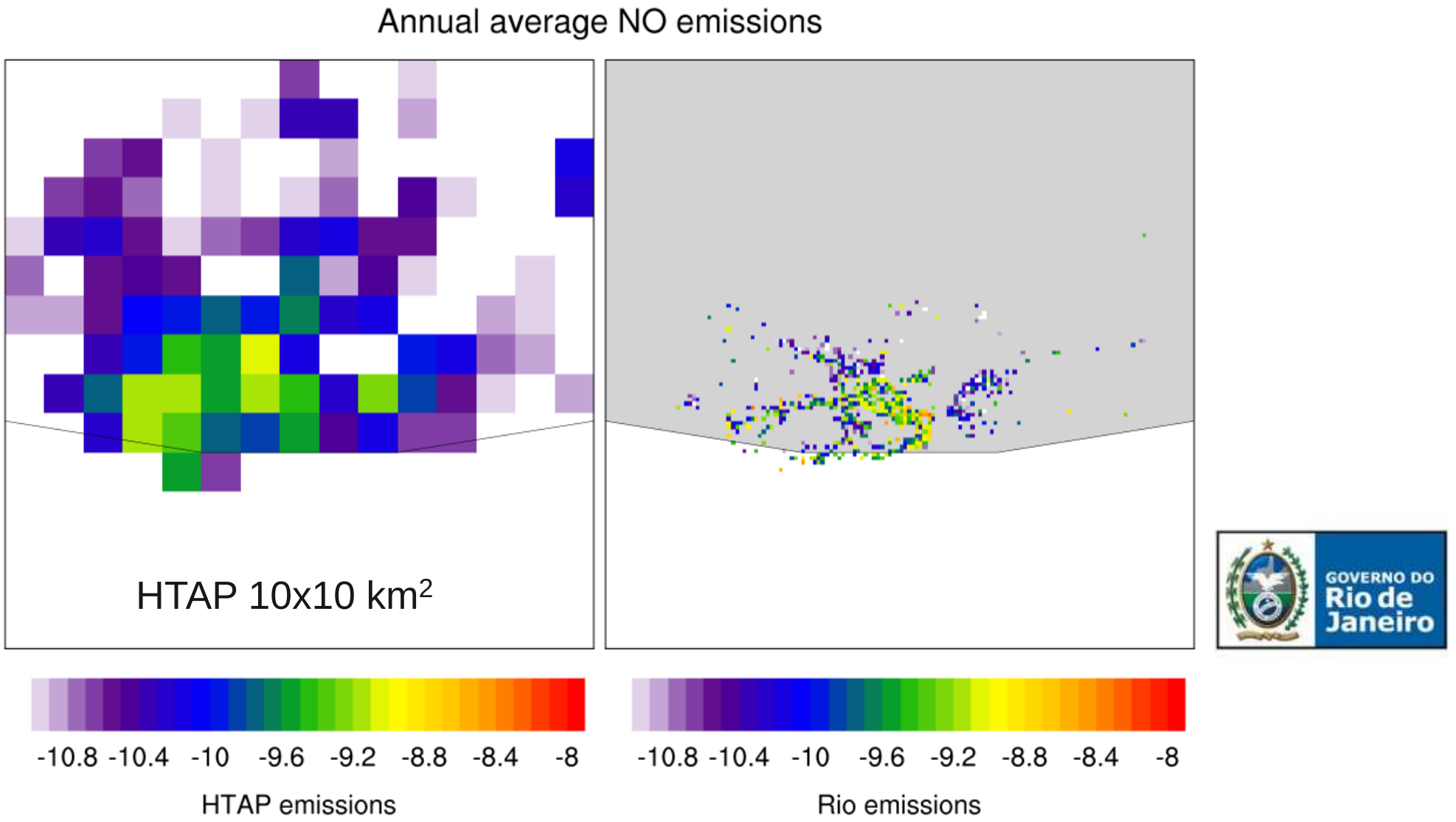



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