



Upgrading the Toolbox:
NASA Resources to Support Air
Quality Management

Bryan N. Duncan, NASA
Bryan.N.Duncan@nasa.gov

HAQAST2020
WEBINAR SERIES



Webinar Objectives

By the end of this webinar, participants will have the necessary information to begin accessing some NASA resources that enhance the applications of health and air quality managers.

Specifically, participants will be introduced to:

1. a user-friendly NASA visualization tool for satellite data.
2. a NASA website that gives an overview of how satellite data aid health & air quality managers.
3. the NASA GEOS-CF global air quality forecast system.
4. the NASA Applied Remote SEnsing Training (ARSET) program.
5. the NASA Health & Air Quality Applied Sciences Team (HAQAST) program.

All NASA data and resources presented here are **free and publicly-available**.

NASA Earth Science Missions

NASA satellite missions are predominately designed for scientific research.

However, some datasets are useful for health and air quality managers.

MAIA is the 1st health-based NASA mission.

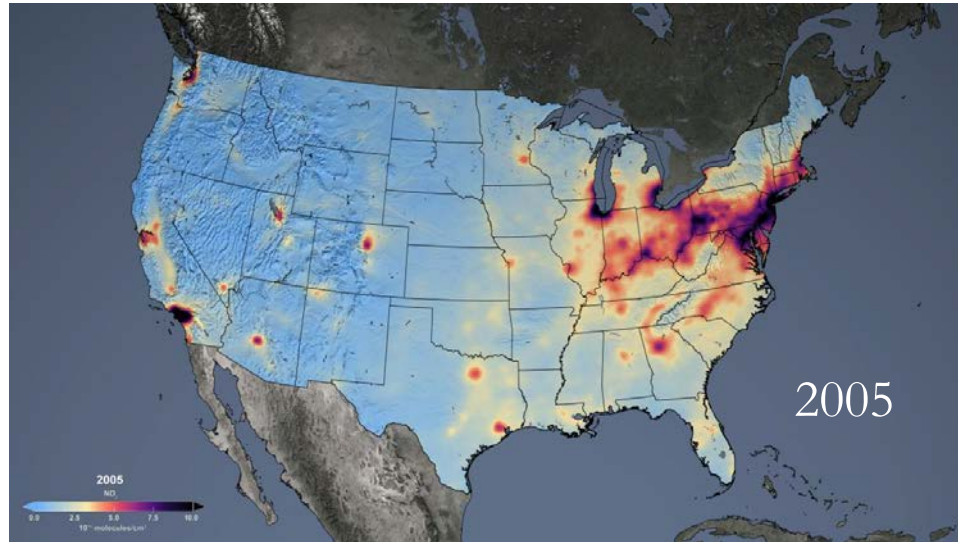




Potentially Useful Space-based Observations

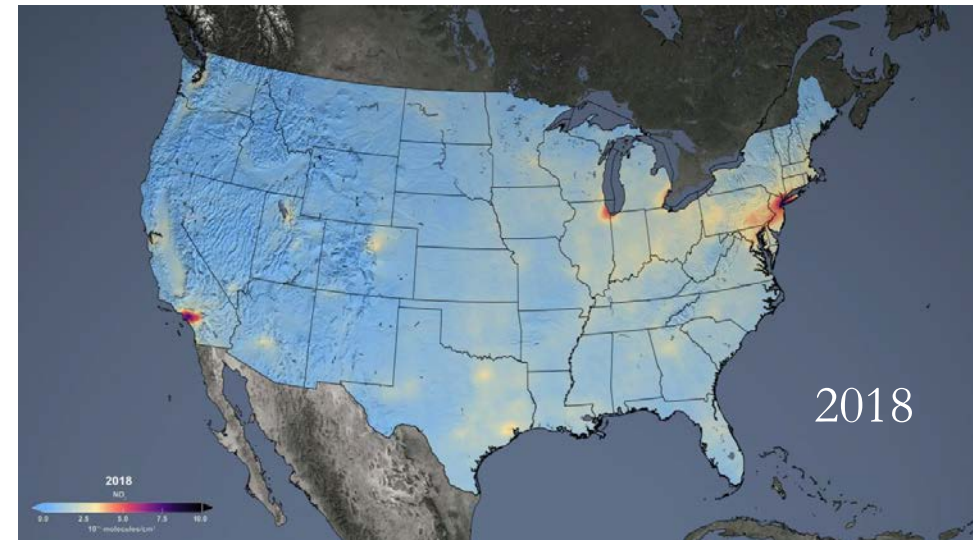
- Aerosols (AOD, fire detection) → can be used to infer “nose-level” PM_{2.5} with atmospheric models
 - Ozone (O₃) → no information on “nose-level” concentrations
 - Nitrogen dioxide (NO₂) → most straightforward to observe & excellent tracer of combustion
 - Carbon monoxide (CO) → another tracer of combustion
 - Sulfur dioxide (SO₂)
 - Ammonia (NH₃)
 - Formaldehyde (HCHO)
 - Surface UV → not a pollutant, but ...
- } *precision and accuracy not suitable for most health studies*

Unique Advantages of Satellite Data: Spatial Coverage & Changes over Time



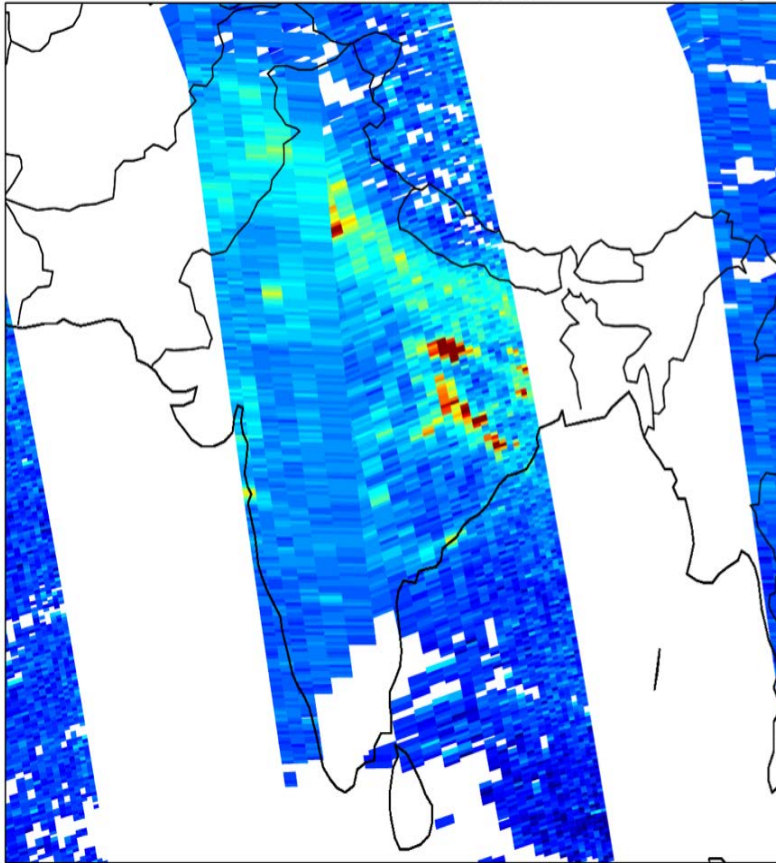
OMI Nitrogen Dioxide: NO₂
(gridded to ~10x10 km²)

