



# 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 ( $\text{NO}_2$ ), sulfur dioxide ( $\text{SO}_2$ ) and fine particulate matter ( $\text{PM}_{2.5}$ ), 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.

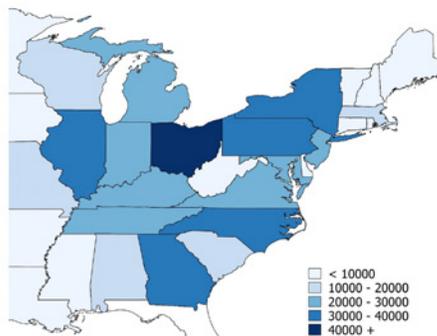
### Impacts of Air Pollution on Health

The pollutants that cause the majority of negative health effects associated with U.S. air pollution are fine particulate matter (PM) and ozone ( $\text{O}_3$ ). 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,  $\text{O}_3$  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. Nitrogen dioxide ( $\text{NO}_2$ ) also causes respiratory issues and is associated with, for instance, new cases of asthma among children (Anenberg et al., 2018).

#### Improved AQ = Improved Health

Between 2002 and 2011, new emissions controls reduced emissions of nitrogen oxides ( $\text{NO}_x$ ) in the eastern US.  $\text{NO}_x$  is a necessary ingredient for the formation of high ozone levels. In 2011 the number of days with unhealthy ozone levels was about 9-13 less than in 2002 in much of the Ohio River Valley, and the Washington, D.C.-Baltimore area had 3-9 fewer days with unhealthy ozone levels (Loughner et al., 2014). In unpublished work, scientists estimate that in the eastern US this improvement in air quality prevented about 570-800 deaths, about 950 hospital admissions due to respiratory symptoms, and about 570 emergency room visits for asthma. More than 430,000 people avoided asthma exacerbation symptoms.

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



### Estimated Benefits of Improving U.S. Air Quality

**Health Benefits:** The average U.S. concentration of  $\text{PM}_{2.5}$  decreased by 37% and average  $\text{O}_3$  decreased by 22% between 1990 and 2015 as estimated from surface air quality instrument data (US EPA, 2018). 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 (Zhang et al., 2018). 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). For example,  $\text{O}_3$  is harmful to vegetation and 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:

**$\text{PM}_{2.5}$  decreased 30%**

over Eastern U.S. from

**1998 to 2012**

Boys et al. (2014)



**$\text{SO}_2$  decreased 50% or more over most power plants in eastern U.S. from 2005 to 2018**

Fioletov et al. (2011; 2016)

**$\text{NO}_2$  decreased 40-60%**

over most U.S. cities from

**2005 to 2018**



Duncan et al. (2016)

**While:**

**47%**

**decrease in U.S. deaths related to air pollution**

**1990: 135,000**

**2010: 71,000**

**Still:**

**1 in 35**

**U.S. Deaths**

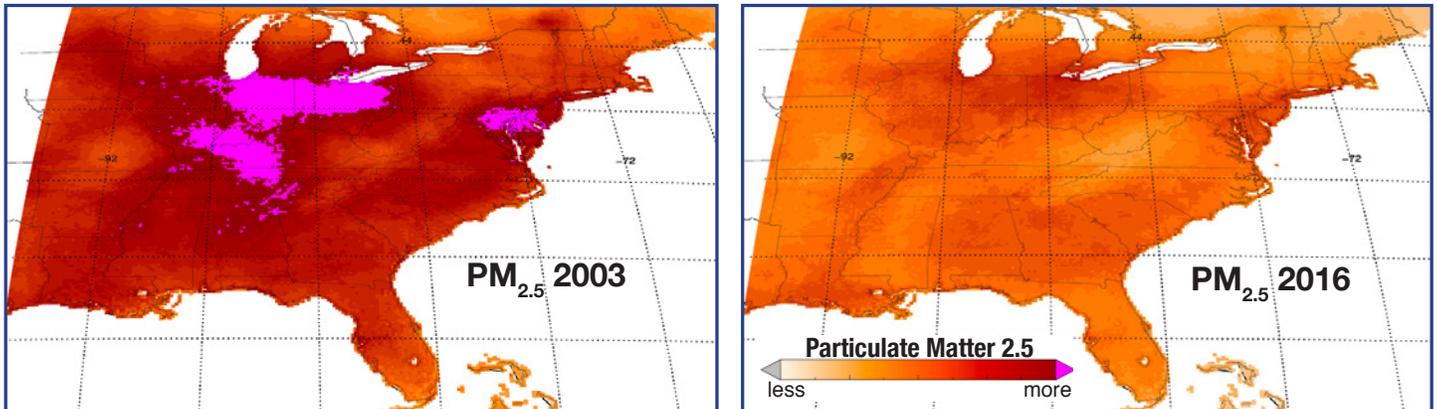
**from air pollution, as many as from traffic accidents and gun shootings combined**