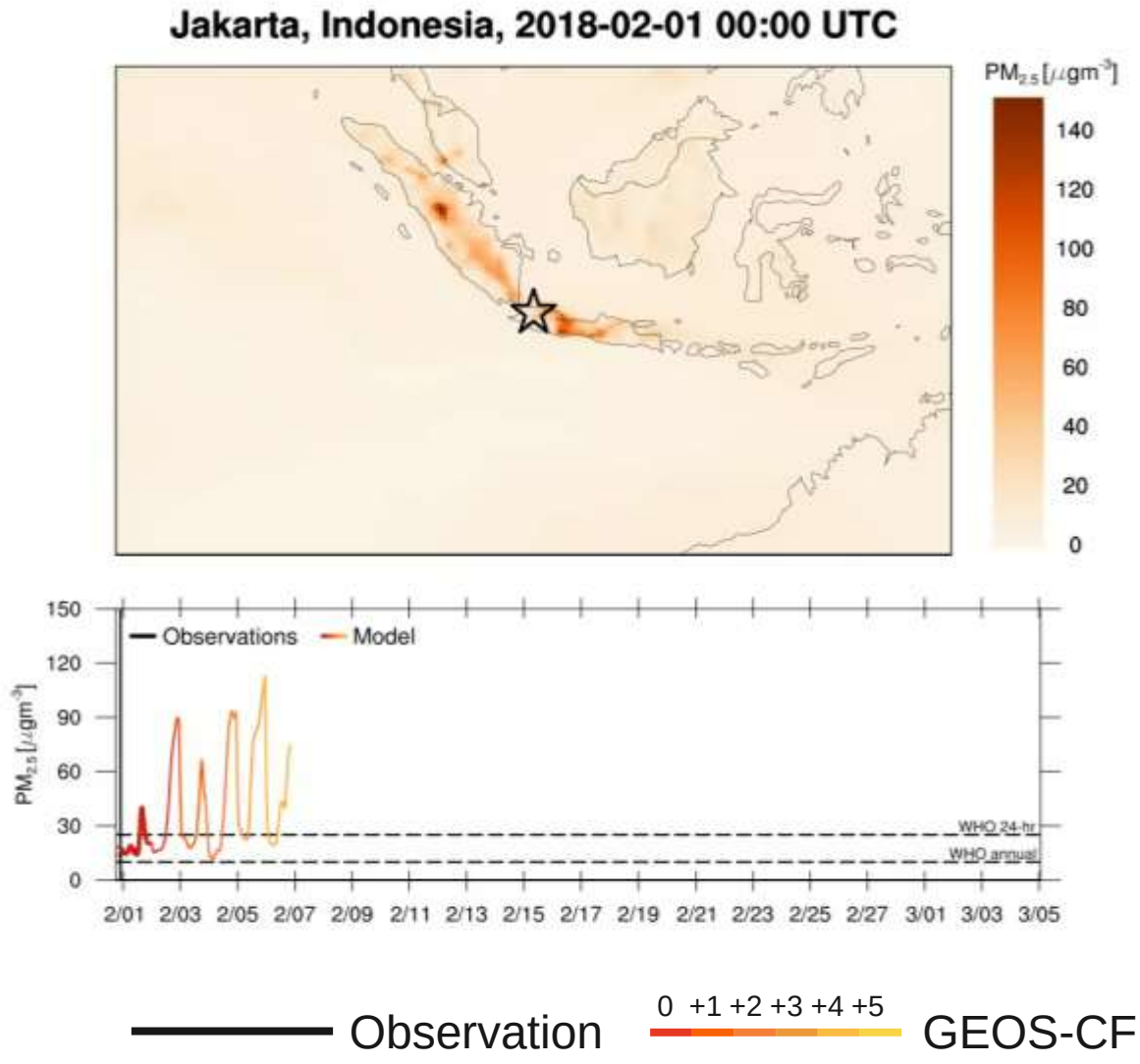
# Partnerships with local governments