Satellite data are validated with independent observations (e.g., AQS, NASA field campaigns) and emissions (e.g., CEMS)



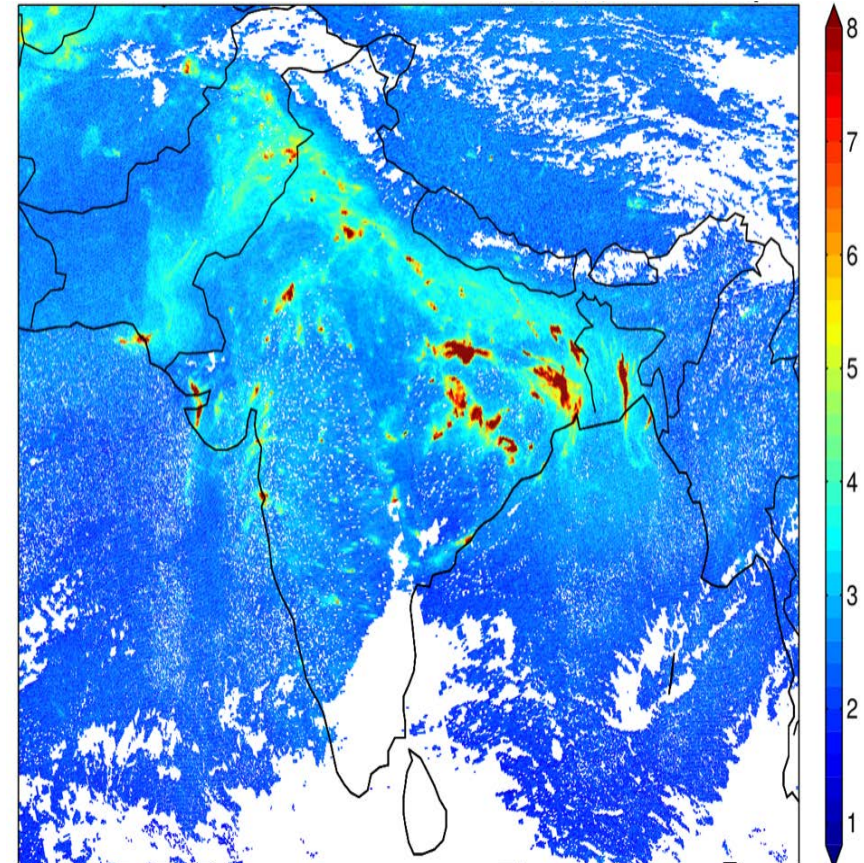
An Exciting Time: Evolving Technology & New Satellites

OMI NO₂



November 28, 2017

TROPOMI NO₂



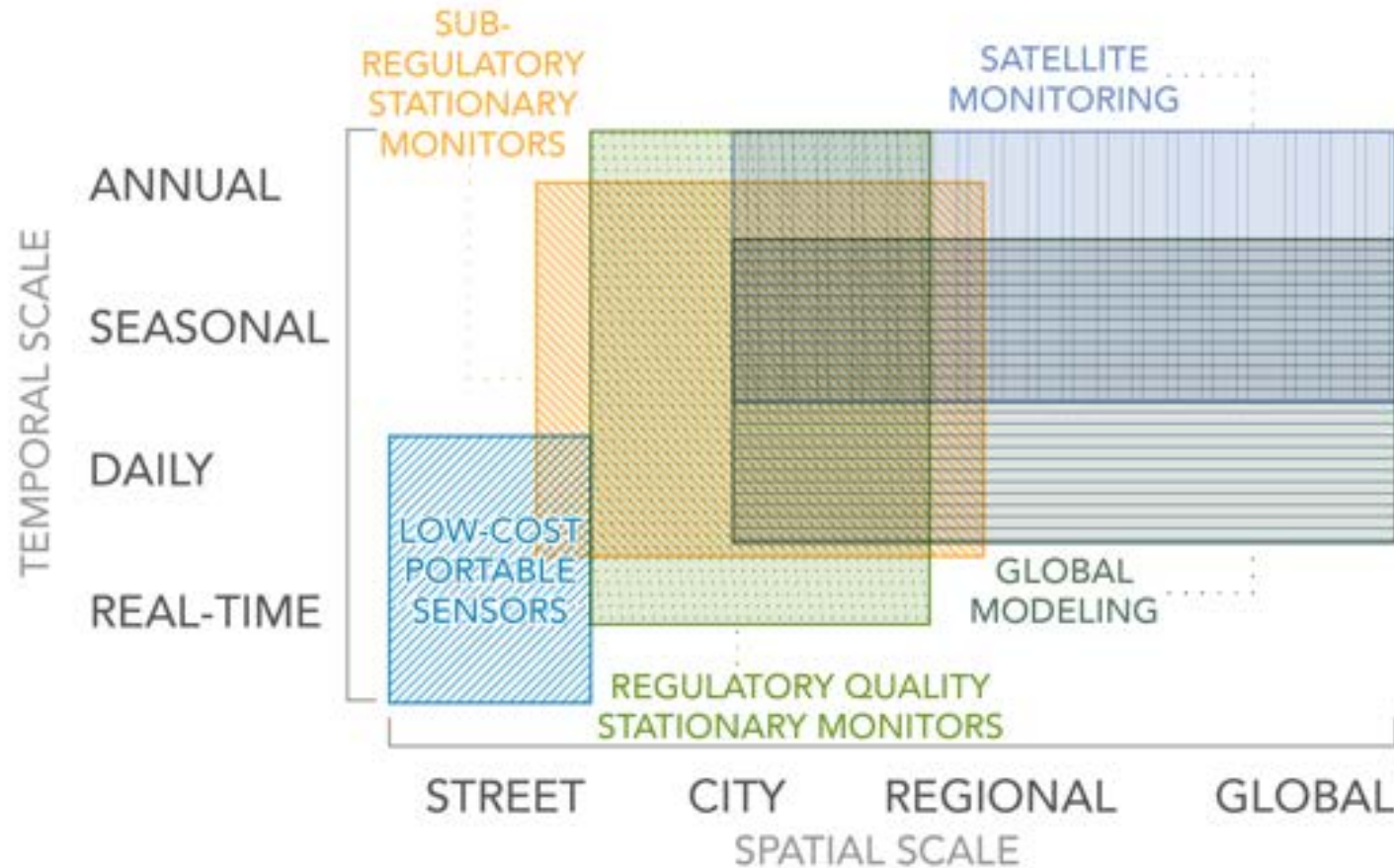
Spatial Resolution = 3.5 x 7.0 km²



A map of the Washington, DC Metropolitan Area. A large black rectangle outlines the entire metropolitan area. Within this area, a blue rectangle labeled "OMI" (Outer Metropolitan Influence) is shown, and a smaller red rectangle labeled "GOME 2 TEMPO" (Greater Outer Metropolitan Environmental and Transportation Planning) is shown within the OMI area. The map includes major highways, cities, and geographical features. A text box in the top right corner reads "Washington, DC Metropolitan Area".

