HAQAST TT: Demonstration of the Efficacy of Environmental Regulations in the Eastern U.S.

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Jason West, *University of North Carolina*

November 28th, 2017; HAQAST Meeting, Columbia University

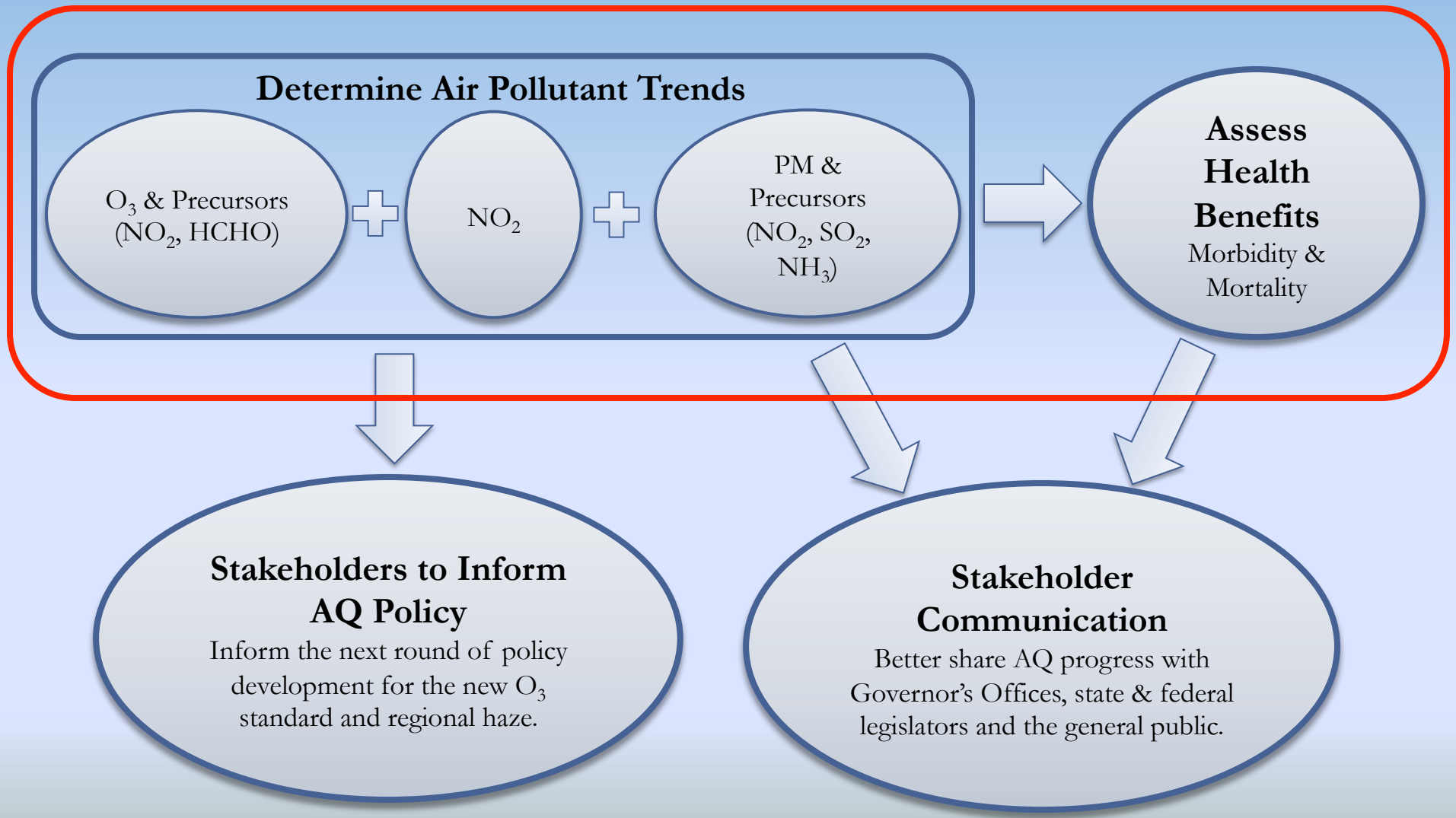
The Team & Stakeholders

- **Lead HAQAST PIs:** Bryan Duncan (NASA; 80%) & Jason West (UNC; 100%)

- **AQ/Health Management Contacts**
  - Susan Wierman (MARAMA)
  - Tad Aburn (MDE)
  - John Walker (EPA)
  - Fuyuen Yip (CDC/NCEH)
  - Paul Miller (NESCAUM)
  - Anne Gobin (CT DEEP)

- **Other HAQAST Participants**
  - Mark Zondlo (Princeton U.; 60%)
  - Yang Liu (Emory U.; 40%)
  - Ted Russell (Georgia Tech; 34%)
  - Arlene Fiore (Columbia U.; 10%)
  - Daven Henze (U. Colorado; 10%)
  - Daniel Tong (George Mason U.; 5%)
  - Pat Kinney (Boston U.)
  - Susan Anenberg (George Washington U.)
  - Lok Lamsal (NASA)

Tiger Team Schematic



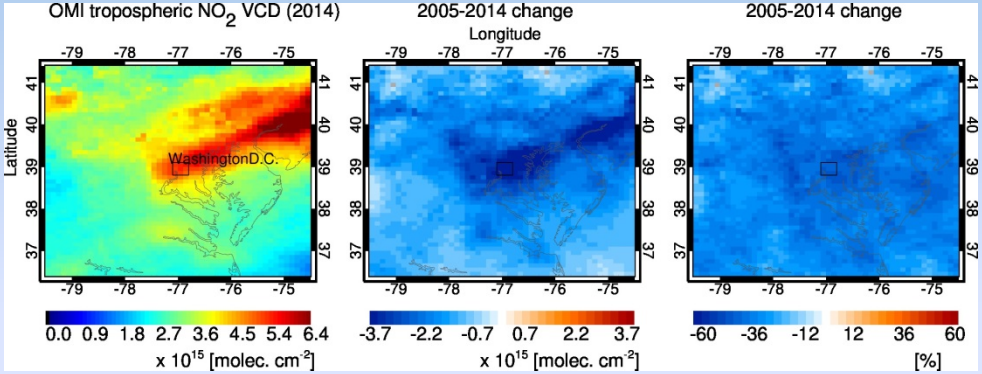
Trends in Ozone, Precursors & Ozone Production