Zhang et al. (2018)

## Satellite Data Demonstrate that US Air Quality is Improving

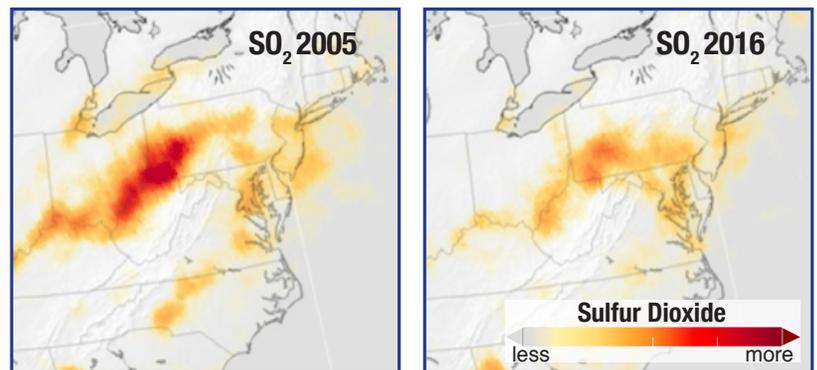
### Fine Particulate Matter and Sulfur Dioxide

Fine particulate matter <math><2.5\ \mu\text{m}</math> in width ( $\text{PM}_{2.5}$ ) is directly emitted to the atmosphere, such as in the form of smoke and dust.  $\text{PM}_{2.5}$  can also form in the atmosphere through chemical reactions that transform gaseous precursor pollutants, such as sulfur dioxide ( $\text{SO}_2$ ), ammonia ( $\text{NH}_3$ ), or nitrogen dioxide ( $\text{NO}_2$ ) to particles (i.e., gas to particle conversion). Satellite data indicate that  $\text{PM}_{2.5}$  levels have decreased by about 30% or more over the Eastern U.S. from 1998 to 2012 because of emission control measures (Boys et al., 2014). Satellite data confirm that the concentrations of several  $\text{PM}_{2.5}$  precursors are going down over time over the U.S.  $\text{NO}_2$  levels decreased by about 40-60% over most major U.S. cities from 2005 to 2017 (Duncan et al., 2016) and  $\text{SO}_2$  levels also decreased dramatically near coal-burning power plants (Fioletov et al., 2011, 2016).