TEMPO (2022)
2 x 5 km² &
greater

“Tools” for the AQ Manager’s “Toolbox”



Integrated Approach to Air Pollution Monitoring

“Each of these technologies has strengths and limitations that need to be considered when integrating them to develop a robust and diverse global air quality monitoring network.”

Figure from Cromar et al. (2019)



Just 5 Easy Steps to Begin Accessing NASA Data

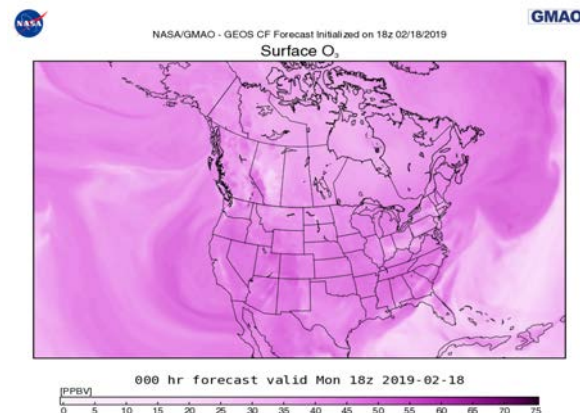
#1: User-friendly visualization tool.



#2: Overview of how satellite data aid health and air quality managers.



#3: Check out AQ forecasts for your favorite world city.



#4: On-line and in-person training on how to work with satellite data.



#5: Work with satellite data experts on your health and air quality applications.

Step#1: Worldview (<https://worldview.earthdata.nasa.gov/>)

Browse images by

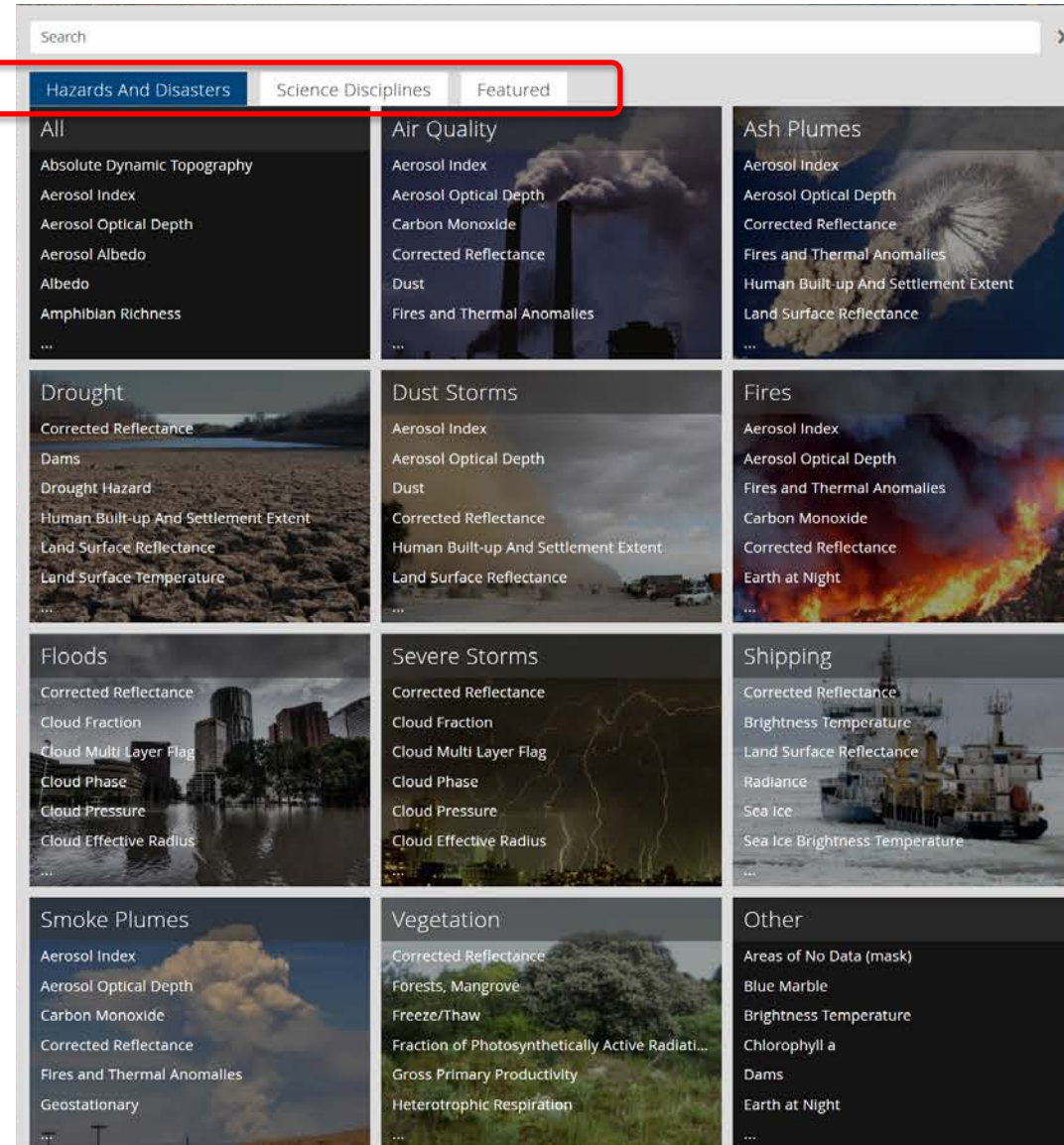
1. Hazards and Disasters
2. Science Discipline
3. Featured Event

AND

Make your own maps.

HAQAST tutorial on using
Worldview:

<https://www.youtube.com/watch?v=7BLyz8AI5vg&t=0s>



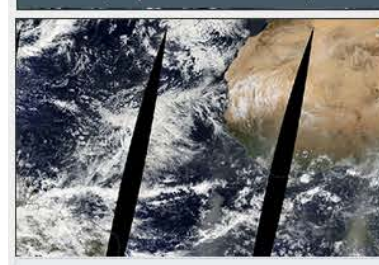
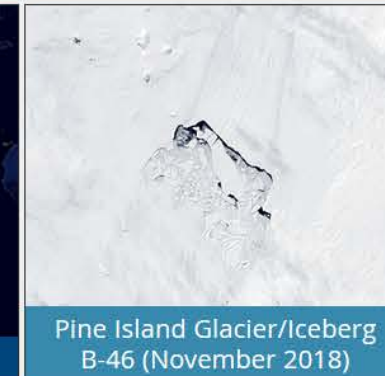
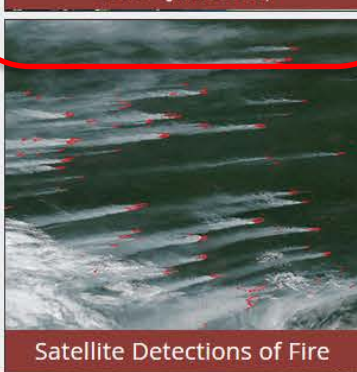
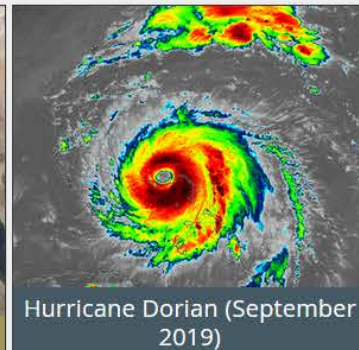
The Worldview tool from NASA's Earth Observing System Data and Information System (EOSDIS) provides the capability to interactively browse over 900 global, full-resolution satellite imagery layers and then download the underlying data.

