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

Bryan Duncan, *NASA Goddard Space Flight Center*
Jason West, *University of North Carolina*

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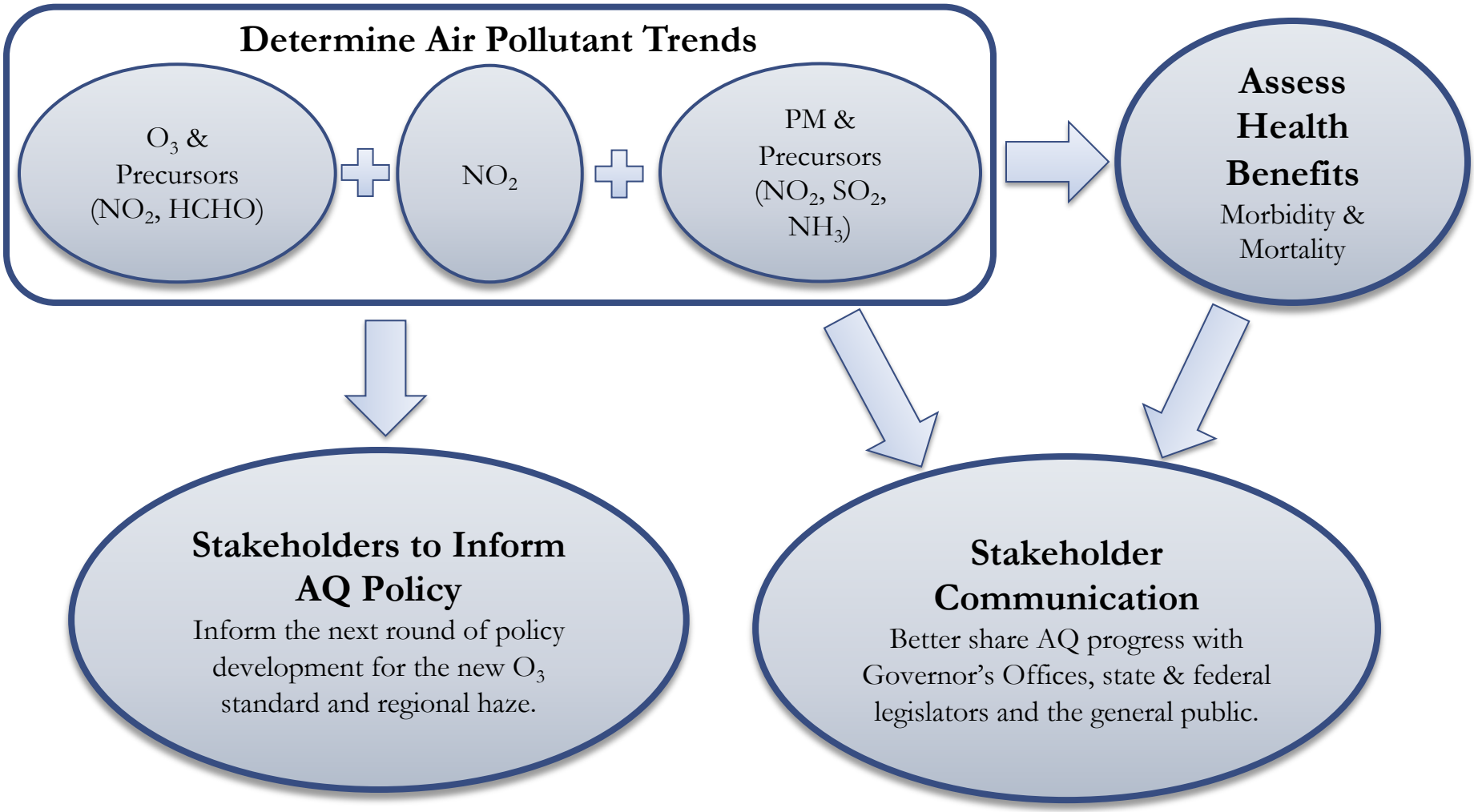
The Team & Stakeholders

- **Lead HAQAST PIs:** Bryan Duncan (NASA) & Jason West (UNC)

