Connecting air quality and health with management: Progress from the UNC HAQAST Team

J. Jason West
Environmental Sciences & Engineering
University of North Carolina, Chapel Hill
west.web.unc.edu
@ProfJasonWest
Global Mapping of Ozone Surface Concentration for Global Burden of Disease

- A first global map has been delivered and used in GBD 2017, another will be delivered next month for GBD 2019.
- 2 papers (Chang, GMD).

Global Air Quality and Health Co-benefits of the Paris Agreement Pledges

- Completing analysis of emissions from GCAM and planning to start simulations this summer.

Tiger Team: Efficacy of Environmental Regulations in the Eastern US

- Trends in US air pollution-related deaths since 1990
  - 1 paper published (Zhang, ACP), 1 in preparation.

Tiger Team: California fires

- Mapping pollutant concentrations, and analyzing health impacts.

Tiger Team: Global indicators

- Global indicators of surface ozone.

Total 4 papers published, many more in preparation.
Goal: Estimate global surface ozone concentrations by statistically fusing global ozone observations and an ensemble of global models.

Stakeholder partners: Global Burden of Disease Assessment – Michael Brauer (UBC), Rick Burnett (Health Canada), Bryan Hubbell (EPA).

Team: Jason West, Marc Serre, Marissa Delang, Jacob Becker, Stephanie Cleland, Elyssa Collins (UNC), Owen Cooper, Kai-Lan Chang (U Colorado & NOAA)
A new method (M^3Fusion v1) for combining observations and multiple model output for an improved estimate of the global surface ozone distribution

Kai-Lan Chang^1,2,3, Owen R. Cooper^2,3, J. Jason West^4, Marc L. Serre^4, Martin G. Schultz^5, Meiyun Lin^6,7, Virginie Marécal^8, Béatrice Josse^8, Makoto Deushi^9, Kengo Sudo^10,11, Junhua Liu^12,13, and Christoph A. Keller^12,13,14

Ozone metric: 2008-2014 average of 6-month average 8-hr. daily maximum surface ozone concentration
Mapping Global Surface Ozone Concentrations for GBD 2017

Step 1 – Spatial interpolation of TOAR measurements

4801 sites, averaged within 2°x2° grid cells
Step 2 – Evaluate each model with respect to observations

<table>
<thead>
<tr>
<th>Model ID</th>
<th>Group</th>
<th>Resolution</th>
<th>Meteorological Forcing</th>
<th>References</th>
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</thead>
<tbody>
<tr>
<td>CHASER</td>
<td>Nagoya University; Japan Agency for Marine-Earth</td>
<td>$2.8^\circ \times 2.8^\circ$</td>
<td>C2</td>
<td>Sudo et al. (2002a, b); Watanabe et al. (2011)</td>
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<td>(MIROC-ESM)</td>
<td>Science and Technology (JAMSTEC), Japan</td>
<td>$2.5^\circ \times 2^\circ$</td>
<td>C2</td>
<td>Oman et al. (2011)</td>
</tr>
<tr>
<td>GEOSCCM</td>
<td>NASA Goddard Space Flight Center, USA</td>
<td>$2^\circ \times 2^\circ$</td>
<td>C1SD</td>
<td>Lin et al. (2012, 2014, 2017)</td>
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<tr>
<td>GFDL-AM3</td>
<td>NOAA Geophysical Fluid Dynamics Laboratory, USA</td>
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<td>C1SD</td>
<td>Lin et al. (2012, 2014, 2017)</td>
</tr>
<tr>
<td>G5NR-Chem</td>
<td>NASA Goddard Space Flight Center, USA</td>
<td>$0.125^\circ \times 0.125^\circ$</td>
<td>+</td>
<td>Hu et al. (2018)</td>
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<td>MOCAGE</td>
<td>Centre National de Recherches Météorologiques; Météo France, France</td>
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<td>Josse et al. (2004); Teyssèdre et al. (2007)</td>
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<td>MRI-ESM1r1</td>
<td>Meteorological Research Institute, Japan</td>
<td>$2.8^\circ \times 2.8^\circ$</td>
<td>C2</td>
<td>Adachi et al. (2013)</td>
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</tbody>
</table>

Interpolated observations
Multi-model mean
Step 3 – Find the linear combination of models in each world region that minimizes error with respect to the interpolated measurement surface.
Mapping Global Surface Ozone Concentrations for GBD 2017

Step 4 – Bias correct within 2° of observation sites (using interpolated surface)

Final Fused Ozone Product

• GBD 2017 – 470,000 (180,000 – 770,000) deaths globally
Global Ozone Mapping for GBD 2019

- Produce ozone maps for all years from 1990 to 2017.