Step#1: Worldview (<https://worldview.earthdata.nasa.gov/>)

Featured Events

Welcome to Worldview! 

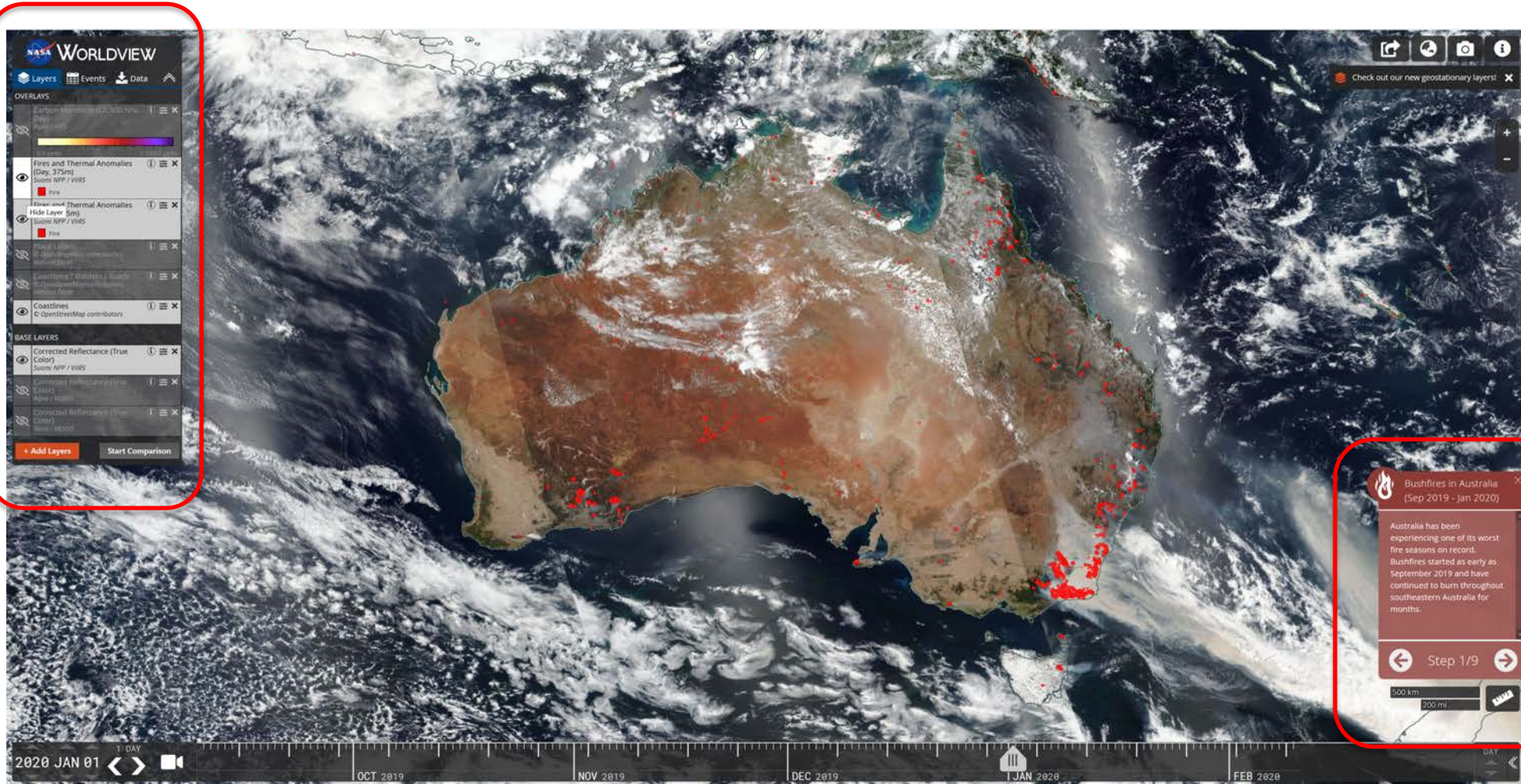
Visually explore the past and the present of this dynamic planet from a satellite's perspective. Select from an array of stories below to learn more about Worldview, the satellite imagery we provide and events occurring around the world. **Start using Worldview →**



Step#1: Worldview (<https://worldview.earthdata.nasa.gov/>)

Add
your
own
layers
of data.

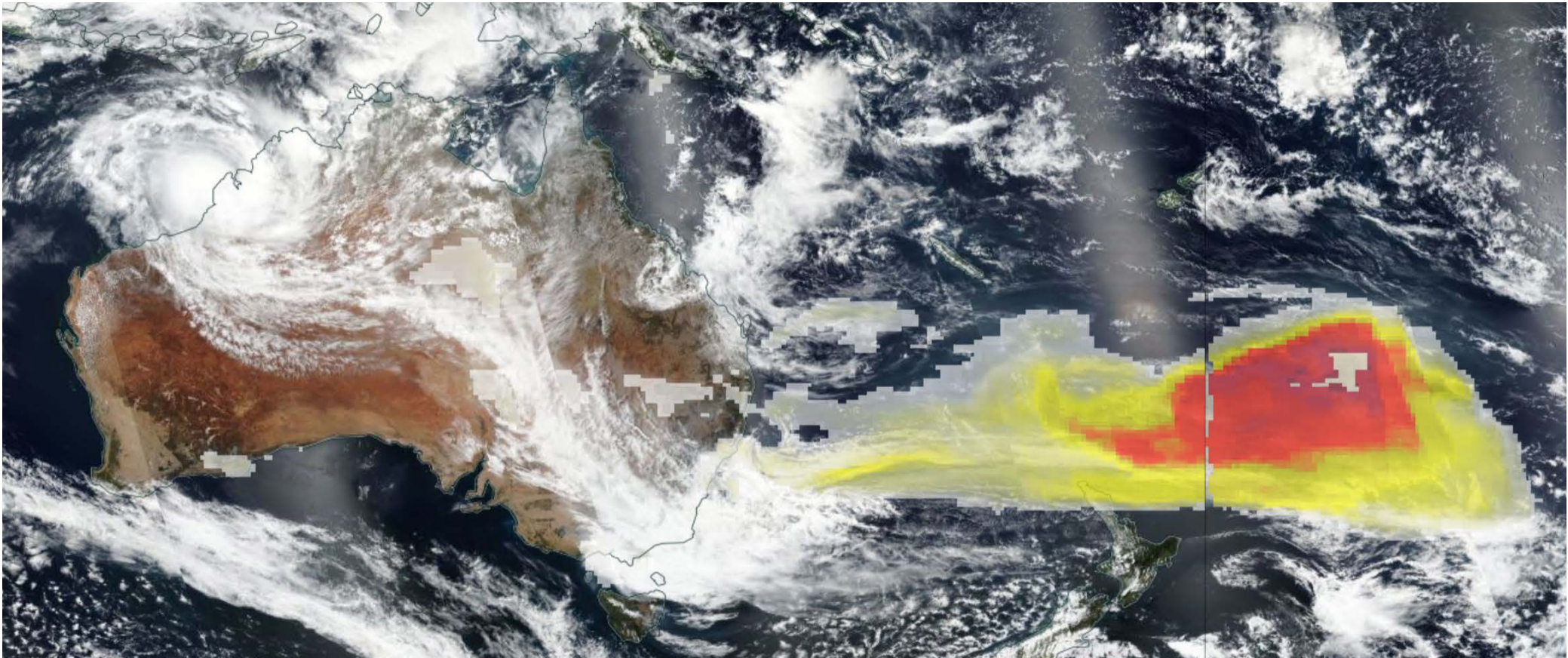
Step
through
pre-made
images on
each topical
event.