- **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 Contributors**
  - Susan Anenberg (George Washington U.)
  - Arlene Fiore (Columbia U.)
  - Yang Liu (Emory U.)
  - Daven Henze (U. Colorado)
  - Daniel Tong (George Mason U.)
  - Pat Kinney (Boston U.)
  - Lok Lamsal (NASA)

Tiger Team Schematic

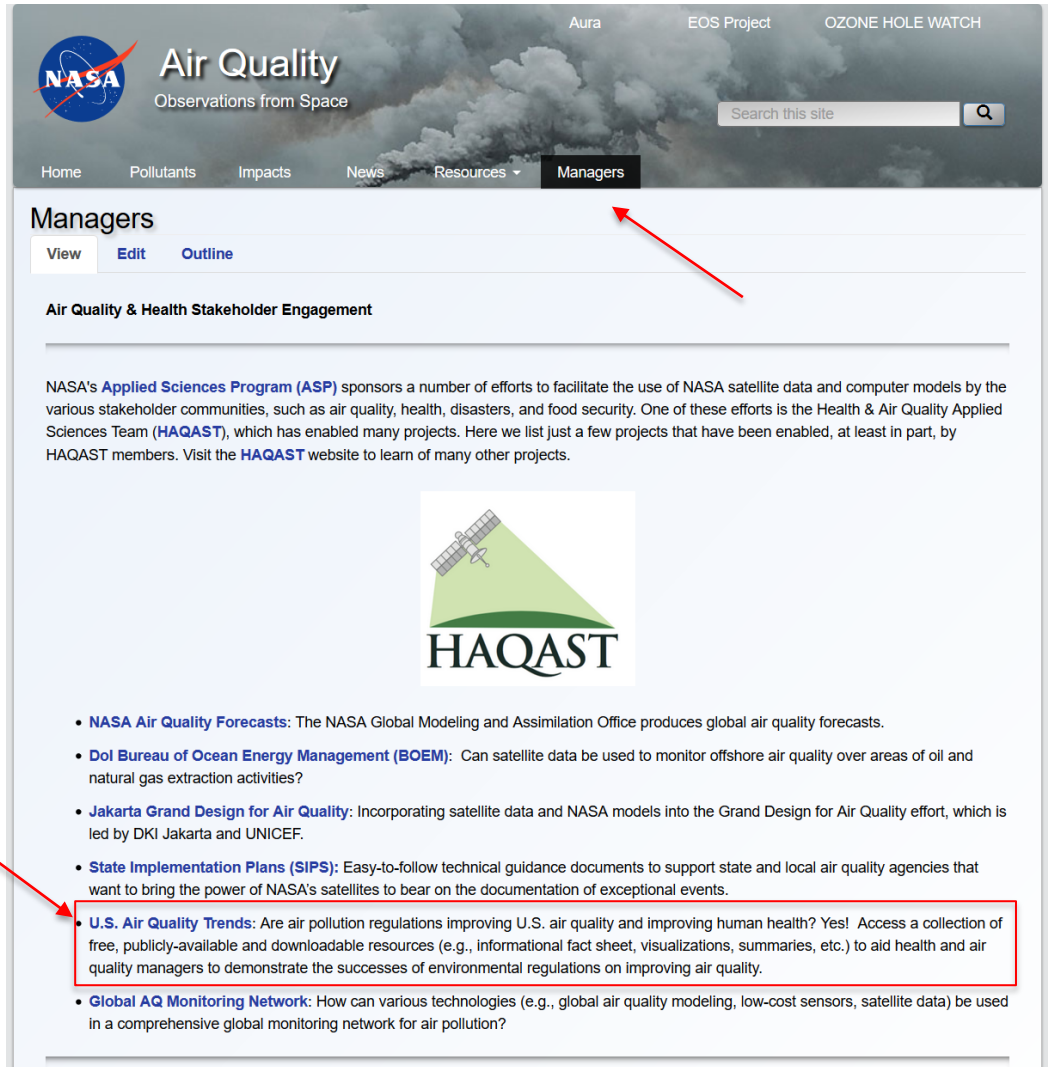


Status: 1) Revamped Air Quality Website

https://airquality.gsfc.nasa.gov

Status: 2) Completed All Deliverables

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



Tiger Team

Aura EOS Project OZONE HOLE WATCH

Air Quality
Observations from Space

Search this site

Home Pollutants Impacts News Resources Managers

U.S. Air Quality Trends

Basic page *U.S. Air Quality Trends* has been updated.