Working with local governments

- Rio De Janeiro
- Jakarta

to improve emissions in the model to *hopefully* improve forecasts

Fires from Indonesia impact urban centers in Singapore and Malaysia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# Sparse publicly available data in Near-Real Time



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# Monitoring stations at US embassies



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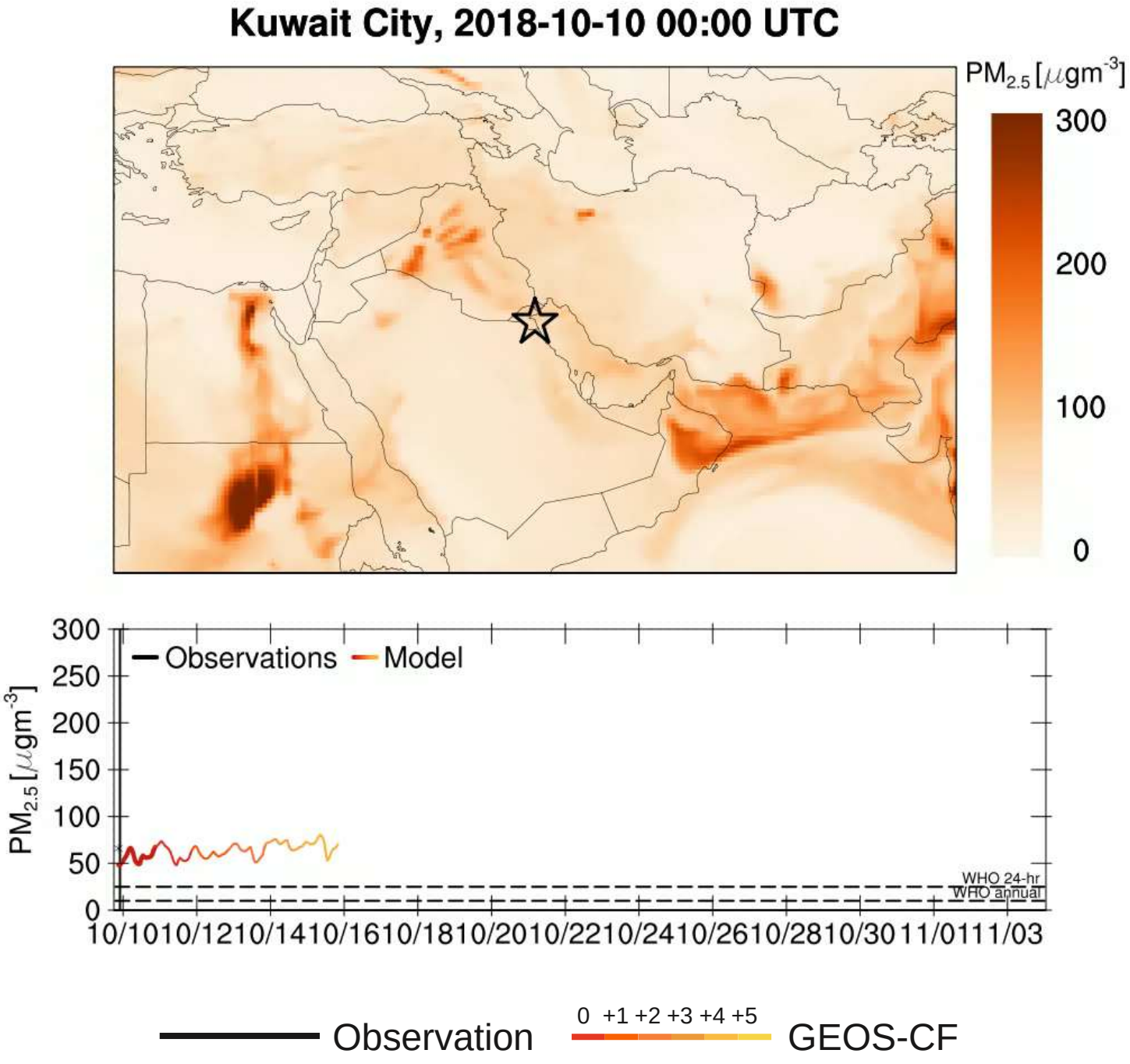
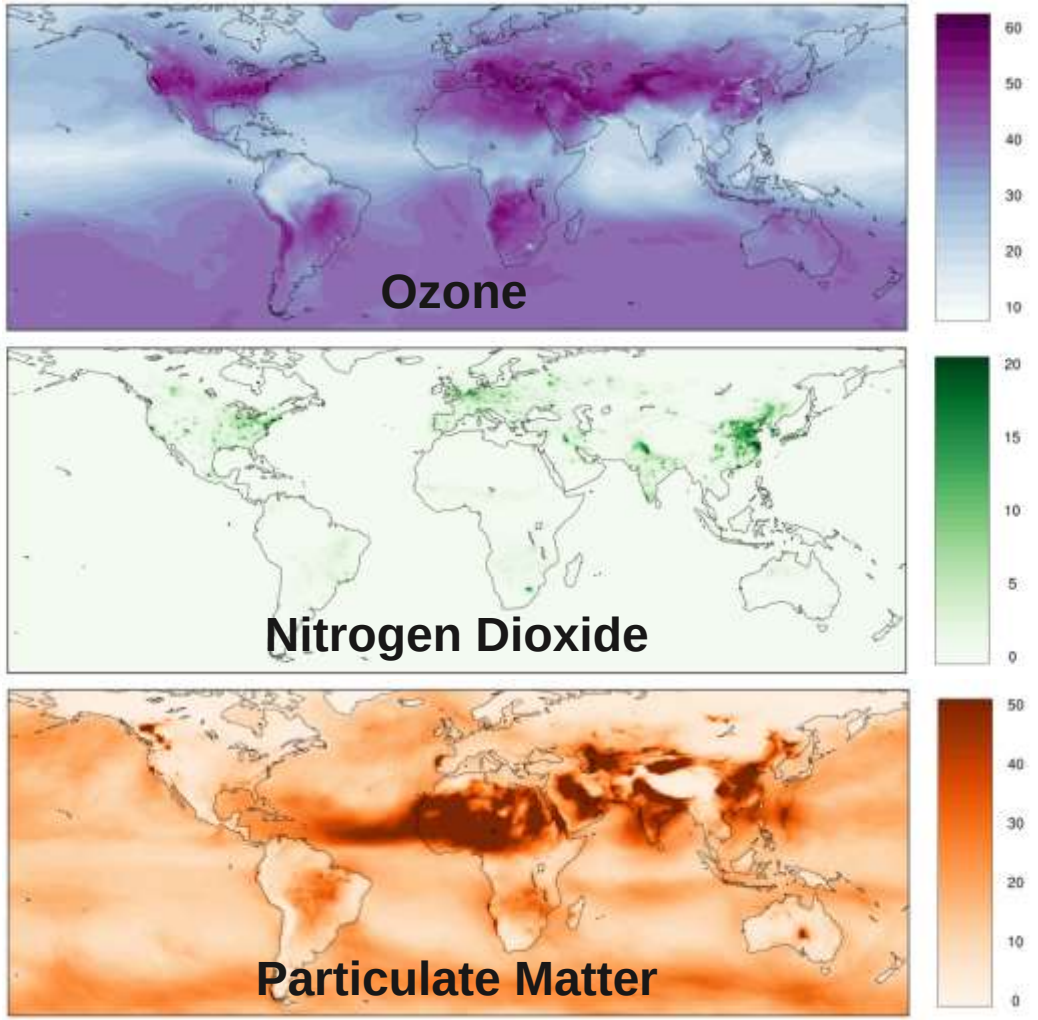