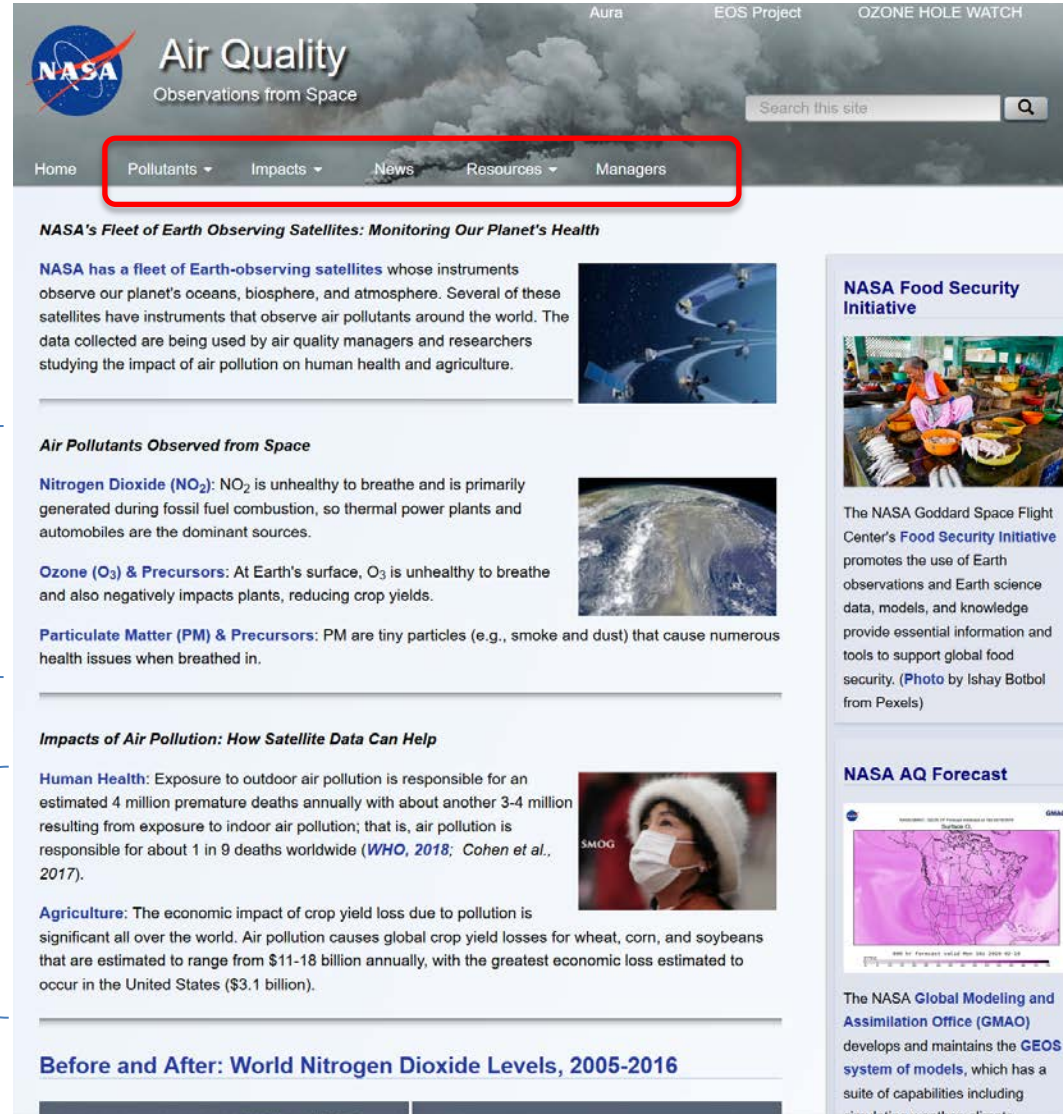
Step#1: Worldview (<https://worldview.earthdata.nasa.gov/>)

One Pre-Made Plot:

Aerosol Optical Depth (unitless): indicator of thickness of smoke



Step#2: AQ Website (<https://airquality.gsfc.nasa.gov>)



NASA Air Quality
Observations from Space

Home Pollutants Impacts News Resources Managers

NASA's Fleet of Earth Observing Satellites: Monitoring Our Planet's Health

NASA has a fleet of Earth-observing satellites whose instruments observe our planet's oceans, biosphere, and atmosphere. Several of these satellites have instruments that observe air pollutants around the world. The data collected are being used by air quality managers and researchers studying the impact of air pollution on human health and agriculture.

Air Pollutants Observed from Space

Nitrogen Dioxide (NO₂): NO₂ is unhealthy to breathe and is primarily generated during fossil fuel combustion, so thermal power plants and automobiles are the dominant sources.

Ozone (O₃) & Precursors: At Earth's surface, O₃ is unhealthy to breathe and also negatively impacts plants, reducing crop yields.

Particulate Matter (PM) & Precursors: PM are tiny particles (e.g., smoke and dust) that cause numerous health issues when breathed in.

Impacts of Air Pollution: How Satellite Data Can Help

Human Health: Exposure to outdoor air pollution is responsible for an estimated 4 million premature deaths annually with about another 3-4 million resulting from exposure to indoor air pollution; that is, air pollution is responsible for about 1 in 9 deaths worldwide (*WHO, 2018; Cohen et al., 2017*).

Agriculture: The economic impact of crop yield loss due to pollution is significant all over the world. Air pollution causes global crop yield losses for wheat, corn, and soybeans that are estimated to range from \$11-18 billion annually, with the greatest economic loss estimated to occur in the United States (\$3.1 billion).