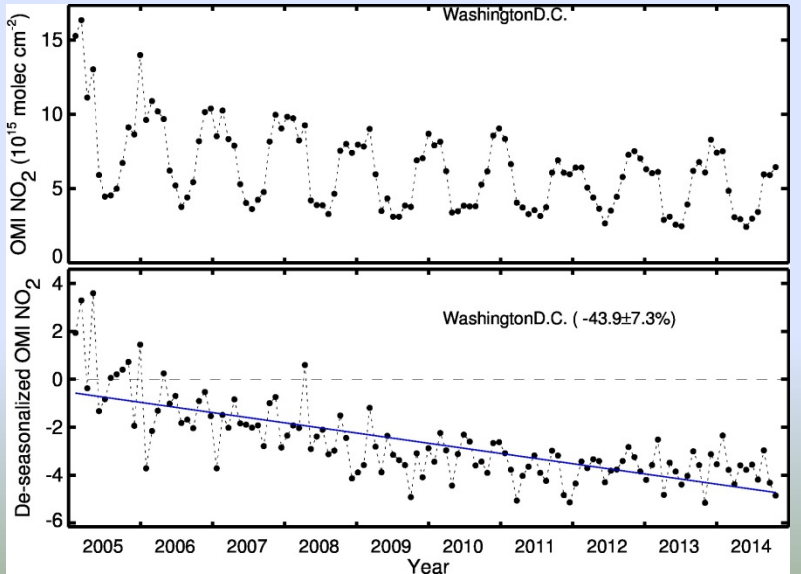
https://airquality.gsfc.nasa.gov/

Duncan, Lamsal

NO_2 website developed under AQAST

Ex. Washington, DC





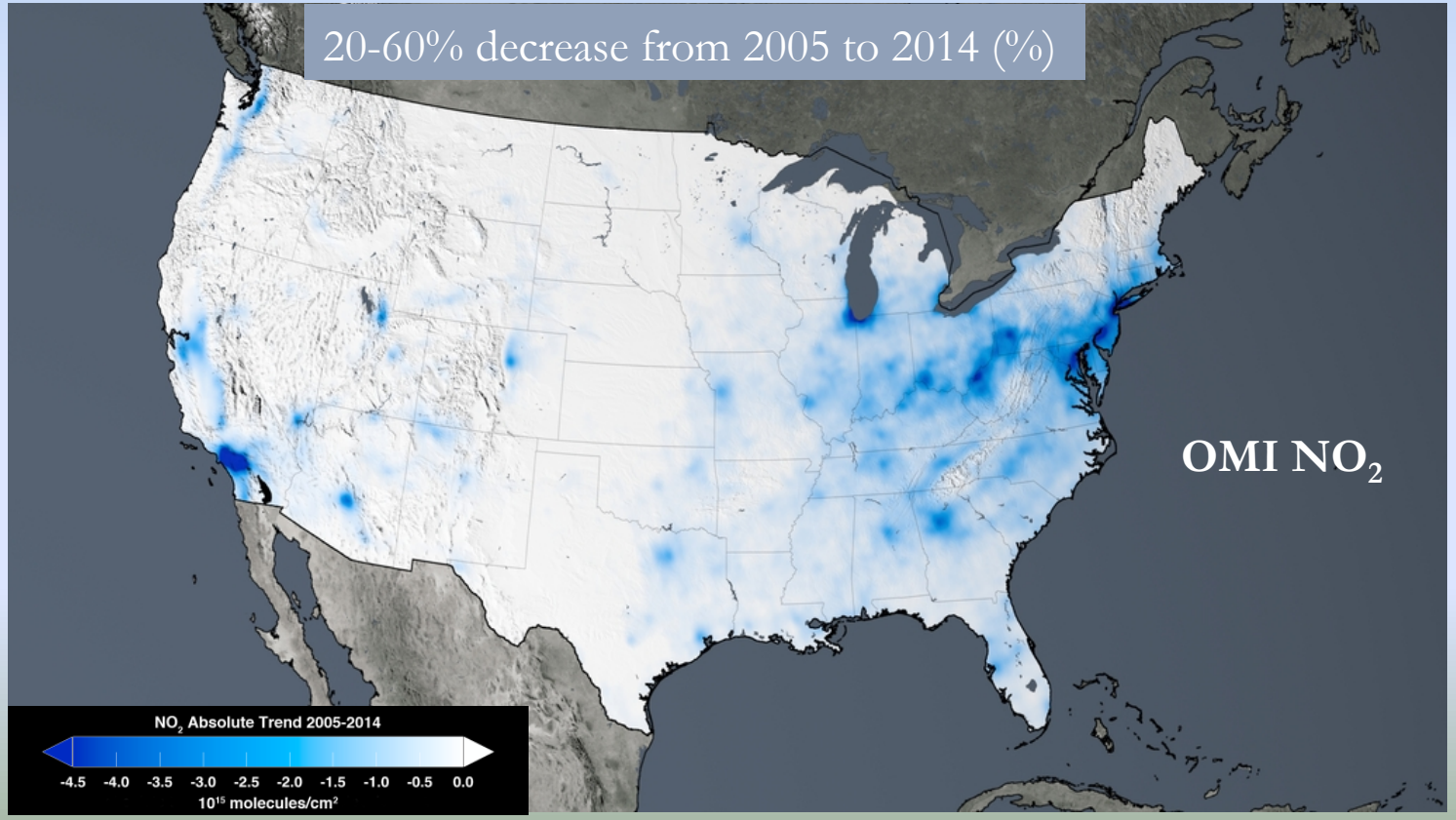
Tiger Team Tasks Completed

- Updated OMI NO_2 trends through 2016.
- Added 125 new U.S. cities.
- Added an OMI NO_2 U.S. animation (2005-2016): https://airquality.gsfc.nasa.gov/video/changes-nitrogen-dioxide-usa-2005-2014

Trends in Ozone, Precursors & Ozone Production

Henze & Lamsal (NO_2)

- OMI NO_2 trends & "nose-level" trends (Lamsal, Henze).
- Uncertainties in NO_2 retrievals (Henze, Lamsal).
- NO_x emission trend estimates with OMI NO_2 (Henze).

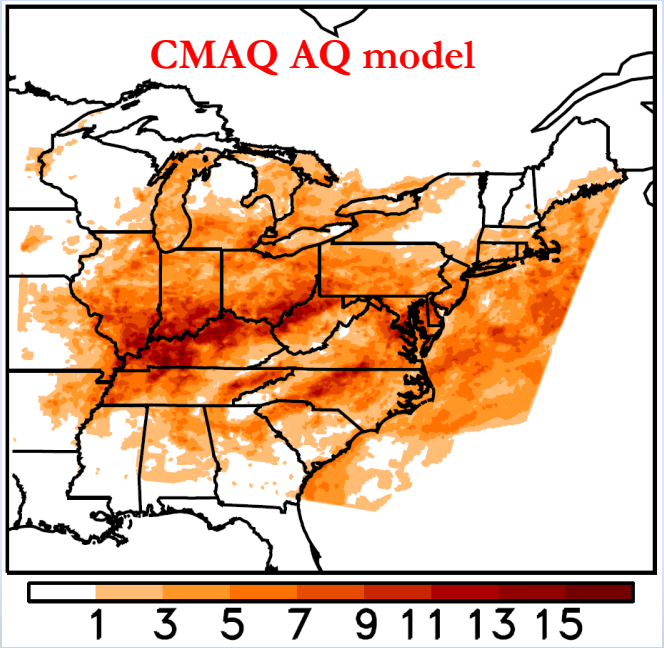


Estimating Health Benefits of NO_2 Reductions

What if emissions reductions had not been implemented?

Test period: July 2011 – A month of record setting heat for the East Coast

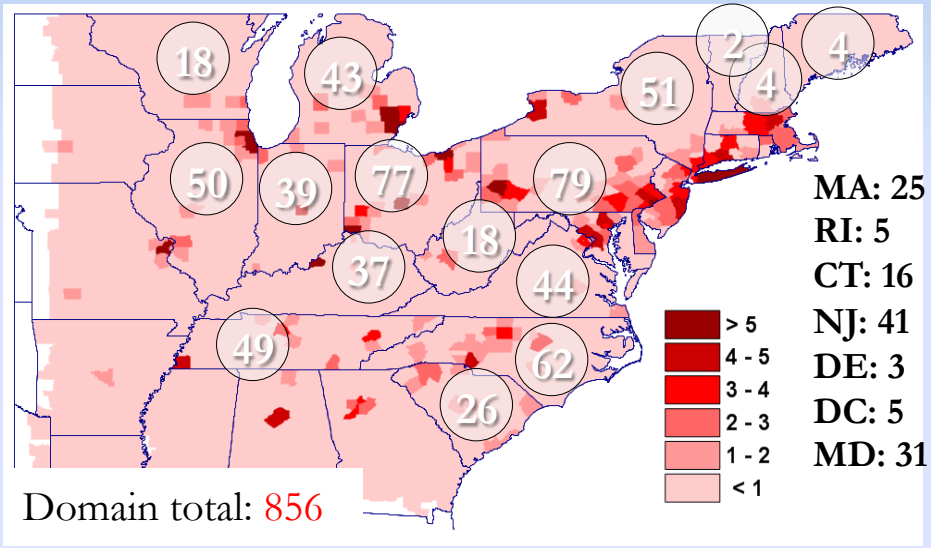
How many more Code Red ozone violations would have occurred if emissions had remained at 2002 levels?



C. Loughner, M. Follette-Cook, K. Pickering, B. Duncan, in prep.

How many lives were saved?

Concentration-Response (C-R) function: Levy et al. 2005



Avoided Morbidity

ER visits – Asthma: 1248

Hospital Admissions – Respiratory: 3801

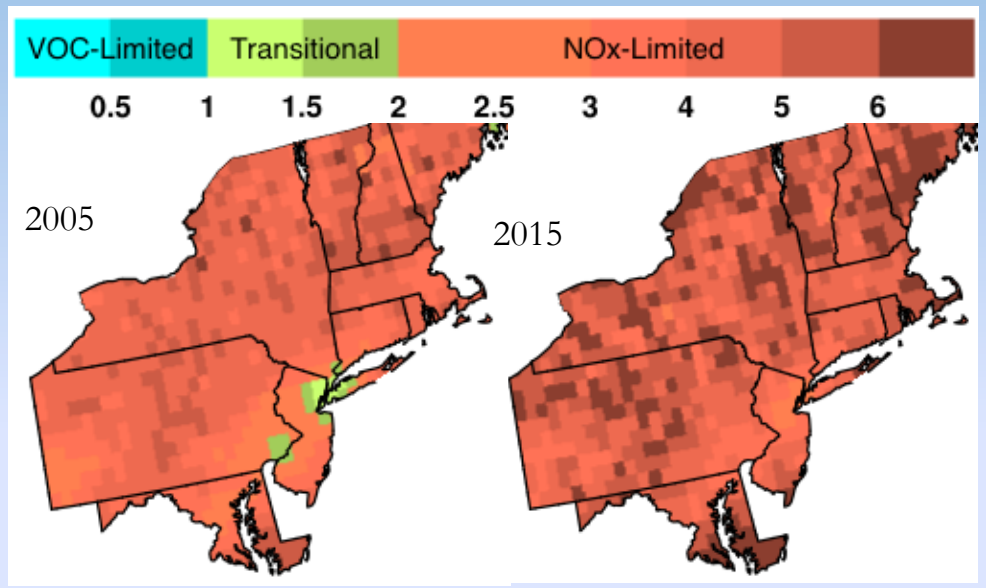
Hospital Admissions – Pneumonia: 1595

EPA Environmental Benefits Mapping and Analysis Program – BenMAP

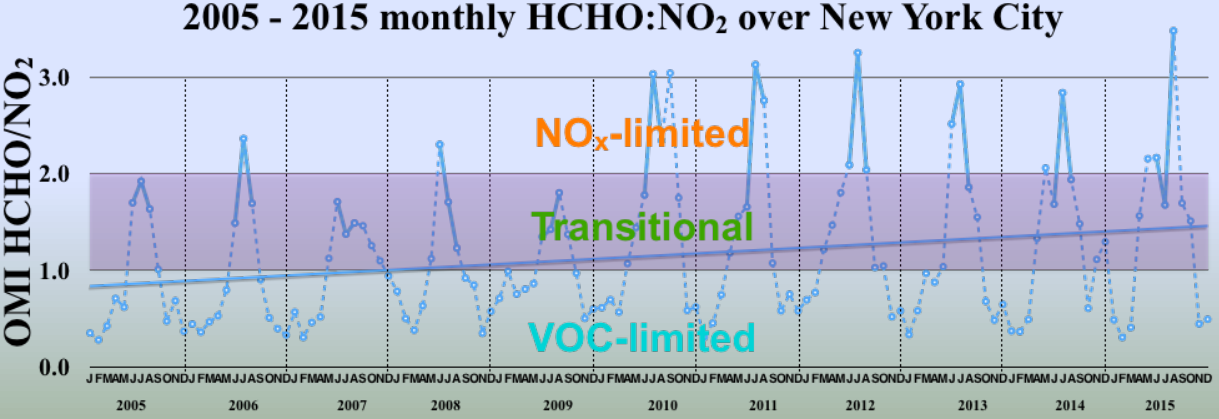
Trends in Ozone, Precursors & Ozone Production

Fiore, Jin

May-September OMI HCHO:NO_2



2005 - 2015 monthly HCHO:NO_2 over New York City



Russell

Southeast U.S.