View Edit Outline

Efficacy of Environmental Regulations to Improve Air Quality in the U.S.

Between 1990 and 2015, the U.S. average concentration of $PM_{2.5}$ decreased by 37% and O_3 decreased by 22% (EPA, 2016). These decreased concentrations are expected to have brought substantial benefits for public health in the U.S., but assessing the health benefit requires an understanding of where air quality has improved, relative to where people live. We demonstrate the efficacy of environmental regulations by analyzing time trends of pollutants in the eastern US. We then apply these trends in exposure to pollutants for estimates of health benefits. Specifically, we analyze satellite, ground-based networks, and model concentration trends for ozone (O_3), nitrogen dioxide (NO_2 – an O_3 precursor), particulate matter (PM), and PM precursors, including NO_2 and sulfur dioxide (SO_2). This work is a product of the NASA HAQAST Year 1 (2017-2018) Tiger Team "Efficacy of Environmental Regulations to Improve Air Quality in the Eastern U.S."

Our team has developed a collection of free, publicly-available and downloadable resources (e.g., informational fact sheet, visualizations, summaries, etc.) to aid health and air quality managers to demonstrate the successes of environmental regulations on improving air quality.

Fact Sheet: Demonstrates that efforts to improve air quality have worked and have had significant health benefits.

Click on the icon to download a fact sheet (DRAFT) demonstrating that efforts to improve air quality have worked and have had significant benefits for human health.

Air Quality Trends as Viewed from Space

NO_2

- Download ready-made plots of satellite NO_2 trends (2005-2016) for various U.S. cities.
- Trends (2005-2013) in satellite NO_2 over major U.S. power plants.

National Aeronautics and Space Administration

DRAFT

Clean Air Act from Space

Environmental Regulations in the U.S. are Working

NASA satellites, with their "god's eye" view, confirm that air quality in the U.S. is improving for a number of air pollutants, including nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and fine particulate matter ($PM_{2.5}$), such as smoke and dust. That is, the Clean Air Act is working. While it is estimated that the health benefits of these pollutant reductions are substantial, levels of pollutants in the U.S. are still an environmental health risk today.

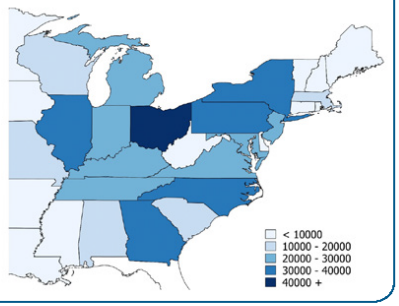
Impacts of Air Pollution on Health

The pollutants that cause the majority of negative health effects associated with U.S. air pollution are fine particulate matter (PM) and ozone (O_3). Exposure to PM causes and/or exacerbates a number of health issues, such as respiratory disease, ischemic heart disease, chronic obstructive pulmonary disease, lung cancer and stroke. When breathed in, O_3 chemically reacts with lung tissue, causing respiratory issues (e.g., shortness of breath, coughing, and aggravation of asthma) and injury to lung tissue that accumulates over time with continued exposure.

Improved AQ = Improved Health

Much of the improvement in O_3 is associated with reductions in emissions of nitrogen oxides (NO_x), a necessary ingredient for the formation of high O_3 levels, from automobiles and thermal power plants. This decrease in NO_x emissions led to an estimated 9-13 fewer violations of the U.S. health standard for O_3 throughout much of the Ohio River Valley and 3-9 fewer violations throughout much of the Washington, DC – Baltimore metropolitan area in July 2011 (Loughner et al., 2014). The lower levels of O_3 that resulted from the NO_x emissions reduction are estimated to have prevented 569-801 deaths, 950 hospital admissions due to respiratory symptoms, 573 emergency room visits for asthma, and asthma exacerbation symptoms for more than 430,000 people in July 2011 over the eastern U.S.

