Air quality forecasts using the NASA GEOS model: A unified tool from local to global scales

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Why we care about air quality

Figure 5: Global estimated deaths by major risk factor and cause, 2015
Using data from the GBD Study, 2016.41

Figure 4: Global estimated deaths (millions) by pollution risk factor, 2005–15
Using data from the GBD Study14 and WHO.34 IHME=Institute for Health Metrics and Evaluation.

The Lancet Commissions, 2017

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Why do we need models?

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

https://epa.maps.arcgis.com
Composition forecasting system (GEOS-CF)

Running since March 2017 (still in test mode)

- 1-day analysis
- 5-day forecast
- O$_3$, NO$_x$, VOCs, PM ...
- c360 resolution (0.25°)
Higher resolution critical to resolve features relevant to air quality

Denver, CO

June 2014

CO [ppmv]

1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Contributors to Air Pollution

- Particulate matter (PM):
  - Organic Carbon
  - Black Carbon
  - Sea salt
- Reactive gases:
  - 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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Health Air Quality Index (HAQI or AQHI)

- HAQI is a function of PM$_{2.5}$, O$_3$, NO$_2$

$$AQHI = \left( \frac{1000}{10.4} \right) \times \left[ (e^{0.000537 \times O_3} - 1) + (e^{0.000871 \times NO_2} - 1) + (e^{0.000487 \times PM_{2.5}} - 1) \right]$$

(Stieb et al., 2008, J. Air & Waste Manage. Assoc.)
Health Air Quality Index (HAQI or AQHI)

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Health Air Quality Index (HAQI or AQHI)

monthly mean PM$_{2.5}$

- PM$_{2.5}$ driver of spatial gradients
Health Air Quality Index (HAQI or AQHI)

- PM$_{2.5}$ driver of spatial gradients
- NO$_2$ is Short-lived
- Extreme gradients
Health Air Quality Index (HAQI or AQHI)

- **PM$_{2.5}$** driver of spatial gradients
- **NO$_2$** is Short-lived
- Extreme gradients
- **O$_3$** influences Background levels
HAQI = f(NO$_2$, PM$_{2.5}$, O$_3$)
OpenAQ surface observation data base
Observations vs. Model Forecast

Reading, UK, 2017-10-08 00:00 UTC

O₃ [ppbv]

Reading, UK, 2017-10-08 00:00 UTC

NOₓ [ppbv]

O₂ [ppbv]

NO₂ [ppbv]

10/08 10/10 10/12 10/14 10/16 10/18 10/20 10/22 10/24 10/26 10/28

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Observations vs. Model Forecast

Reading, UK, 2017-10-08 00:00 UTC

PM$_{0.1}$ [μg/m$^3$]

Observations vs. Model forecast

PM$_{0.1}$ [μg/m$^3$]
OpenAQ surface observation data base
Surface O$_3$ observations compared to GEOS CF
Diurnal cycle of surface $O_3$ is reproduced at the higher resolution

$0.25^{\circ}$

$2^{\circ}$
It is a work in progress….

- Ongoing model evaluation / benchmarking
- Implement GEOS-Chem v11-02d
Current GEOS-Chem version is known to have high surface O$_3$

$v11$-02d: updated halogen chemistry

Currently implemented

Sherwen et al., 2017, Faraday Discuss.
It is a work in progress….

- Ongoing model evaluation / benchmarking
- Implement GEOS-Chem v11-02d
- Share model output in 2018
  - If interested please email one of us
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