Kuwait City, 2018-10-10 00:00 UTC
PM2.5 [μgm-3]
300
200
100
0
Observations
Model
PM2.5 [μgm-3]
300
250
200
150
100
50
0
WHO 24-hr
WHO annual
10/10 10/12 10/14 10/16 10/18 10/20 10/22 10/24 10/26 10/28 10/30 11/01 11/03
Observation
0 +1 +2 +3 +4 +5
GEOS-CF

# Application: Health Air Quality Index (HAQI)

HAQI is a **multi-pollutant** index




- **$O_3$ influences Background levels**
- **$NO_2$ is Short-lived**
- **Extreme gradients**
- **$PM_{2.5}$ driver of spatial gradients**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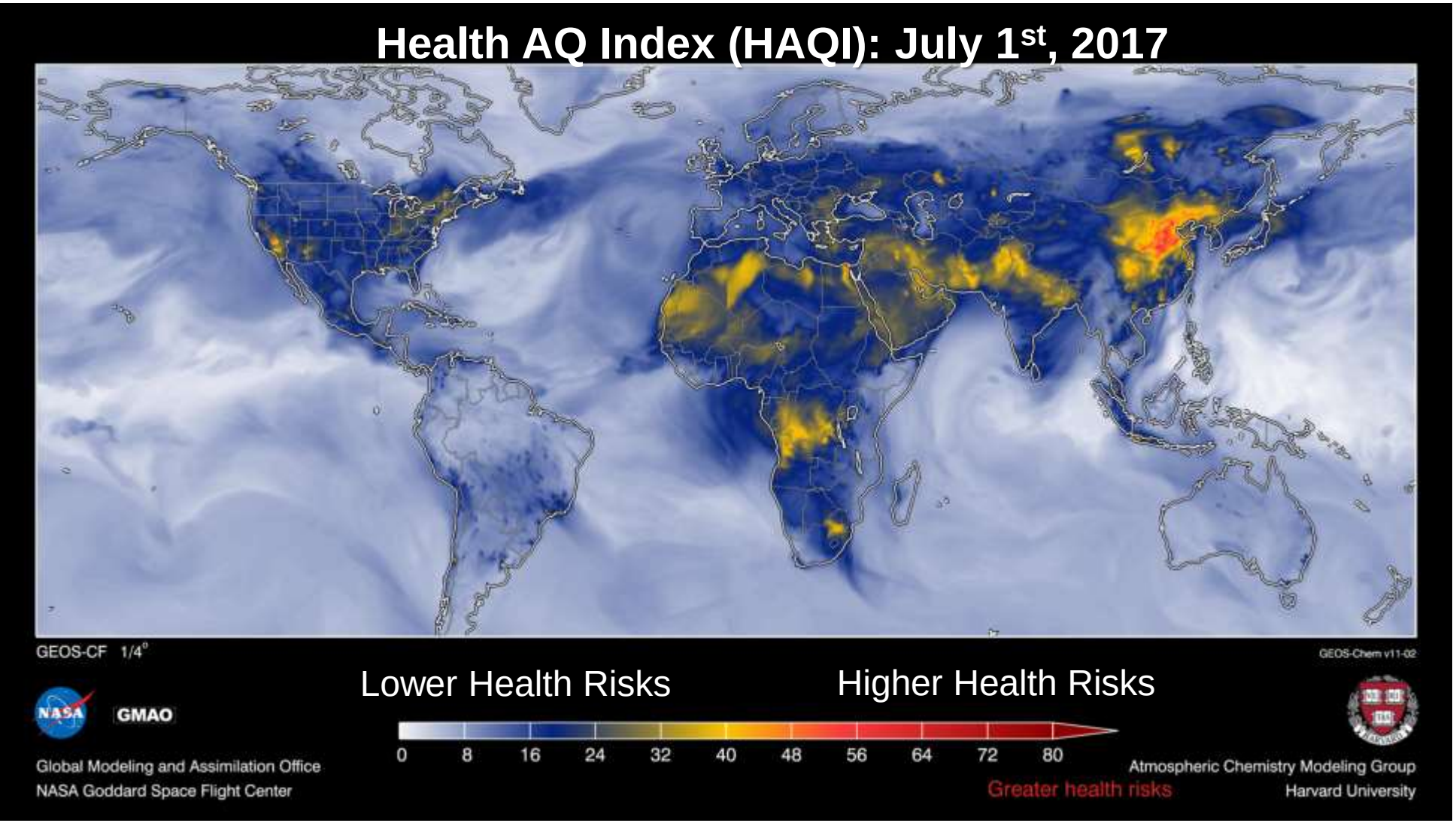
# Application: Health Air Quality Index (HAQI)