Avoided Asthma Exacerbations in July 2011 from Air Pollution Decreases since 2002



Estimated Benefits of Improving U.S. Air Quality

Health Benefits: The U.S. average concentrations of $PM_{2.5}$ decreased by 37% and O_3 decreased by 22% between 1990 and 2015 as estimated from surface air quality instrument data. These substantial improvements are estimated to have had concomitant health benefits (i.e., avoided deaths and improvements in health). For instance, it is estimated that deaths related to air pollution exposure in the U.S. decreased by about 47 percent, dropping from about 135,000 deaths in 1990 to 71,000 in 2010. Despite these improvements, about 1 in 35 U.S. deaths today is associated with air pollution, which is as many deaths from all traffic accidents and all gun shootings combined.

Economic Benefits: The benefits of air pollution mitigation more than 30 times exceed the associated costs; although the U.S. dedicates roughly $65 billion annually to improve air quality, there is a resulting $2 trillion in benefits from economic production due to reduced premature mortality (US EPA, 2011).

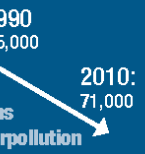
From 2005-2017
NASA satellite data show that:

$PM_{2.5}$ decreased 30–40% over U.S.

SO_2 decreased 90% over power plants

NO_2 decreased 40–60% over U.S. cities

While:



47% decrease in U.S. deaths related to airpollution

Still:

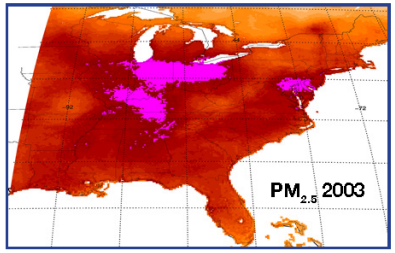
1 in 35 U.S. Deaths from air pollution,
as many as from traffic accidents and gun shootings combined

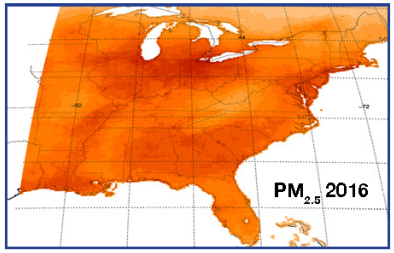
Satellite Data Demonstrate that US Air Quality is Improving

DRAFT

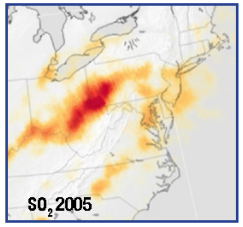
Fine Particulate Matter and Sulfur Dioxide

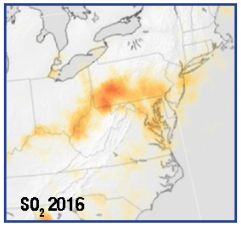
Fine particulate matter <2.5 µm in width ($PM_{2.5}$) is directly emitted to the atmosphere, such as in the form of smoke and dust, but can also form in the atmosphere through chemical reactions that transform gaseous pollutants (e.g., sulfur dioxide (SO_2), ammonia (NH_3), nitrogen dioxide (NO_2) to particles (i.e., gas to particle conversion). Satellite data indicate that $PM_{2.5}$ levels have decreased by about 30% or more over the Eastern U.S. from 2003 to 2016 because of emission control measures. Satellite data confirm that the concentrations of several $PM_{2.5}$ precursors are going down over time over the U.S. NO_2 levels have decreased by about 40-60% over most major U.S. cities from 2005 to 2017 and SO_2 levels have also decreased dramatically near coal-burning power plants.





Surface $PM_{2.5}$ levels, as inferred from NASA satellite data, have decreased by about 30-40% from 2005 to 2016.





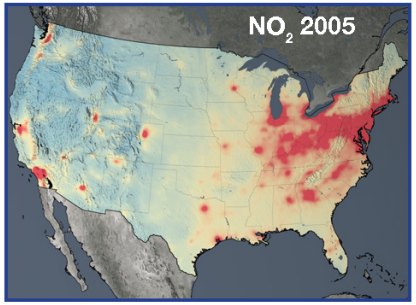
Substantial decreases in SO_2 concentrations from thermal power plants have contributed to the overall decline of $PM_{2.5}$ in the Eastern U.S. from 2005-2016.