Develop and apply empirical models for O_3 and PM over the SE US to provide alternative estimates of the response of O_3 and PM to precursor emissions and controls.

Is there a detectable decrease in OMI NO_2 since January 1st, 2017?

Duncan, Lamsal

Tier 3 Gasoline Sulfur Program

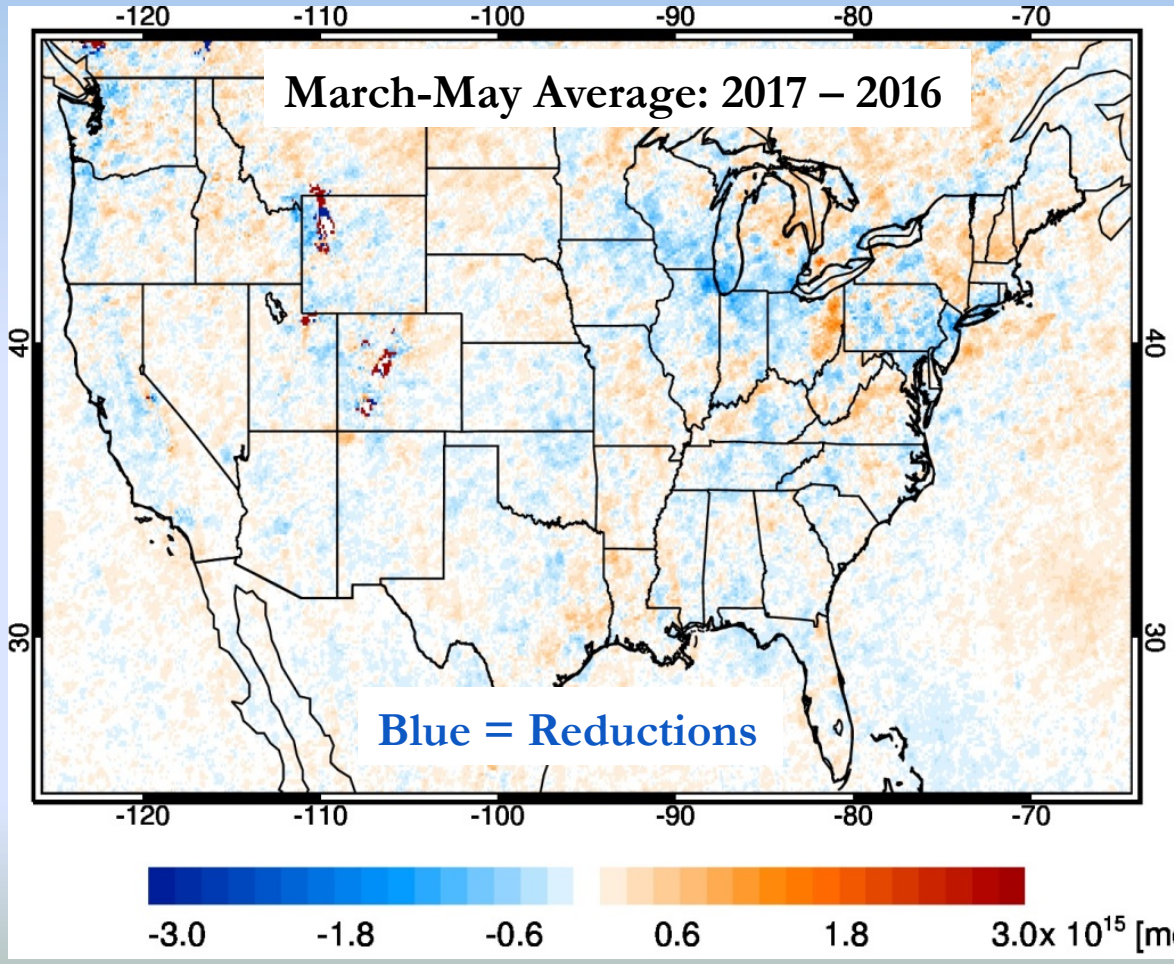
January 1st, 2017: Low-sulfur gasoline required to improve efficiency of catalytic converters.

Therefore, NO_x emissions reductions expected from cars & trucks.

Does OMI detect lower NO_2?

Fly-in-the-ointment:

Meteorological variability.

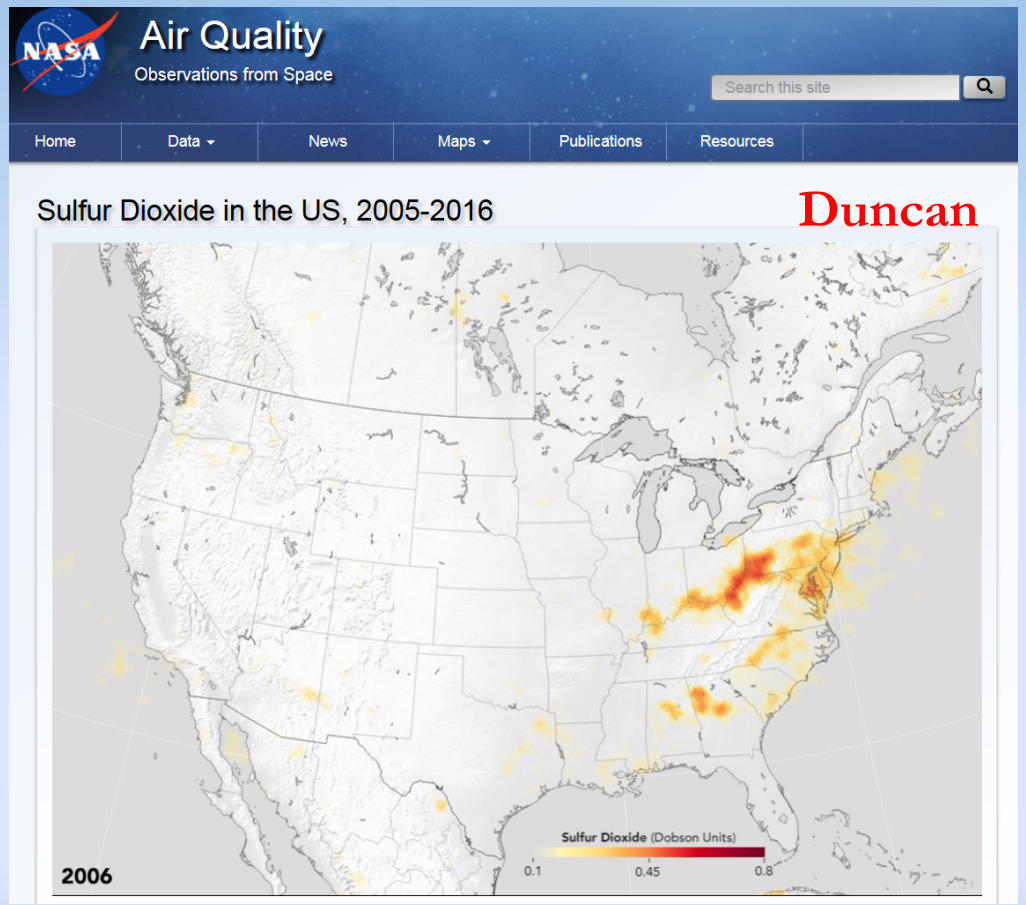


Trends in Ozone, Precursors & Ozone Production

- Surface O_3 cannot be inferred from satellite data.
- Surface monitor O_3 trends (Fiore, Henze?).
- Model surface O_3
  - Posterior simulations with satellite-constrained NO_x & SO_2 emissions (Henze).
  - Global MERRA-2/GMI CTM model trends (1980-2016) (Duncan).
  - N. America Chemical Reanalysis (NACR) for 2009–present provides blended surface concentrations from NOAA National AQ Forecast & EPA surface monitors (Daniel Tong).
  - EPA CMAQ simulation for the U.S. from 1990-2010 at 36 km resolution.

Trends in PM & Precursors

OMI SO_2 animation (2005-2016) to the AQ website.