HAQI developed by Kevin Cromar from NYU

HAQI is a function:

- Maximum daily 8-hour average $O_3$
- 24-hour-average $NO_2$
- 24-hour-average $PM_{2.5}$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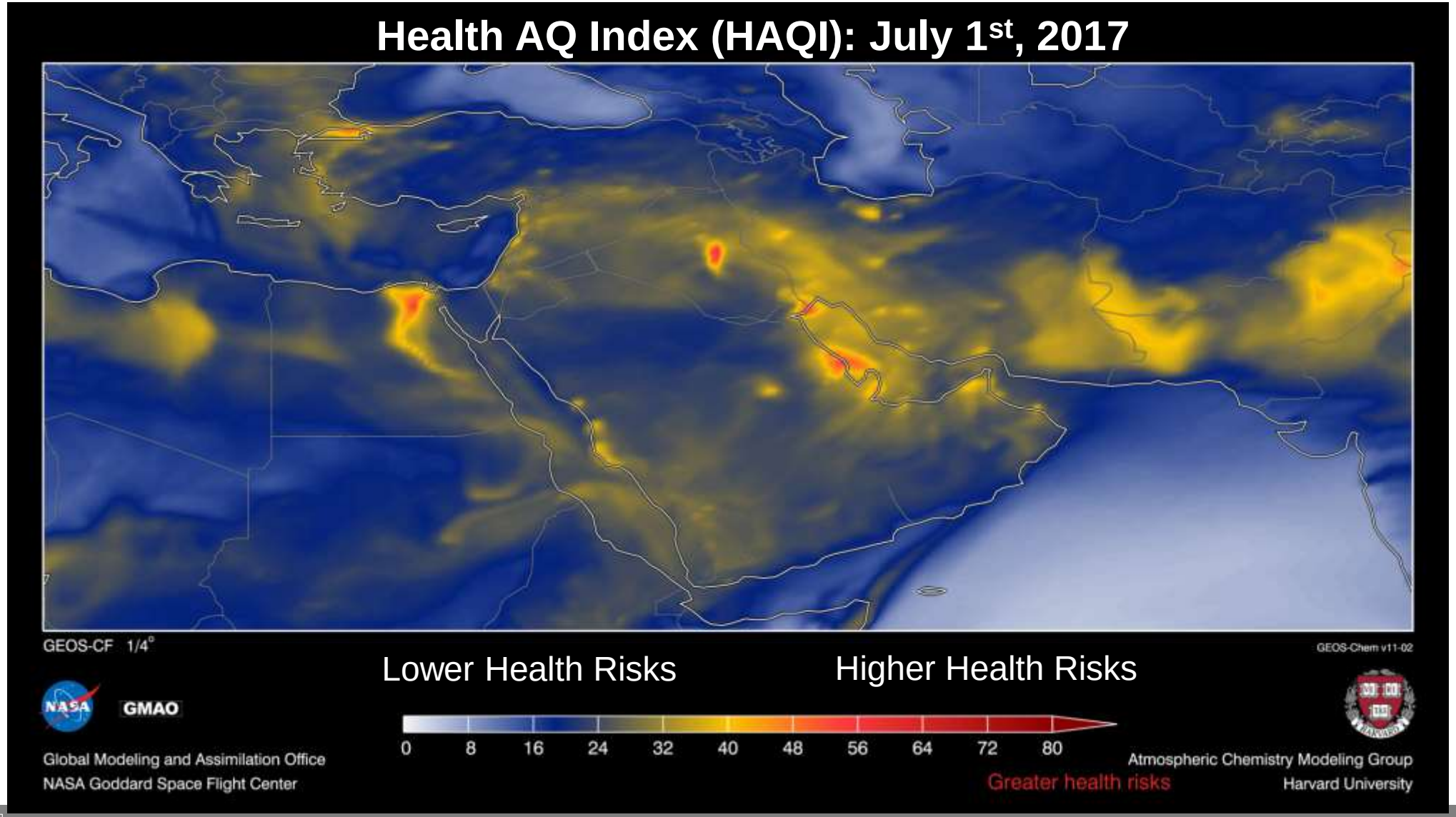
# Application: Health Air Quality Index (HAQI)