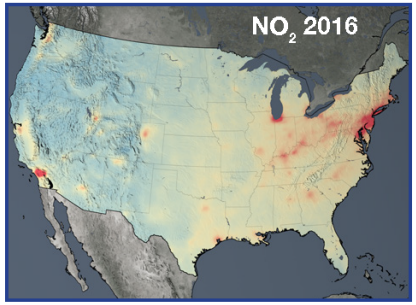
Ozone and Nitrogen Dioxide

At Earth's surface, ozone (O_3) is an air pollutant that is not directly emitted into the air, but instead it is formed through chemical reactions in the atmosphere when ultraviolet (UV) radiation from the sun interacts with nitrogen oxides (NOx = NO_2 + NO) and volatile organic compounds (VOCs). Both compounds are released to the atmosphere through human actions, such as the burning of fossil fuels. (Surface O_3 pollution is not to be confused with the stratospheric "ozone layer," which filters out most harmful UV rays from the sun.)

With today's technology, it is not currently feasible to monitor surface levels of O_3 from space. However, it is possible to observe NO_2 levels from space and NO_2 serves as an effective proxy for NOx. While NO_2 is unhealthy to breathe, NOx is primarily regulated to improve air quality as it is a necessary ingredient of the formation of unhealthy levels of O_3. Satellite data indicate that there have been substantial decreases (40-60%) in NO_2 levels over most major U.S. cities between 2005 and 2017. Surface air quality monitors in the U.S. indicate that there has been about a 15% decrease in surface O_3 from 2005 to 2016. However, satellite data and surface monitors both indicate that the downward trend in NO_2 has stalled since about 2011 (Jiang et al., 2018).

O_3 is also harmful to vegetation and even reduces yields for some crops (e.g., soybeans), costing an estimated $3.1 billion annually in the U.S. (Averny et al., 2011).





NASA satellite data show that NO_2 has decreased by 40-60% over U.S. cities from 2005-2016.

MILESTONES

1990 — CAA amendments. included mandates for SO_2 and NO_x reductions to control acid rain

1995 — ESA GOME instrument first observes NO_2, SO_2, and CH_2O

1997-2012 — Harvard Six Cities Study connected air pollution to mortality and showed that mortality went down when air quality improved.

1999 — NASA Terra MODIS and MISR instruments provides first state-of-art global maps of aerosol distribution, an important step in monitoring surface $PM_{2.5}$

2000-2009 — American Cancer Society Study is reanalyzed, updated, and extended in several studies, consistently reporting associations between particulate pollution and mortality

2004 — NASA Aura OMI instrument first measures trace gas air pollutants at sub-urban levels.

2006 — NASA CALIPSO instrument measures vertical distribution of aerosols, and important parameter in estimation of surface $PM_{2.5}$

2008 — OMI confirms large reductions in NO_2 and SO_2 levels over thermal power plants due to emission controls

2015 — OMI data reveal a 40-60% reduction in NO_2 levels over major U.S. cities between 2005-2015

2016 — NOAA/NASA ABI instrument provides very high frequency aerosol measurements for tracking fire smoke, volcanic plumes and dust storms

2017 — ESA TROPOMI instrument observes NO_2, SO_2, CH_2O, and CO at unprecedented sub-urban spatial resolutions and on daily time-scales

2019+ — Upcoming Launches: NASA MAIA, the first satellite mission dedicated to human health, and NASA TEMPO, the first geosynchronous satellite to observe many pollutants hourly

Satellite Data Aid Assessing Impacts of Wildfire Pollution

Numerous satellite datasets are used to identify wildfire locations, assess burned area, track smoke transport, issue air quality alerts, and to estimate health effects. Despite significant progress on reducing anthropogenic $PM_{2.5}$, wildfires are an infrequent, but significant source of $PM_{2.5}$ that can expose large populations to unhealthy levels of pollution. For instance, smoke from persistent wildfires in the Western U.S. during 2017 and 2018 degraded air quality in a number of large cities, such as San Francisco, Portland, and Seattle. While less frequent in the Eastern U.S., fire smoke is a significant health risk. For instance, wildfires in the Southeast U.S. impacted large regions, including heavily populated cities like Atlanta, in the fall of 2016.