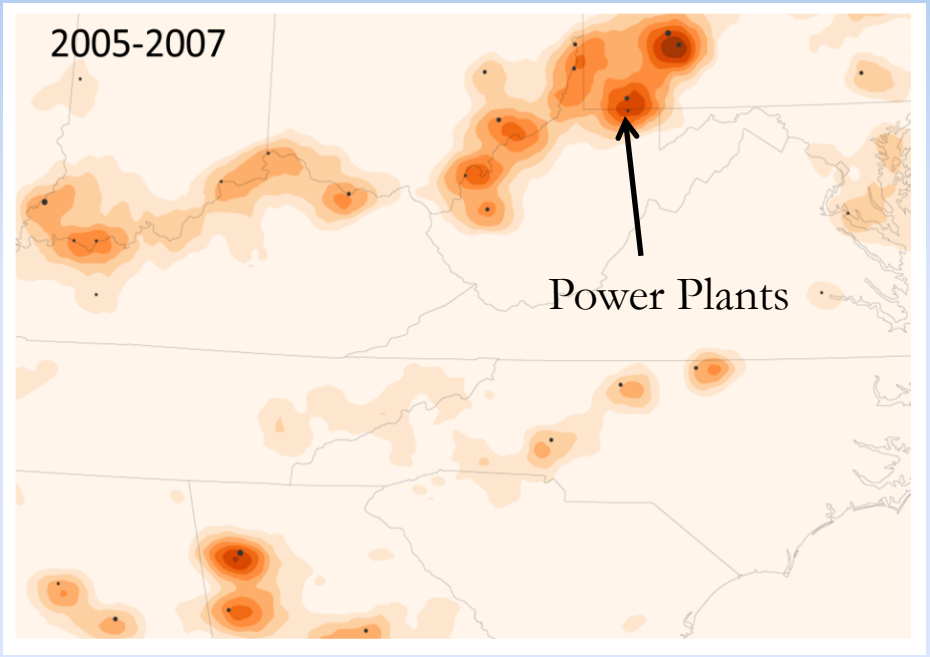


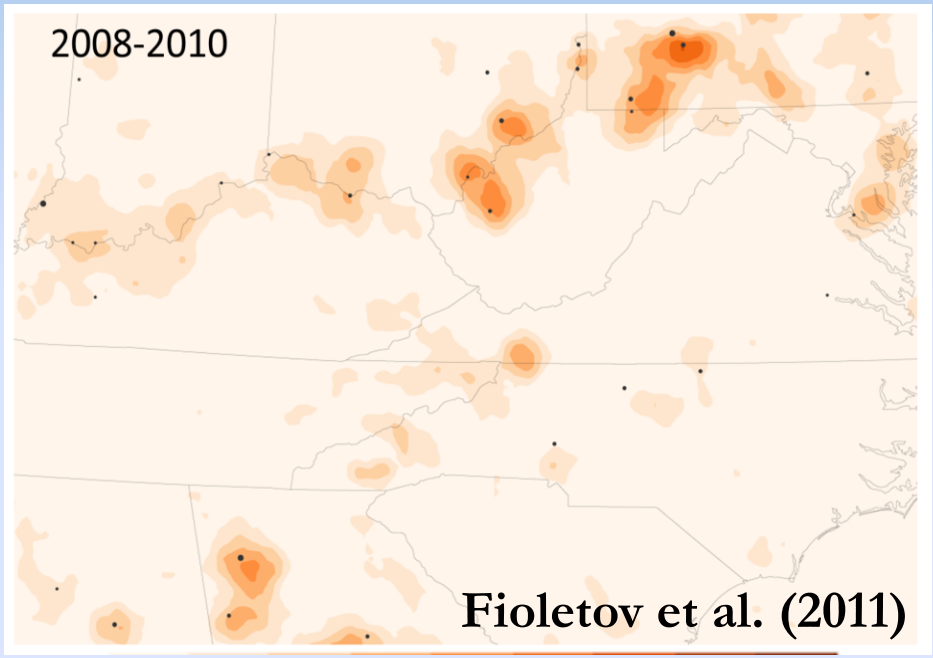
https://airquality.gsfc.nasa.gov/video/sulfur-dioxide-usa

Henze SO_2 emission trend estimates with **OMI SO_2**

Trends in PM & Precursors

OMI SO_2





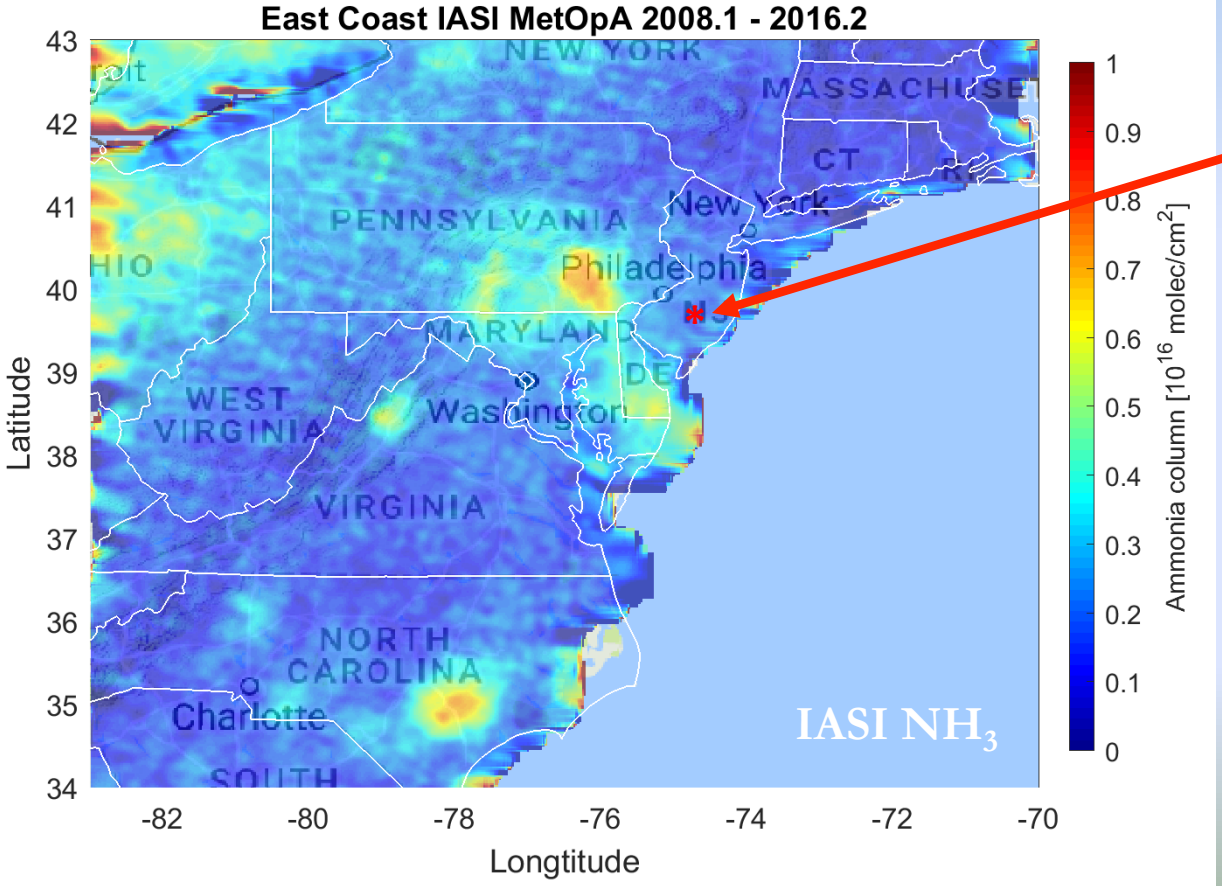
< 0.1 0.5 >0.8 DU

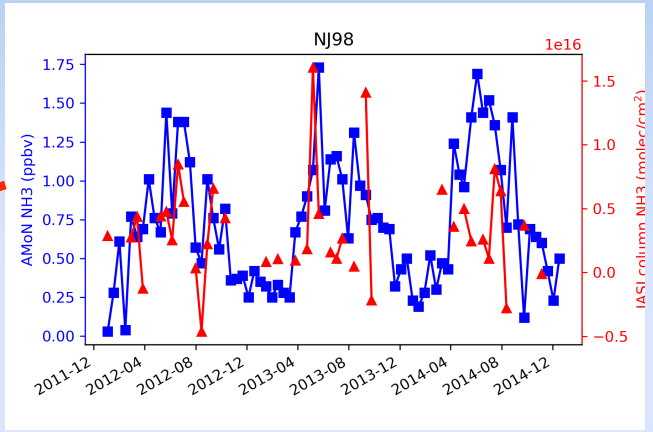
https://airquality.gsfc.nasa.gov/video/sulfur-dioxide-usa

Trends in Ozone, Precursors & Ozone Production

Zondlo (NH_3)

- IASI NH_3 oversampling algorithm for high-resolution NH_3 maps (K. Sun, X. Guo)
- Examining trends in SE PA, southern DE, and eastern NC agricultural regions (+ urban)
- Also comparing to Ammonia Monitoring Network trends where possible (D. Pan)





Above: Comparison of AMoN and IASI within ±30 km window for central NJ (low NH_3 site)

Most AMoN sites not located near sources in eastern US!

Trends in PM & Precursors

- Surface PM can be inferred from satellite data with a chemistry transport model.
  - Dalhousie satellite-based estimates (multi-year average: 1998-2012)
- Surface monitor PM trends
  - Combine satellite-based [$PM_{2.5}$] estimates with CTM simulations in a Bayesian ensemble modeling framework to evaluate the long-term trends in $PM_{2.5}$ over NY state (Liu – whole Eastern U.S. too?).
- Model surface PM
  - Global MERRA-2/GMI CTM model trends (1980-2016) (Duncan).
  - N. America Chemical Reanalysis (NACR) for 2009–present provides blended surface concentrations from NOAA National AQ Forecast & EPA surface monitors (Daniel Tong).
  - EPA CMAQ simulation for the U.S. from 1990-2010 at 36 km resolution

Air Pollution-Related Deaths in the US

Global Burden of Disease results for the US in 2015 (Cohen et al., 2017):