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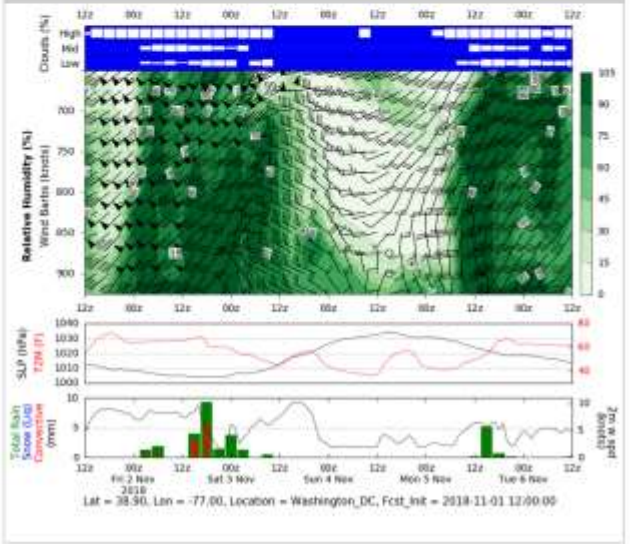
# fluid.nccs.nasa.gov

Global Modeling and Assimilation Office GMAO

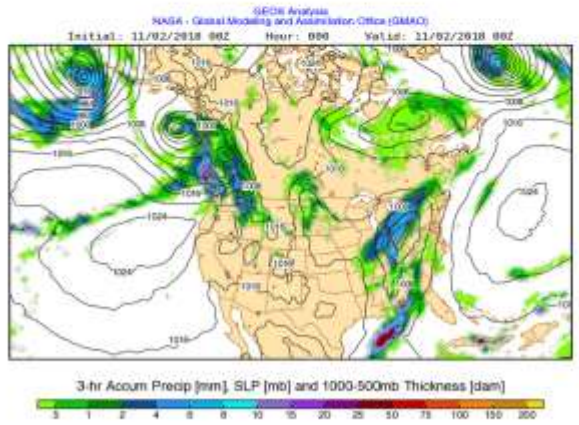
Weather | Mission Support | CF | Reanalysis | Seasonal