Satellite image of California wildfires October 11, 2017
Blazes that started on a few hundred acres around Napa Valley were fanned by strong northeasterly winds into more than 100,000 acres of burned land in just two days impacting the air quality for entire counties in California.

NASA Health and Air Quality Applied Sciences Team (HAQAST)

NASA's Applied Science Program launched the three-year Health and Air Quality Applied Sciences Team (HAQAST) in the fall of 2016. The team includes thirteen air quality and public health scientists spread across the U.S., in government offices and public and private universities. HAQAST uses NASA satellite data to help solve real-world public health and air quality problems, working with stakeholders all around the world on issues from wildfire smoke to diesel emissions. HAQAST also pursues short-term, high-impact projects in small groups called Tiger Teams. This factsheet is the result of a Tiger Team, entitled "Efficacy of Environmental Regulations to Improve Air Quality in the Eastern U.S.", which is led by Dr. Bryan Duncan (NASA) and Dr. Jason West (UNC). More results of this Tiger Team can be found on the NASA Air Quality Web site: https://airquality.gsfc.nasa.gov/

Further Reading

NASA Health and Air Quality Applied Sciences Team: https://haqast.org

DRAFT

For More About Air Quality Data

The sources of information presented in this factsheet may be found at: airquality.gsfc.nasa.gov
Health and Air Quality Applied Sciences Team: haqast.org
Visit arset.gsfc.nasa.gov for information on accessing and visualizing NASA satellite data.

Air Quality Trends as Viewed from Space

NO_2

- Download ready-made plots of satellite NO_2 trends (2005-2016) for various U.S. cities.
- Trends (2005-2013) in satellite NO_2 over major U.S. power plants.
- A recent study using satellite data of NO_2 by Jiang et al. (2018) indicates that the downward trend in NO_2 has stalled since about 2011: *Jiang et al. (2018), Unexpected slowdown of US pollutant emission reduction in the past decade, Proceedings of the National Academy of Sciences, 201801191; DOI: 10.1073/pnas.1801191115.*
- Animation of annual mean NO_2 (satellite data) over the U.S. from 2005 to 2016.
- Still of annual mean NO_2 (satellite data) over the Mid-Atlantic/Ohio River Valley and U.S. in 2005 and 2016.

O_3 & Precursors

- Satellite data of ozone's chemical precursors show that ozone production has decreased in the eastern U.S. from 2005 to present.

PM & Precursors

- Satellite data are used to infer surface trends of PM and its chemical precursors, which have decreased in the eastern U.S. from 2005 to present.
- Animation of annual mean SO_2 (satellite data) over the eastern U.S. from 2005 to 2017
- Animation of annual mean $PM_{2.5}$ (estimated from satellite data) over the eastern U.S. from 2003 to 2016

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*Estimated Health Benefits of Air Quality Improvements**

*No satellite data were used in these estimated benefits.

Surface PM, O_3, & Human Health (1990-2010)

- Jason West (HAQAST) led a recent model (i.e., no satellite data) study (Zhang et al., 2018) that estimates the concomitant health benefits (i.e., avoided deaths) of improvements in U.S. air pollution levels of $PM_{2.5}$ and O_3 from 1990 to 2010. Their analyses show that deaths related to air pollution exposure in the U.S. decreased by about 47 percent, dropping from about 135,000 deaths in 1990 to 71,000 in 2010. [press release] [NASA news story]

Surface O_3 & Human Health

- A model study by Loughner et al. (2014) estimated that the anthropogenic emissions reductions that occurred between 2002 and 2011 led to potentially 9-13 fewer O_3 exceedances (using the 2011 maximum eight hour average O_3 standard of 75 ppbv) throughout much of the Ohio River Valley and 3-9 O_3 fewer exceedances throughout much of the Washington, DC – Baltimore, MD metropolitan area in July 2011. In unpublished work, we estimate, over the study region (most of the Eastern US), that

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Economy

- The benefits of air pollution mitigation more than 30 times exceed the associated costs; although the U.S. dedicates roughly $65 billion annually to improve air quality, there is a resulting $2 trillion in benefits from economic production due to reduced premature mortality (US EPA, 2011). The EPA has quantified the benefits of the U.S. Clean Air Act in a report, entitled "**Benefits and Costs of the Clean Air Act 1990-2020, the Second Prospective Study**."