Ambient $PM_{2.5}$: 88,400 (66,800 – 115,000) deaths

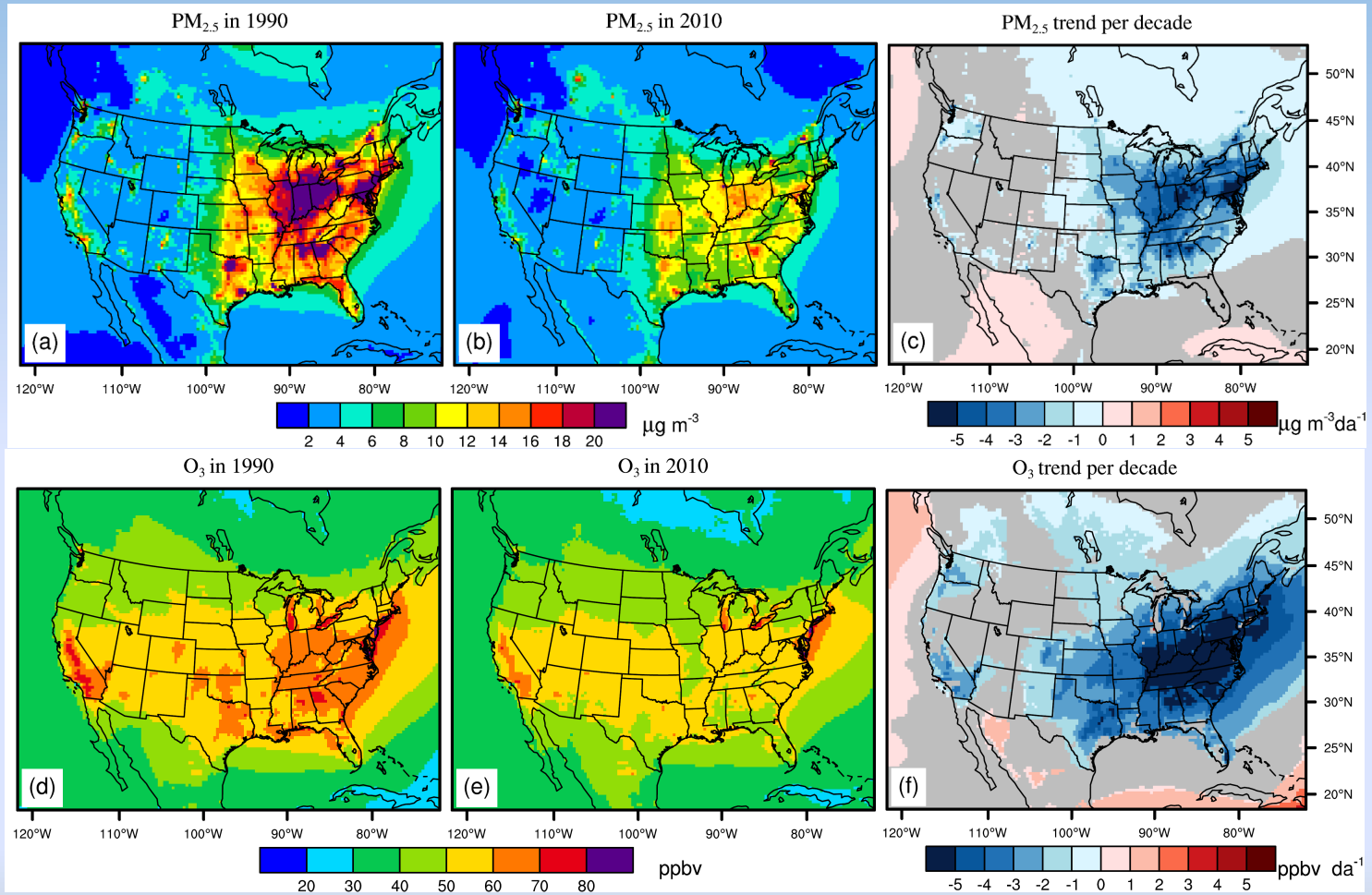
Ambient Ozone : 11,700 (4,400 – 19,600) deaths

1 in 26 US deaths

Estimation of Health Benefits

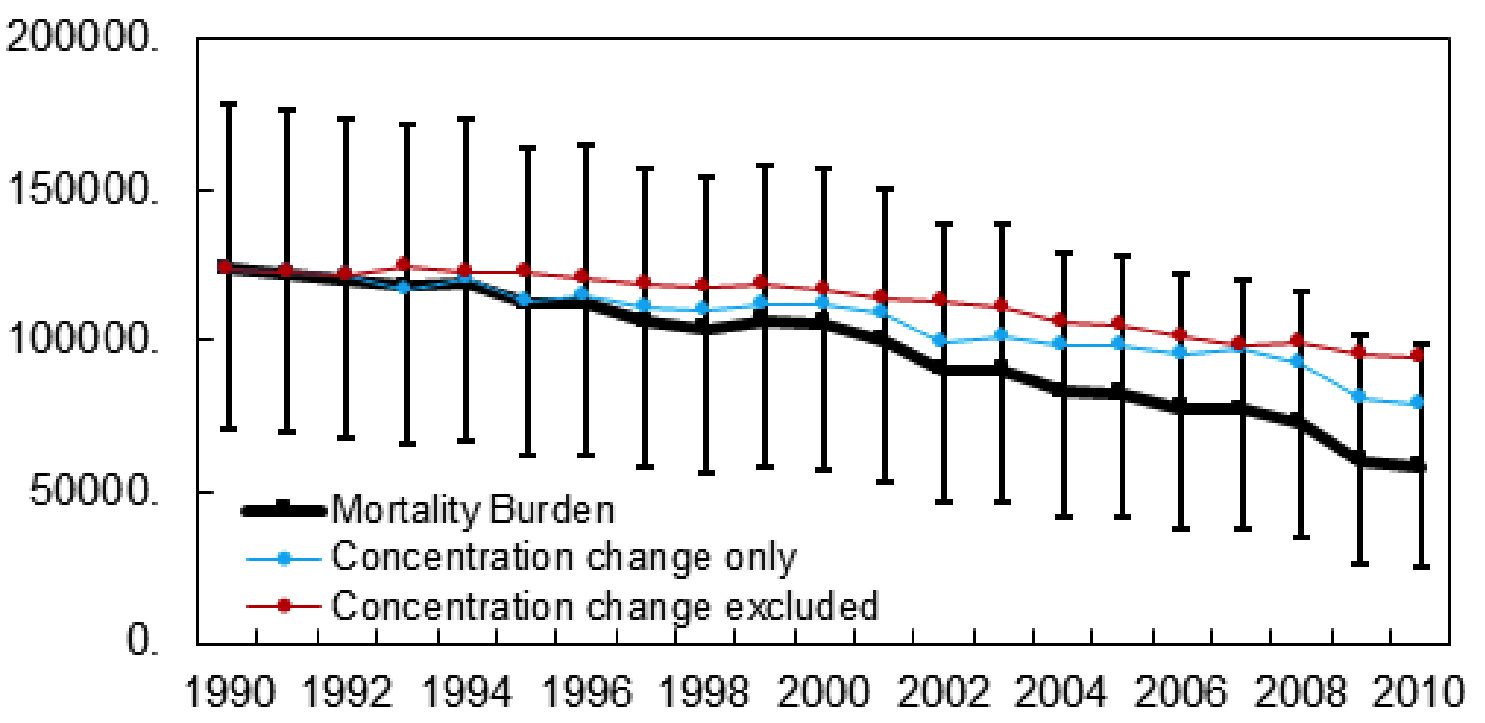
- Estimate of the total burden of O_3 and $PM_{2.5}$ on premature human mortality for the US population in each year (West) using 3 datasets:
  - EPA's 21-year CMAQ simulation (1990-2010)
  - Daniel Tong's Chemical Reanalysis (2009-2015)
  - Dalhousie $PM_{2.5}$ dataset (1998-2012 average)
- Asthma exacerbation and incidence from $PM_{2.5}$, O_3, and NO_2 individually - 0.1°x0.1° (Anenberg, Kinney, West).

US Air Pollution Trends (1990-2010)



Results from a 21-year CMAQ simulation by the EPA (Gan et al. 2015; 2016)

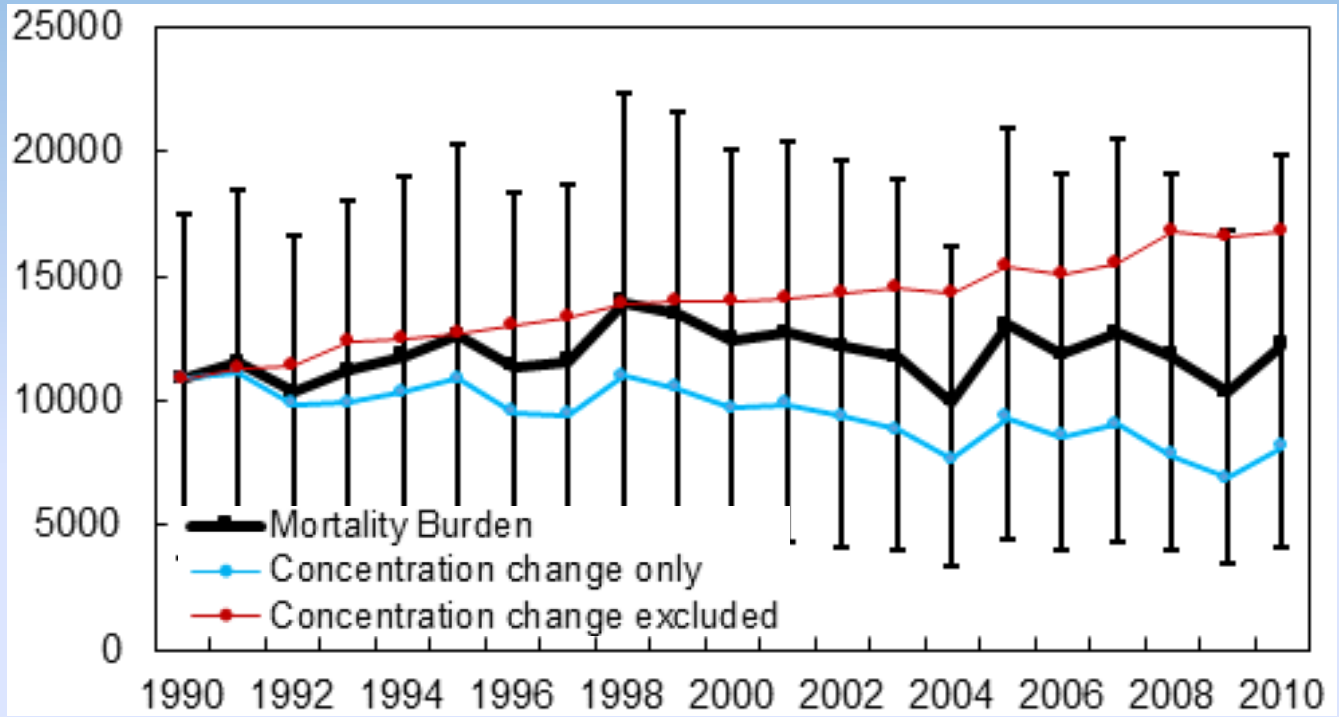
$PM_{2.5}$ Mortality Trends (1990-2010)