Before and After: World Nitrogen Dioxide Levels, 2005-2016

NASA Food Security Initiative

The NASA Goddard Space Flight Center's Food Security Initiative promotes the use of Earth observations and Earth science data, models, and knowledge provide essential information and tools to support global food security. (Photo by Ishay Botbol from Pexels)

NASA AQ Forecast

The NASA Global Modeling and Assimilation Office (GMAO) develops and maintains the GEOS system of models, which has a suite of capabilities including simulation weather, climate

“Pollutants” tab

Lots of info, ready-made images & animations

“Impacts” tab

Overview of how air pollution affects human health & agriculture

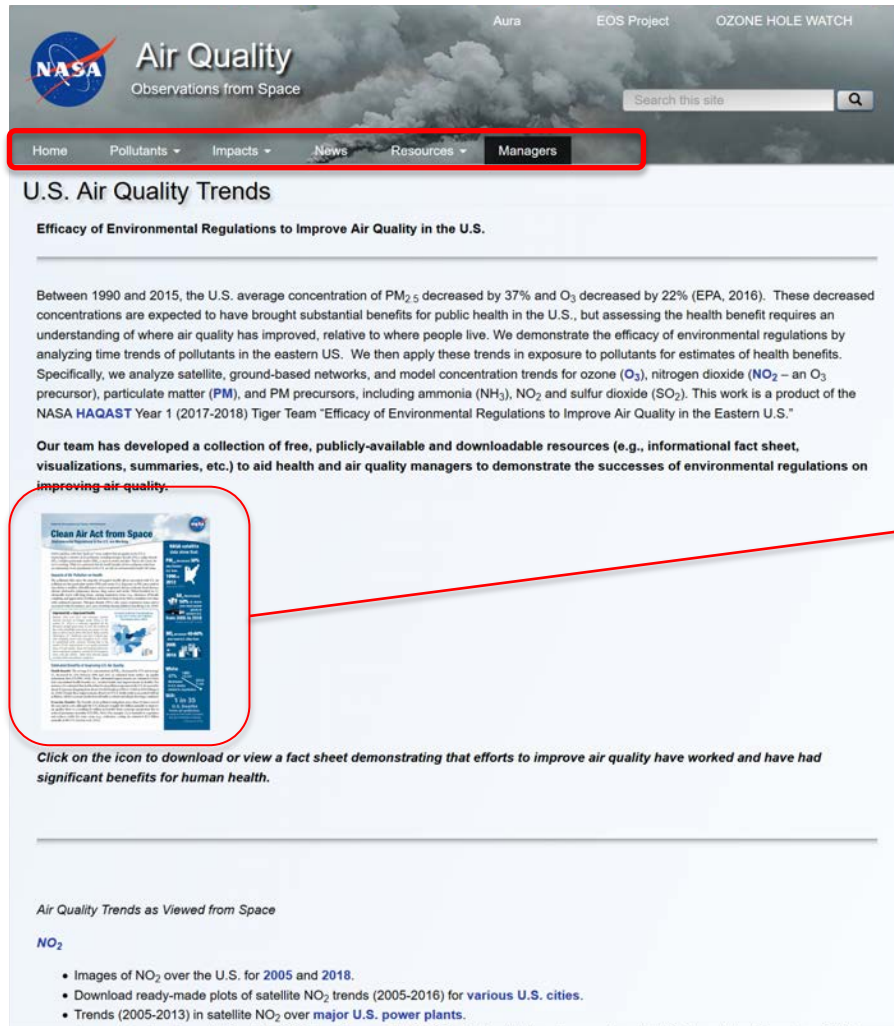
“Resources” tab

- Webtools for data access
- Factsheets
- AQ websites
- Outreach

Sidebar links to NASA Programs

- Food Security
- AQ Forecasts
- ARSET
- HAQAST
- Applied Sciences

Step#2: AQ Website (<https://airquality.gsfc.nasa.gov>)



Air Quality
Observations from Space

Home Pollutants Impacts News Resources **Managers**

U.S. Air Quality Trends

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 U.S. 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 ammonia (NH_3), 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.

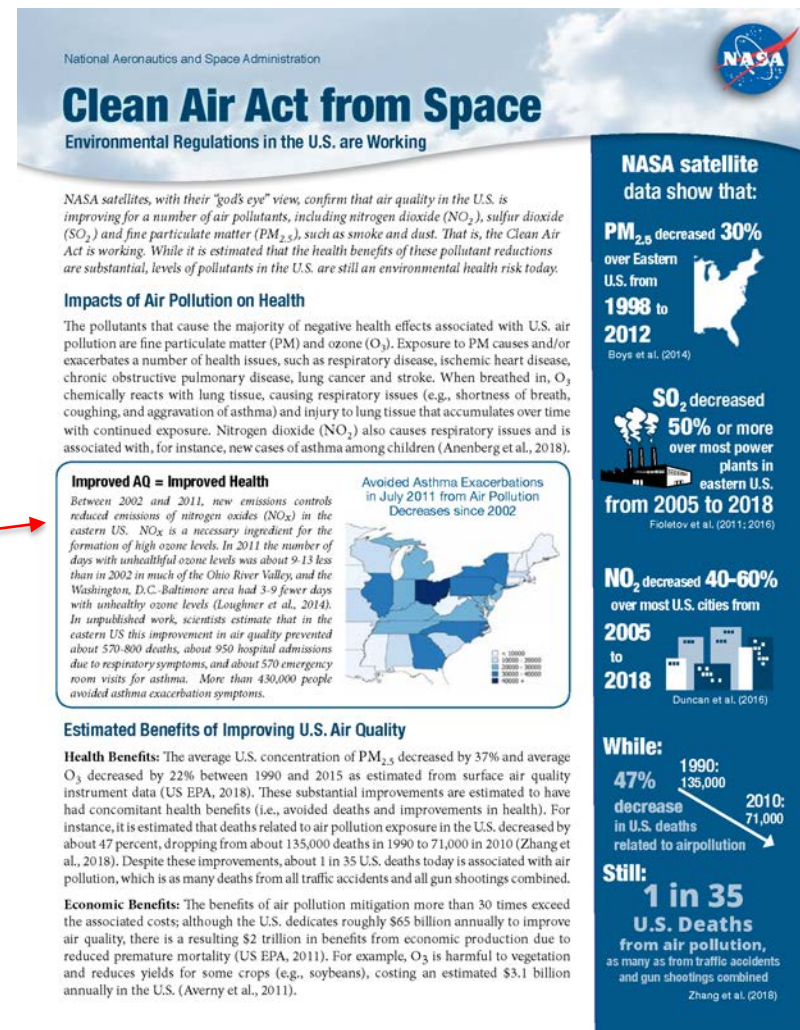
Clean Air Act from Space

Click on the icon to download or view a fact sheet 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

- Images of NO_2 over the U.S. for 2005 and 2018.
- 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

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. Nitrogen dioxide (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 (NO_x) in the eastern U.S. 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 U.S. 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 $PM_{2.5}$ decreased by 37% and average 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, 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:

- $PM_{2.5}$ decreased 30% over Eastern U.S. from 1998 to 2012**
Boys et al. (2014)
- SO_2 decreased 50% or more over most power plants in eastern U.S. from 2005 to 2018**
Fioletov et al. (2011; 2016)
- NO_2 decreased 40-60% over most U.S. cities from 2005 to 2018**
Duncan et al. (2016)

While:

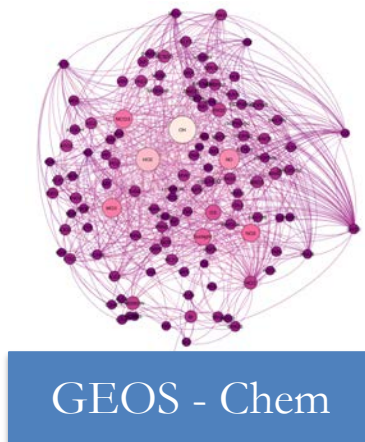
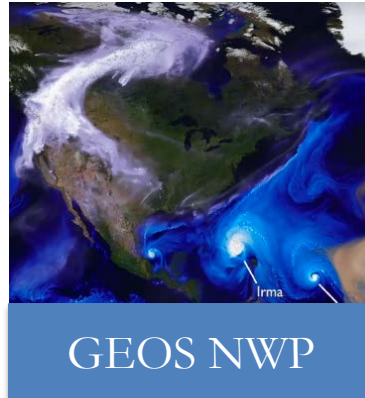
- 47% decrease in U.S. deaths related to air pollution**
1990: 135,000
2010: 71,000
- Still: 1 in 35 U.S. Deaths from air pollution, as many as from traffic accidents and gun shootings combined**
Zhang et al. (2018)

“Managers” tab:

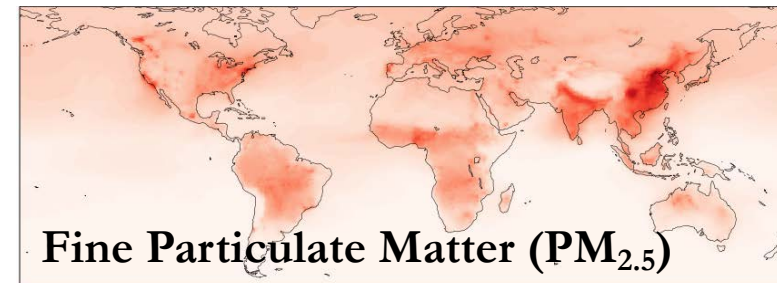
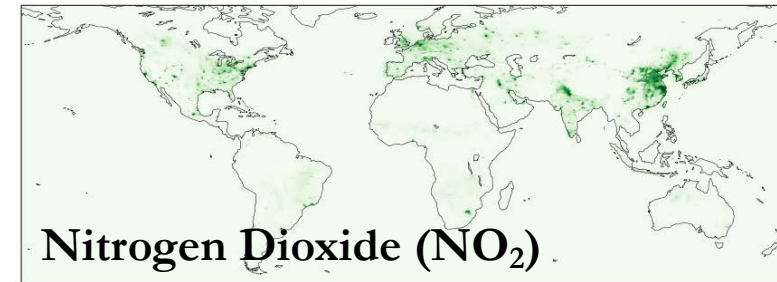
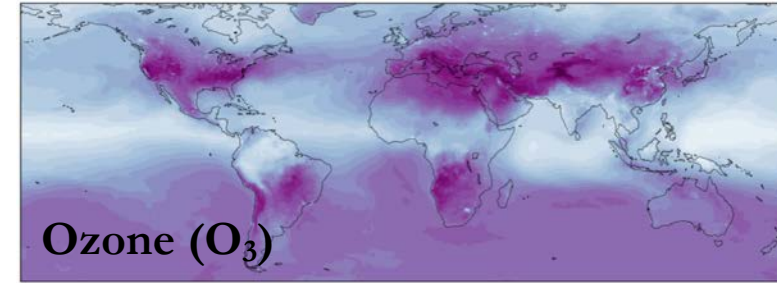
Examples of HAQAST projects, such as on US air quality trends.

Step#3: Global AQ Forecasts*

(https://gmao.gsfc.nasa.gov/weather_prediction/GEOS-CF/)



- ❖ 250 Chemical Species
- ❖ 725 Chemical Reactions



*Product of NASA Global Modeling and Assimilation Office (GMAO)
Christoph A. Keller (Christoph.A.Keller@nasa.gov)
K. Emma Knowland (K.E.Knowland@nasa.gov)