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to **References**

HAQAST Co-Leads: Dr. Bryan N. Duncan (**Bryan.N.Duncan@nasa.gov**), Dr. Jason West

HAQAST Participants: Dr. Arlene Fiore, Dr. Susan Anenberg, Dr. Daven Henze, Dr. Daniel Tong, Dr. Lok Lamsal, Dr. Yang Liu

Stakeholder Partners: Susan Wierman (MARAMA), Tad Aburn (MDE), John Walker (EPA), Fuyuen Yip (CDC/NCEH), Paul Miller (NESCAUM), Anne Gobin (CT DEEP), Neal Fann (EPA), Susan Wierman (MARAMA), Paul Garbe (CDC), Rish Vaidyanathan (CDC)

Status: 3) Stakeholder Feedback

NEXT STEP:

AQ/Health Management Contacts

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

***** All Stakeholders are welcome to provide feedback.**

Year 2.5 Progress Update, PI Bryan N. Duncan

A Satellite-Based Global Health Air Quality Index (HAQI): Development and Assessment

- Work with NASA GMAO (*Christoph Keller, Emma Knowland*) to develop and evaluate global AQ forecast system (https://airquality.gsfc.nasa.gov/forecast; not in original proposal; requested by stakeholder - UNICEF)
  - Went "Live" on November 2, 2018!
  - Evaluation & subsequent model debugging ongoing, but lack AQ data in most world cities.
  - Developing relationships with several partner cities: Rio de Janeiro (received their AQ data and emissions inventory), Jakarta (series of meetings in March; submitted collaboration proposals, which were accepted; https://airquality.gsfc.nasa.gov/nasas-involvement-jakarta-grand-design-air-quality).
  - Working with stakeholders, including IBM, U.S. Army Public Health Center (January 14th, 2019 meeting), to facilitate access to forecasts.
  - Writing global AQ forecast system description paper.
- Development of a global Health Air Quality Index (HAQI) – *Kevin Cromar* (Co-I; NYU)
  - Completed.
- Novel applications of satellite data
  - Working with NASA GSFC's new Food Security Office to develop a theme on the impact of air pollution on crop yields. Completed website and factsheet: https://airquality.gsfc.nasa.gov/food-security
  - Submitted ATS Workshop (May 2017) report: "Air Pollution Monitoring for Health Research and Patient Care: An American Thoracic Society Workshop Report"
- Secured Interagency Agreement with Dept. of Interior Bureau of Ocean Energy Management (BOEM; https://airquality.gsfc.nasa.gov/bureau-ocean-energy-management-boem)
  - Submitted draft report on feasibility of using satellite data to monitor offshore air quality in ONG areas.
  - Planning May 2019 ocean cruise in the Gulf of Mexico.
- 2 stakeholder talks; maintain AQ website (https://airquality.gsfc.nasa.gov); maintain Ozone Garden at GSFC Visitor Center; 2 AQ publications

Tiger Team Participation

- TT Duncan & West: Efficacy of Environmental Regulations on AQ & Health
  - Completed development of materials (https://airquality.gsfc.nasa.gov/us-air-quality-trends) for stakeholders to demonstrate that air quality regulations are working in the eastern U.S.
  - Completed upgrade of AQ website: https://airquality.gsfc.nasa.gov
- TT Fiore: Supporting the use of satellite data in regional haze planning
  - Contributing trends in Asian & U.S. NO_2 and SO_2 (e.g., https://airquality.gsfc.nasa.gov/particulate-matter; https://airquality.gsfc.nasa.gov/surface-level-ozone)
  - Exploring TROPOMI data of NO_2, SO_2, & HCHO
- TT Anenberg:
  - Exploring TROPOMI data of NO_2, SO_2, & HCHO
  - Contributing surface concentrations in global NO_2