- $PM_{2.5}$ 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.

work by Yuqiang Zhang

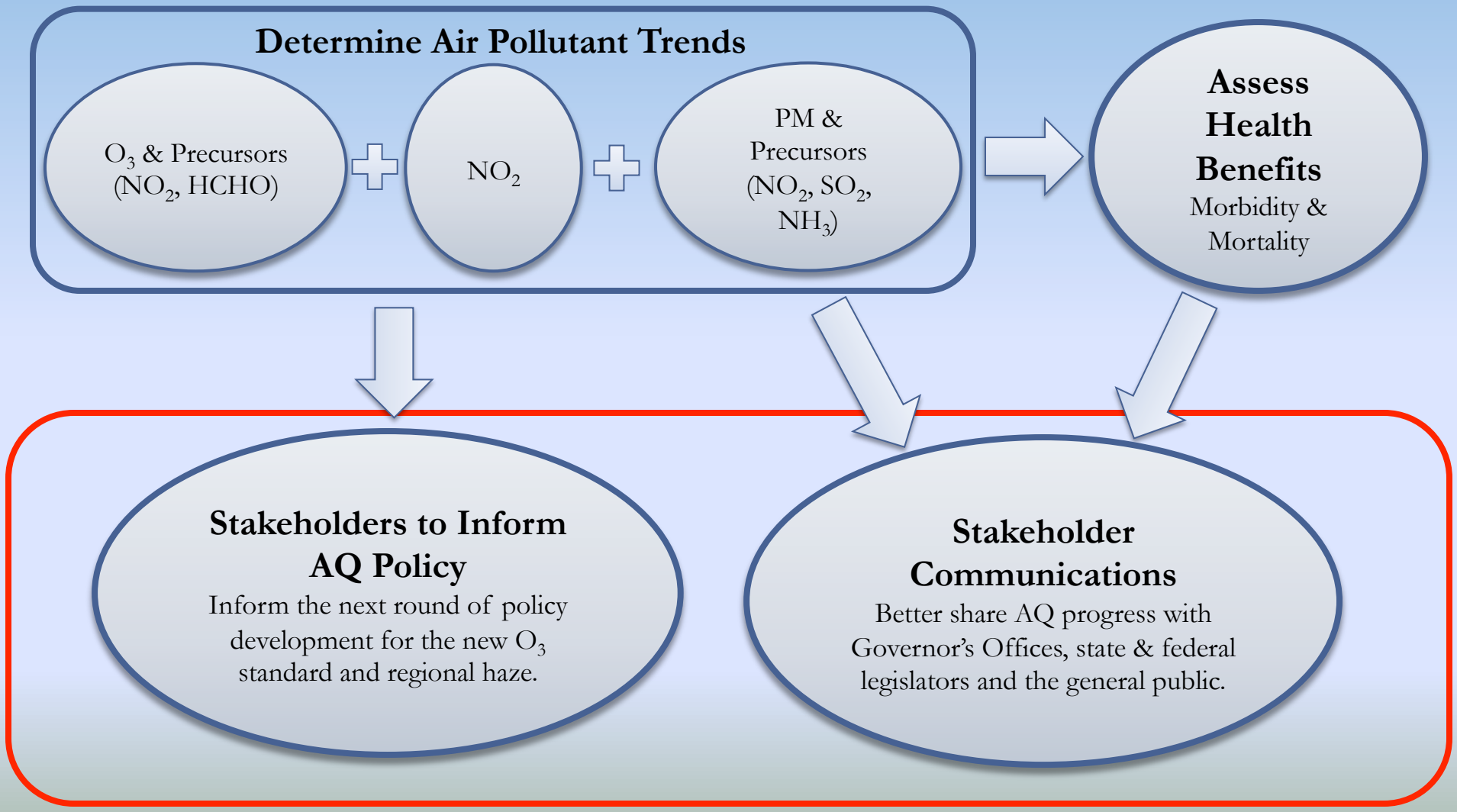
O_3 Mortality Trends (1990-2010)



- 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.

work by Yuqiang Zhang

Communications



Communications

Complementary Approaches

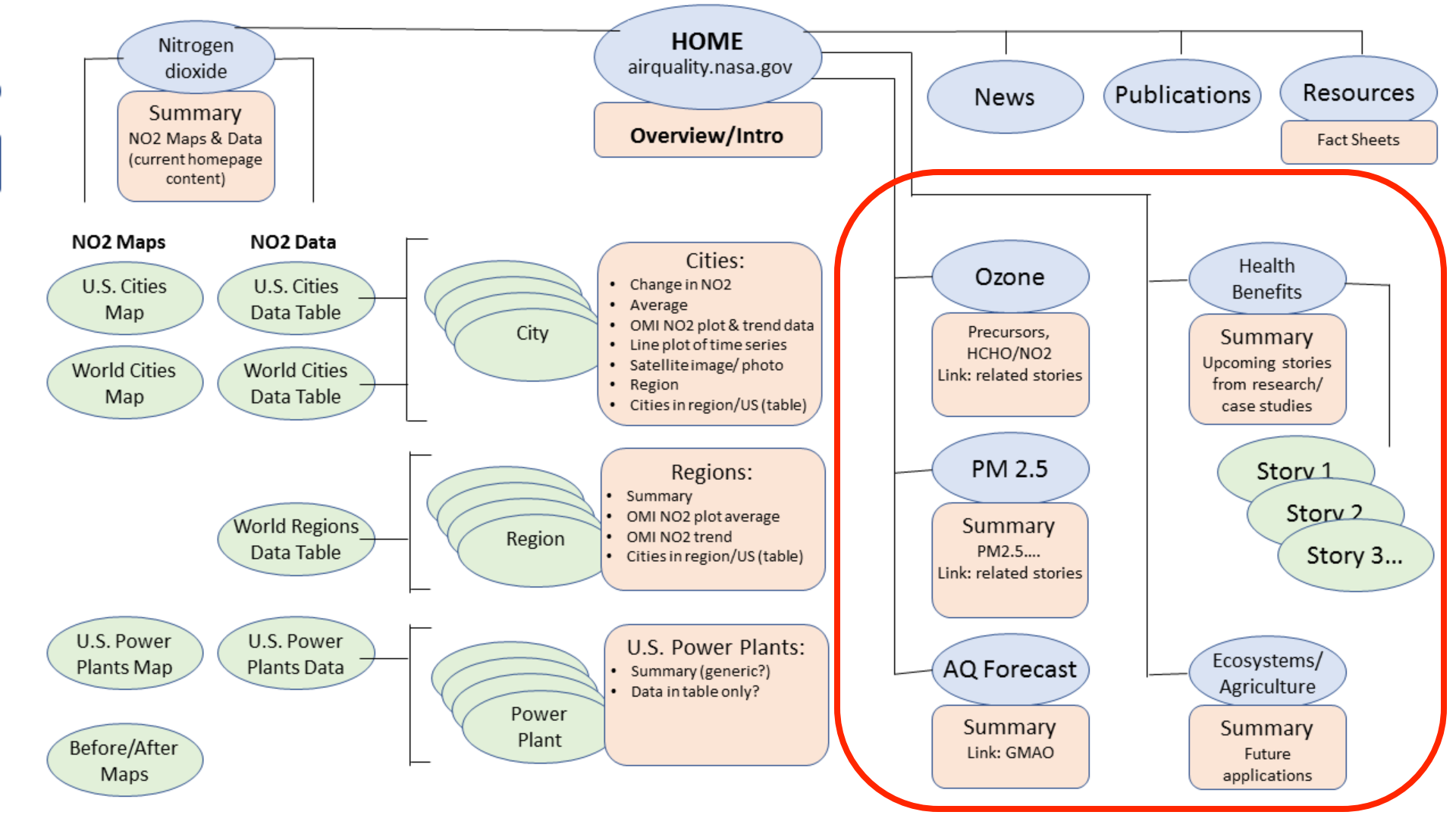
- Hire a Communications writer (identifying candidate)
- Make use of NASA resources
  - Web developer to augment airquality.gsfc.nasa.gov
  - Cool stories often are chosen for press releases (e.g., 2014 & 2015 AQAST AQ campaigns), Earth Observatory stories (e.g., Jin & Fiore), etc.
- Make use of university press releases from HAQAST members

Potential Deliverables (identify with Stakeholder input)

- Summary report
- Augmented website with new tabs: "O_3", "PM", "NO_2", and "Health"
  - Downloadable fact sheets, images, etc.