## Weather Analyses and Forecasts

### Datagrams



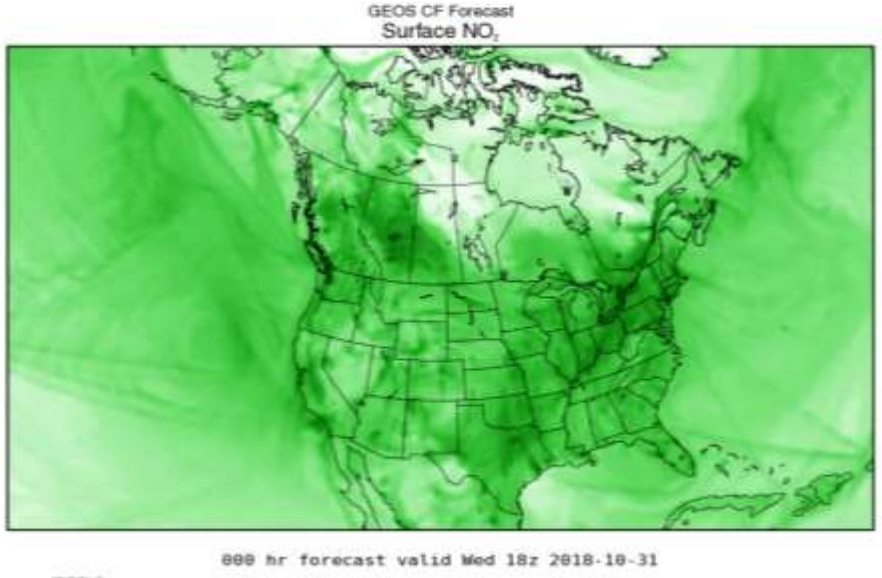
### WxMaps




Weather | Mission Support | CF | Reanalysis

## GMAO Composition Forecast Products

### Concentrations





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# Collaborations & Opportunities

Government, Public, NGO, Industry

Research / Mitigation

Flight campaign planning


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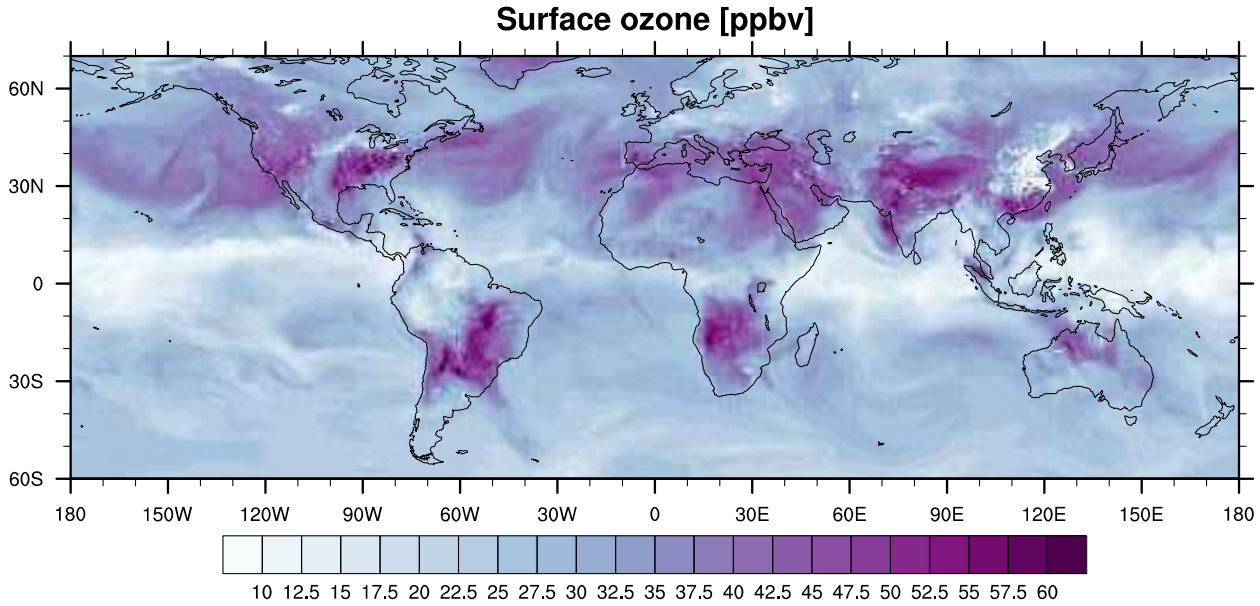
# Thank you!

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