- Perform a new data fusion with observations using Bayesian Maximum Entropy method.

- Add new observations from China and elsewhere, updated models.

- Add fine spatial structure using NASA G5NR (0.125°).

- New maps have nearly been completed for 1990 to 2010.

- See poster by Jacob Becker and Marissa DeLang
Bayesian Maximum Entropy Methods
Global Ozone Mapping for GBD 2019

Observations for 2005

M$^3$Fusion for 2005

CAMP ANALYSIS for 2004 2005 2006

BME Estimate for 2005
Goal 1: Map PM$_{2.5}$ during the Oct. 2017 wildfires, fusing together observed & modeled PM$_{2.5}$ concentrations

- Surface observation data from both FRM/FEM & temporary monitoring stations
- Model data from BAAQMD CMAQ run

maps for Oct. 10, 2017, 24-hr average PM$_{2.5}$
Goal 2: Use the PM$_{2.5}$ map to estimate the acute health impact of the Oct. 2017 wildfires, specifically the attributable respiratory hospital admissions.

Future work will extend this approach to more health endpoints and pollutants.

- See poster by Stephanie Cleland
Health Benefits of Decreases in PM$_{2.5}$ and Ozone in the United States, 1990-2015

Omar Nawaz, Yuqiang Zhang, Daniel Q. Tong, Aaron van Donkelaar, Randall Martin, J. Jason West

* Air pollutant datasets:
  - A 21-year CMAQ simulation (1990-2011) EPA
  - N. America PM$_{2.5}$ satellite-derived data combined with a model and surface observations (1999-2012) SAT

* We use annual county-level population and baseline cause-specific mortality rates from the CDC to assess air pollution mortality in each year.
Trends in PM$_{2.5}$ (SAT)
US PM$_{2.5}$-related deaths

Zhang, ACP 2018; Nawaz, in prep.
Comparison with Other Studies ($PM_{2.5}$)

Zhang, ACP 2018; Nawaz, in prep.
PM$_{2.5}$ mortality decreased by 53% from 123,700 (70,800-178,100) deaths in 1990 to 58,600 (24,900-98,500) in 2010.

Without the decrease in PM$_{2.5}$ since 1990, the burden would have only decreased by 24%.

PM$_{2.5}$ reductions since 1990 have decreased deaths in 2010 by about 35,800.
US $O_3$-related deaths

Zhang, ACP 2018; Nawaz, in prep.
Comparison with Other Studies ($O_3$)

Zhang, ACP 2018; Nawaz, in prep.
Ozone mortality increased by 13% from 10,900 (3,700-17,500) deaths in 1990 to 12,300 (4,100-19,800) in 2010.

Without the decrease in ozone since 1990, the burden would have increased by 55%.

Ozone reductions since 1990 have decreased deaths in 2010 by about 4,600.
In the US, air pollution kills:

109,000 (2017 from GBD), 1 in 25 US deaths
47,000 (2015 our work), 1 in 58 US deaths

Diabetes: 80,000
Influenza & pneumonia: 52,000
All suicides: 45,000
All transportation accidents: 43,000
Breast cancer: 42,000
All gun shootings: 39,000
Prostate cancer: 30,000
Parkinson’s: 30,000
Leukemia: 23,000
HIV AIDS: 6,000

2016 data from CDC
Global burden of disease of air pollution (2017)

Global Deaths per Year

Ambient PM$_{2.5}$ pollution: 2.9 (2.5 – 3.4) million  
1 in 19 deaths globally!

Ambient ozone pollution: 0.47 (0.18 – 0.77) million

Household air pollution from solid fuels: 1.6 (1.4 – 1.9) million  
1 in 45 deaths globally!

Ambient PM$_{2.5}$ pollution is the 8$^{th}$ leading risk factor for death globally.

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Burnett et al. (PNAS, 2018) estimate 8.9 (7.5-10.3) million deaths from PM$_{2.5}$ in 2015.