Beefing Up the AQ Website

Proposed New Portion



Next Steps

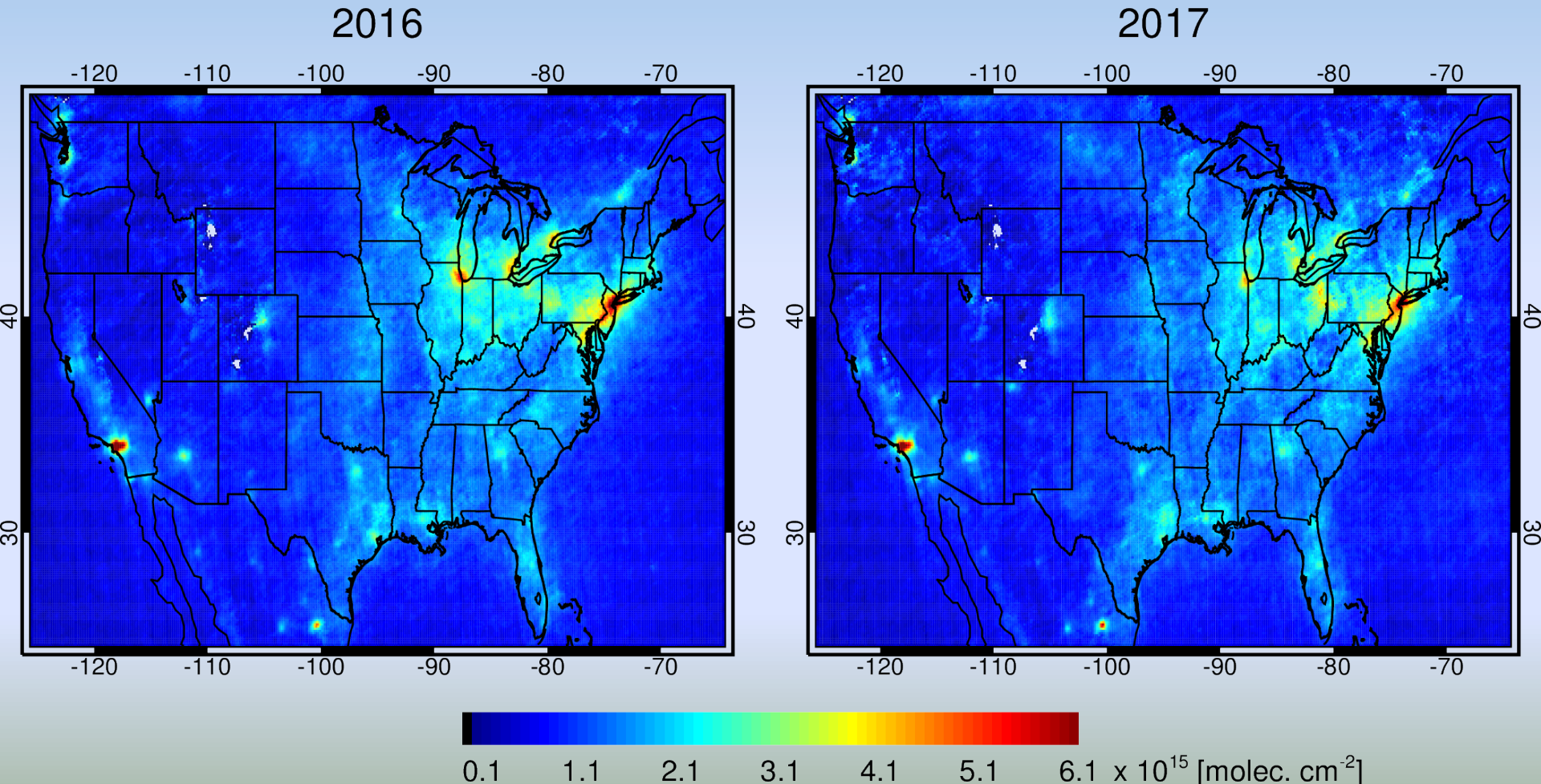
- TT members to complete remaining analyses on air pollution trends and concomitant health benefits
- December telecon with TT members – prepare summary presentation
- January telecon with Stakeholders – solicit their feedback
- Begin work on modifying AQ website
- Communications writer to iterate with Stakeholders on TT deliverables (e.g., fact sheets, website, etc.)

Extra Slides

Is there a detectable decrease in NO_2 since January 1st, 2017?

Duncan, Lamsal

OMI NO_2 Data (March-May Average)



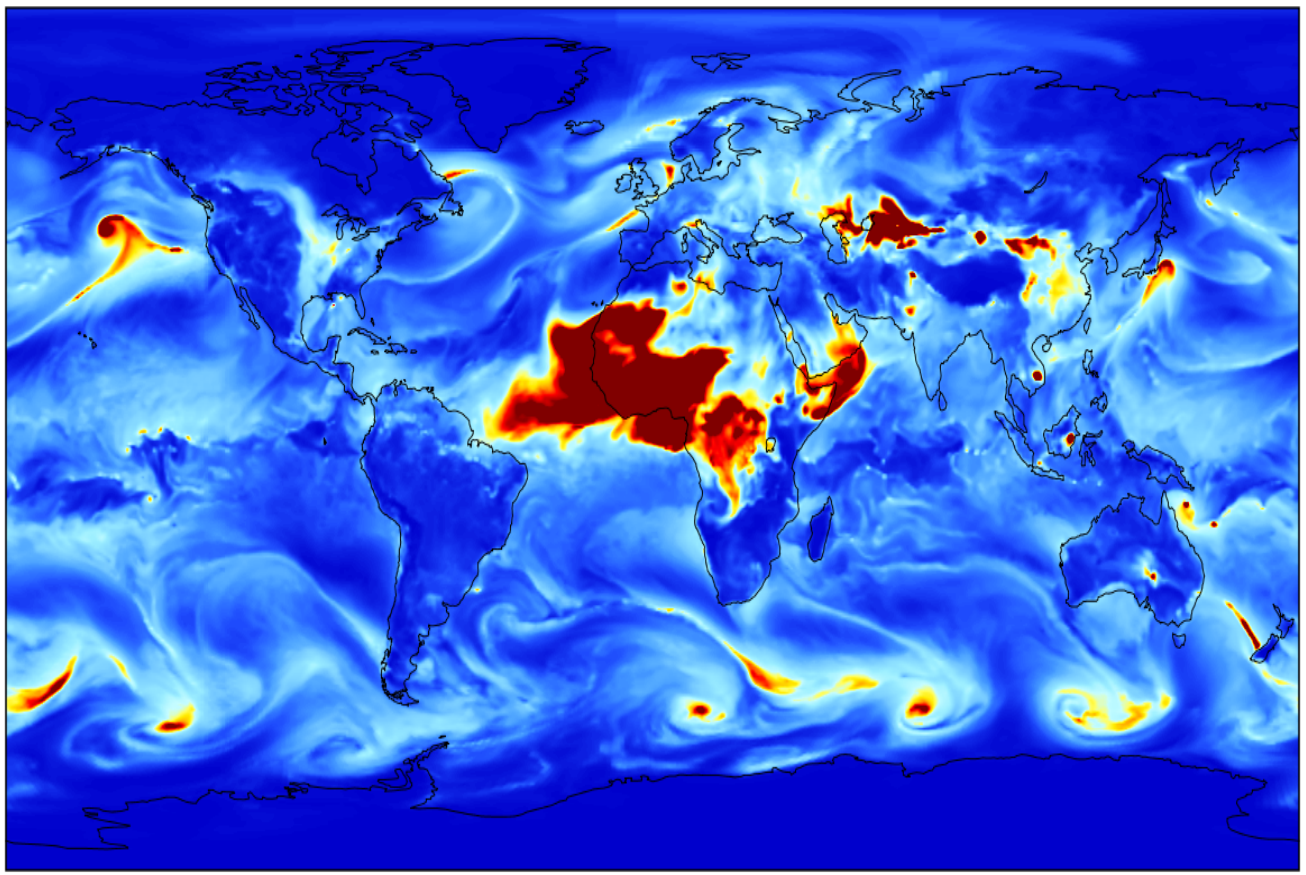
Simulated Trends in Ozone & PM

General Overview on the MERRA-2 GMI Global Simulation

- NASA GMAO/614 GEOS-5 Replay simulation for the MERRA-2 period (1980 – 2016, continuing into the future as emission data sets become available)
- Replay is a constrained dynamics run using 3 hourly ASM (U, V, T, P) fields from MERRA-2
- Using the native MERRA-2 resolution (run at C180 or 0.5° and output on same MERRA-2 horizontal grid (0.625° x 0.5°)
- Including full Stratospheric and Tropospheric chemistry from the Global Modeling Initiative (GMI) chemical mechanism
- Also includes the GOCART aerosol module with SU, DU, SS, OC, BC, and NI
- The simulation is available to all those with access to NCCS Discover right now and we will be working to make it available through OpenDAP (or by contacting Luke Oman, e-mail: luke.d.oman@nasa.gov)

Particulate Matter ($PM_{2.5}$)

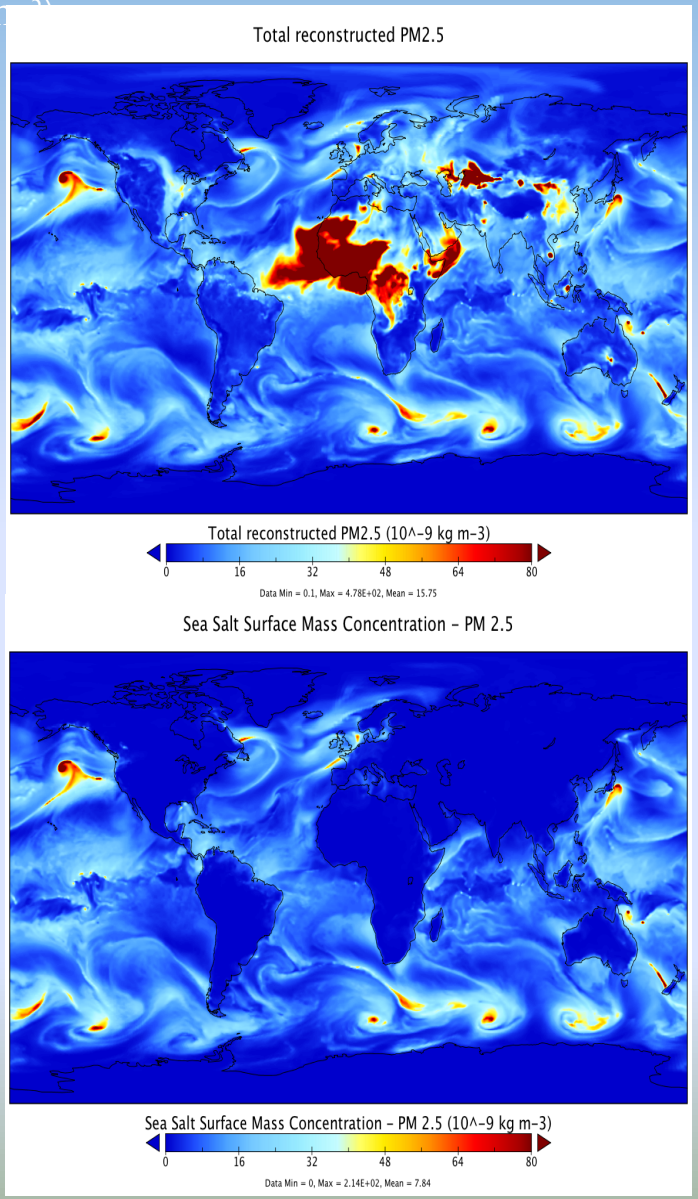
Total $PM_{2.5}$ = $DU_{2.5}$ + $SS_{2.5}$ + SU + $NI_{2.5}$ + NH_4 + OC + BC