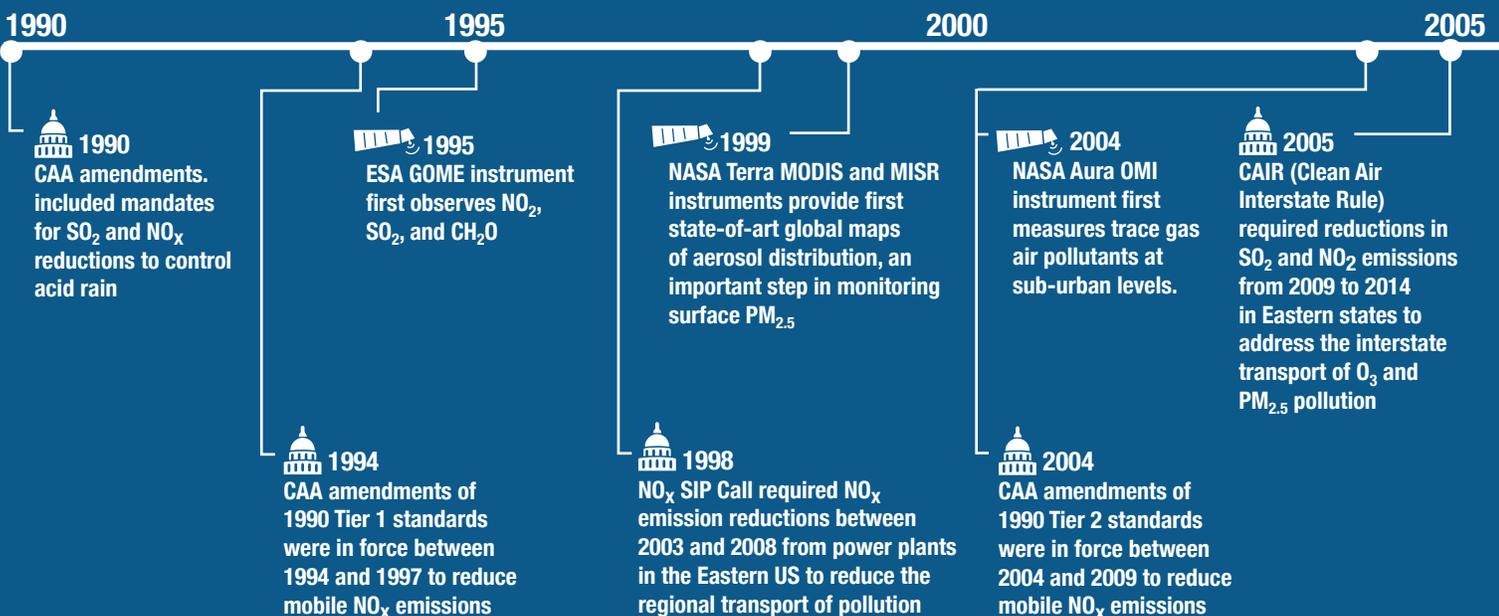


Surface  $\text{PM}_{2.5}$  levels, as inferred from NASA satellite data, have decreased about 30% from 1998 to 2012 (Boys et al., 2014). The spatial distributions of annual pollutants are shown for 2003 and 2016.

$\text{SO}_2$  concentrations decreased over most U.S. power plants in the Eastern U.S. by 50% or higher (Fioletov et al., 2011, 2016). These decreases have contributed to the overall decline of  $\text{PM}_{2.5}$  in the Eastern U.S. from 2005-2016.