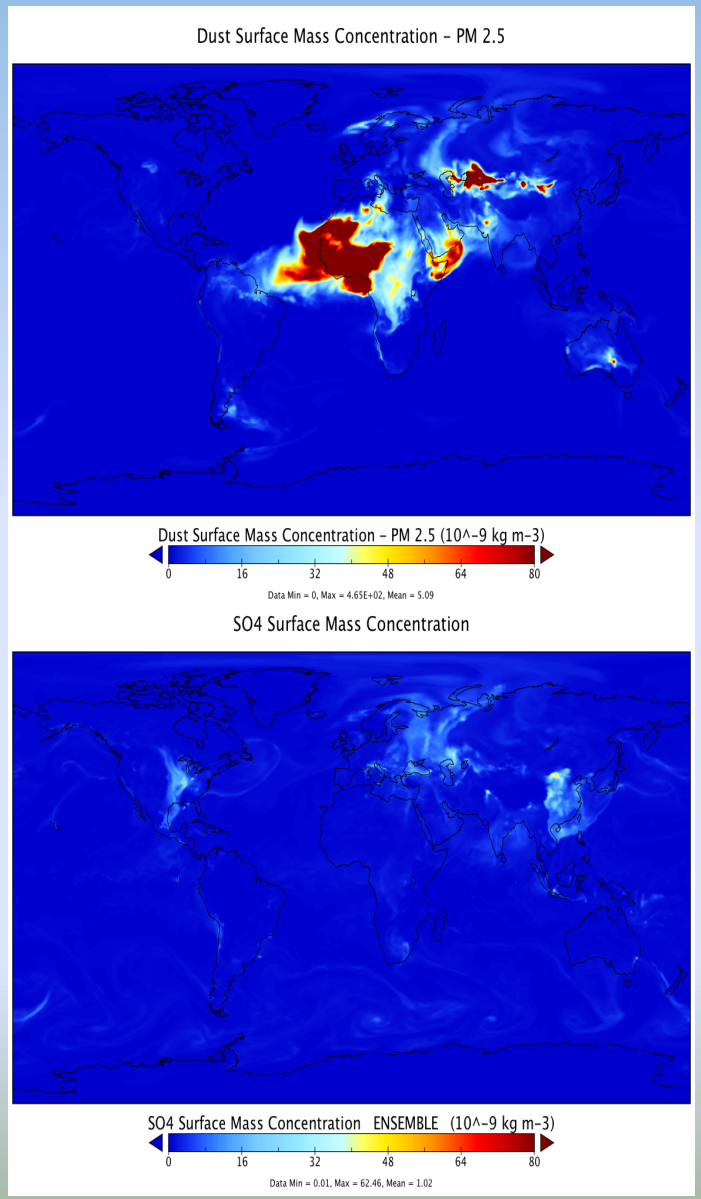


Example: Jan 15, 1998 1230z

Particulate Matter ($PM_{2.5}$)

Total $PM_{2.5} = DU_{2.5} + SS_{2.5} + SU + NI_{2.5} + NH_4 + OC + BC$ (in $\mu g / m^3$)

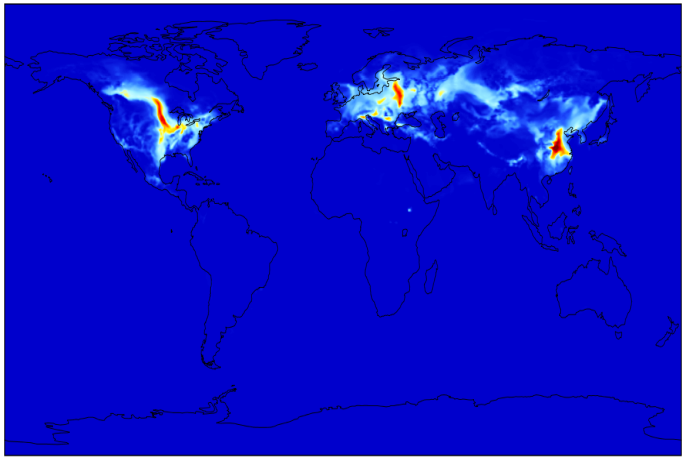




Other Individual Components of $PM_{2.5}$

Note different scale 0-20 vs. 0-80 (μ g /m^3)

Nitrate Surface Mass Concentration [PM2.5]

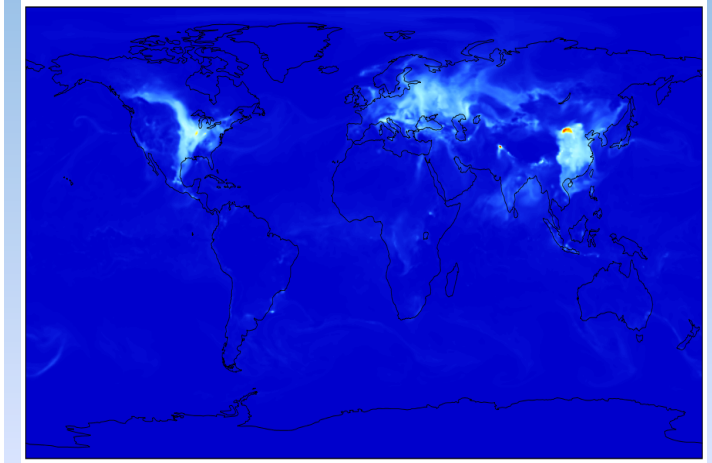


Nitrate Surface Mass Concentration [PM2.5] ENSEMBLE (10^-9 kg m-3)

0 4 8 12 16 20

Data Min = 6.47E-07, Max = 22.26, Mean = 0.25

Ammonium Surface Mass Concentration

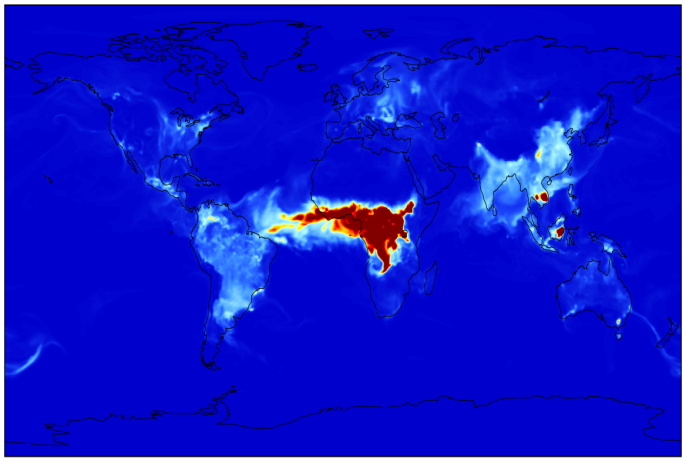


Ammonium Surface Mass Concentration ENSEMBLE (10^-9 kg m-3)

0 4 8 12 16 20

Data Min = 0, Max = 24.35, Mean = 0.33

Organic Carbon Surface Mass Concentration

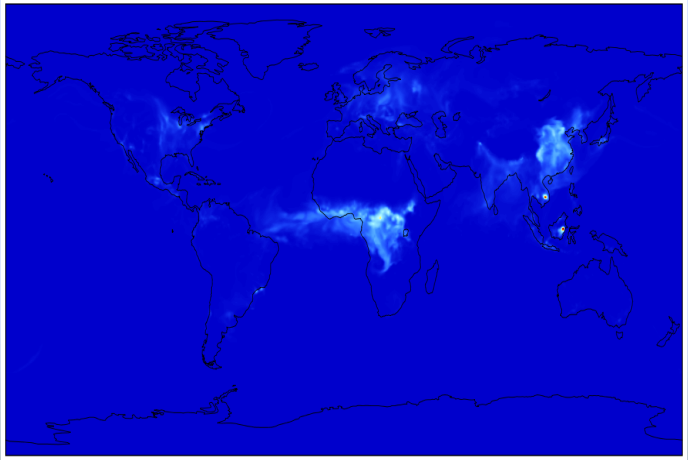


Organic Carbon Surface Mass Concentration ENSEMBLE (10^-9 kg m-3)

0 4 8 12 16 20

Data Min = 0, Max = 2.69E+02, Mean = 0.95

Black Carbon Surface Mass Concentration



Black Carbon Surface Mass Concentration ENSEMBLE (10^-9 kg m-3)

0 4 8 12 16 20

Data Min = 2.93E-05, Max = 22.9, Mean = 0.14

Air Quality Health Indicies

Example of the Canadian AQHI for Aug. 4, 1988 22z - O_3, NO_2, $PM_{2.5}$