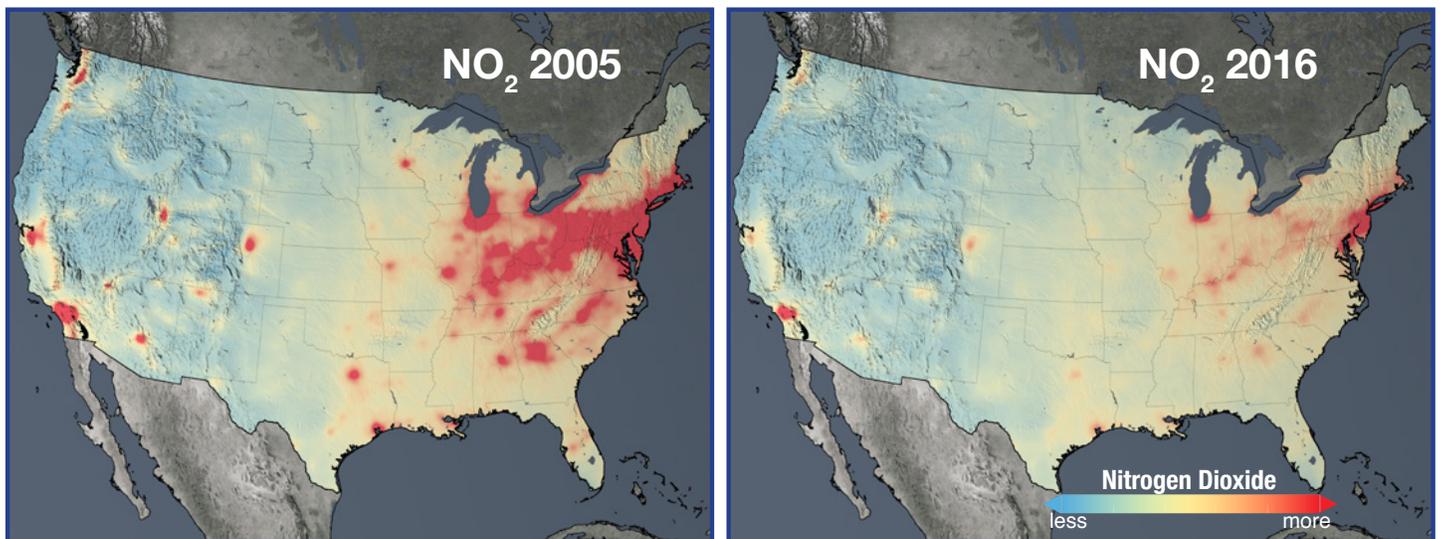
## MILESTONES



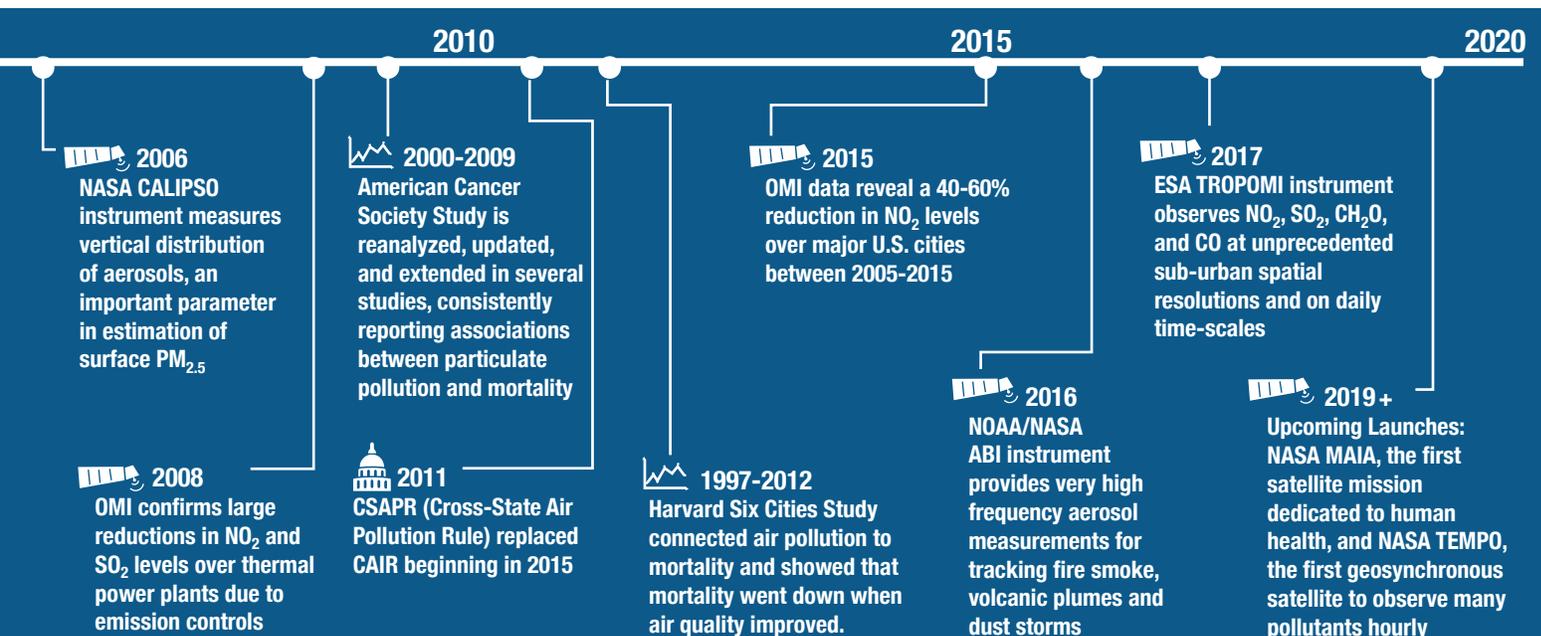
## Ozone and Nitrogen Dioxide

At Earth's surface, ozone (O<sub>3</sub>) is an air pollutant that is not directly emitted into the air, but instead is formed through chemical reactions in the atmosphere when ultraviolet (UV) radiation from the sun interacts with nitrogen oxides (NO<sub>x</sub> = NO<sub>2</sub> + 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<sub>3</sub> 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<sub>3</sub> from space. However, it is possible to observe NO<sub>2</sub> levels from space and NO<sub>2</sub> serves as an effective proxy for NO<sub>x</sub>. While NO<sub>2</sub> is unhealthy to breathe, NO<sub>x</sub> is primarily regulated to improve air quality as it is a necessary ingredient of the formation of unhealthy levels of O<sub>3</sub>. Satellite data indicate that there have been substantial decreases (40-60%) in NO<sub>2</sub> 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<sub>3</sub> from 2005 to 2016 (US EPA, 2018). However, satellite data and surface monitors both indicate that the downward trend in NO<sub>2</sub> has stalled since about 2011 (Jiang et al., 2018).



NASA satellite data show that NO<sub>2</sub> has decreased by 40-60% over U.S. cities from 2005-2016 (Duncan et al., 2016).



## Satellite Data Help Assess Impacts of Wildfire Pollution

Numerous satellite datasets are used to identify wildfire locations, assess burned area, track smoke transport, issue air quality alerts, and estimate health effects. Despite significant progress on reducing anthropogenic PM<sub>2.5</sub>, wildfires are an infrequent, but significant source of PM<sub>2.5</sub> 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.*

## For More About Air Quality Data

Images, animations, and other information related to this factsheet may be found at [airquality.gsfc.nasa.gov/us-air-quality-trends](https://airquality.gsfc.nasa.gov/us-air-quality-trends). Visit [arset.gsfc.nasa.gov](https://arset.gsfc.nasa.gov) for information on accessing and visualizing NASA satellite data. Health and Air Quality Applied Sciences Team website [haqast.org](https://haqast.org).



## 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/>

## References

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