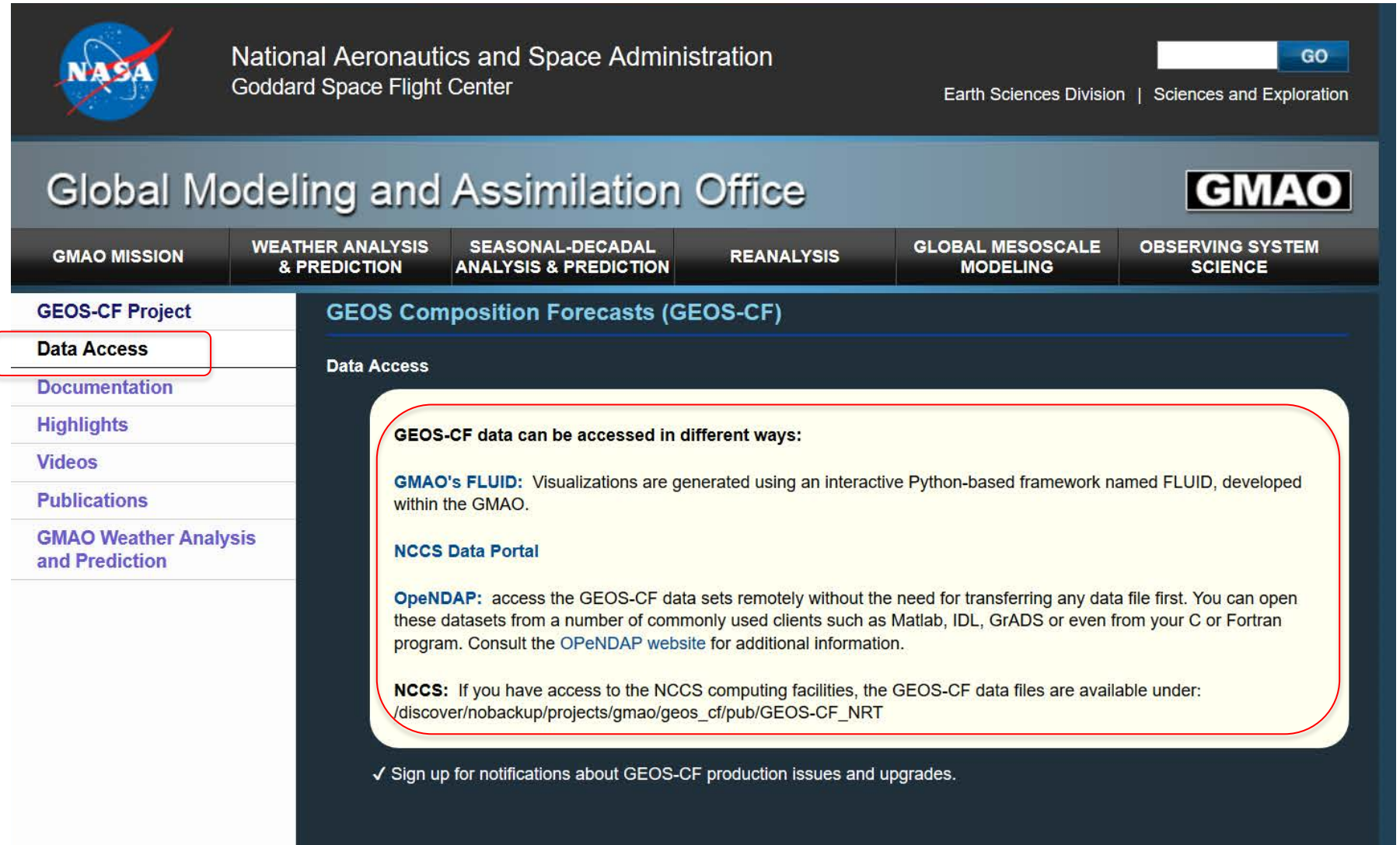
Step#3: Global AQ Forecasts

(https://gmao.gsfc.nasa.gov/weather_prediction/GEOS-CF/)

Download the forecasts and make your own plots.

AND

Use the FLUID visualization tool.



NASA National Aeronautics and Space Administration
Goddard Space Flight Center

Earth Sciences Division | Sciences and Exploration

Global Modeling and Assimilation Office

GMAO

- GMAO MISSION
- WEATHER ANALYSIS & PREDICTION
- SEASONAL-DECADAL ANALYSIS & PREDICTION
- REANALYSIS
- GLOBAL MESOSCALE MODELING
- OBSERVING SYSTEM SCIENCE

GEOS-CF Project

- Data Access**
- Documentation
- Highlights
- Videos
- Publications
- GMAO Weather Analysis and Prediction

GEOS Composition Forecasts (GEOS-CF)

Data Access

GEOS-CF data can be accessed in different ways:

GMAO's FLUID: Visualizations are generated using an interactive Python-based framework named FLUID, developed within the GMAO.

NCCS Data Portal

OpenDAP: access the GEOS-CF data sets remotely without the need for transferring any data file first. You can open these datasets from a number of commonly used clients such as Matlab, IDL, GrADS or even from your C or Fortran program. Consult the [OPeNDAP website](#) for additional information.

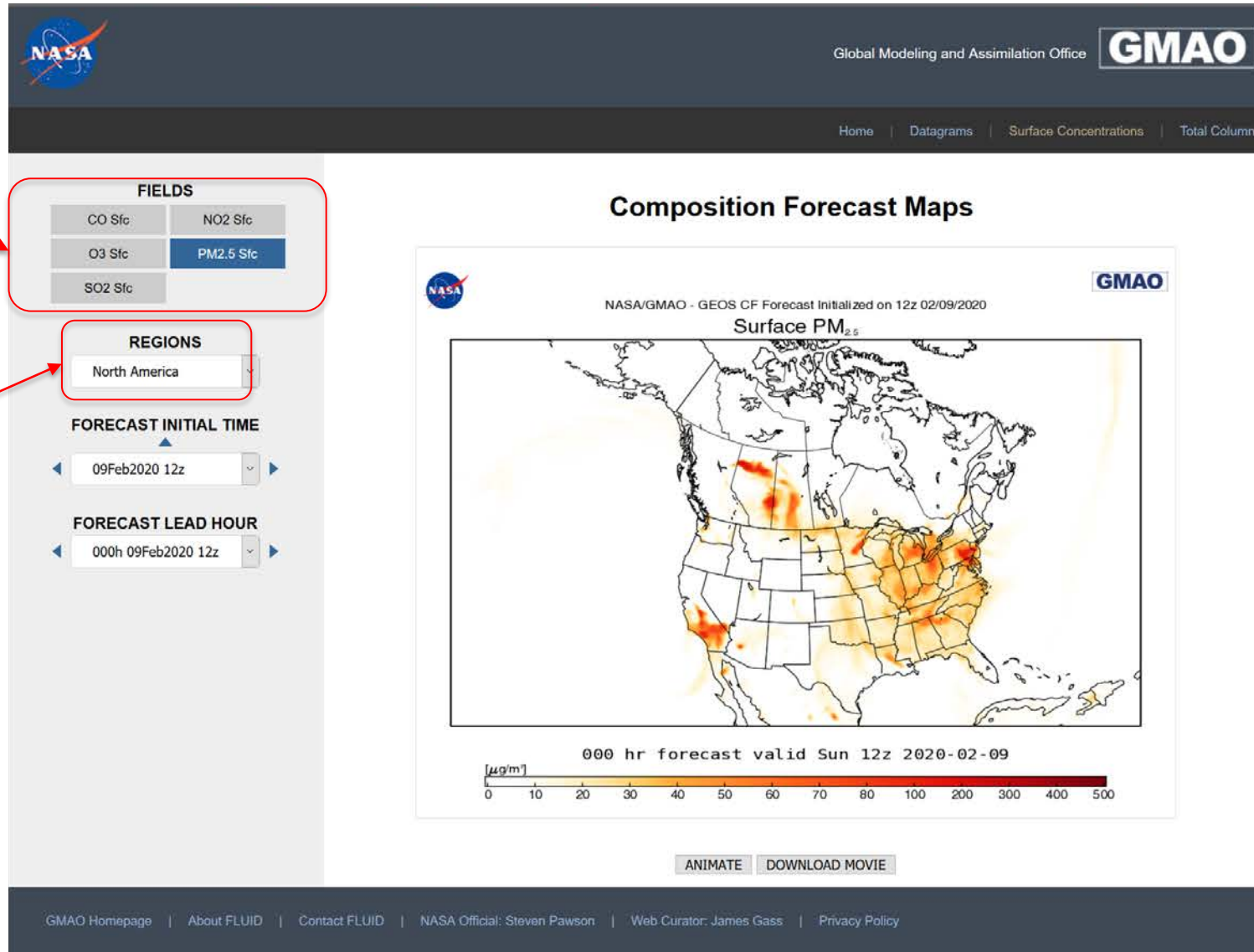
NCCS: If you have access to the NCCS computing facilities, the GEOS-CF data files are available under:
/discover/nobackup/projects/gmao/geos_cf/pub/GEOS-CF_NRT

✓ Sign up for notifications about GEOS-CF production issues and upgrades.

Step#3: AQ Forecasts (<https://fluid.nccs.nasa.gov/cf/>)

Pick a pollutant.

Pick a world region.



Composition Forecast Maps

NASA/GMAO - GEOS CF Forecast Initialized on 12z 02/09/2020

Surface PM_{2.5}

000 hr forecast valid Sun 12z 2020-02-09

[µg/m³]

0 10 20 30 40 50 60 70 80 100 200 300 400 500

ANIMATE DOWNLOAD MOVIE

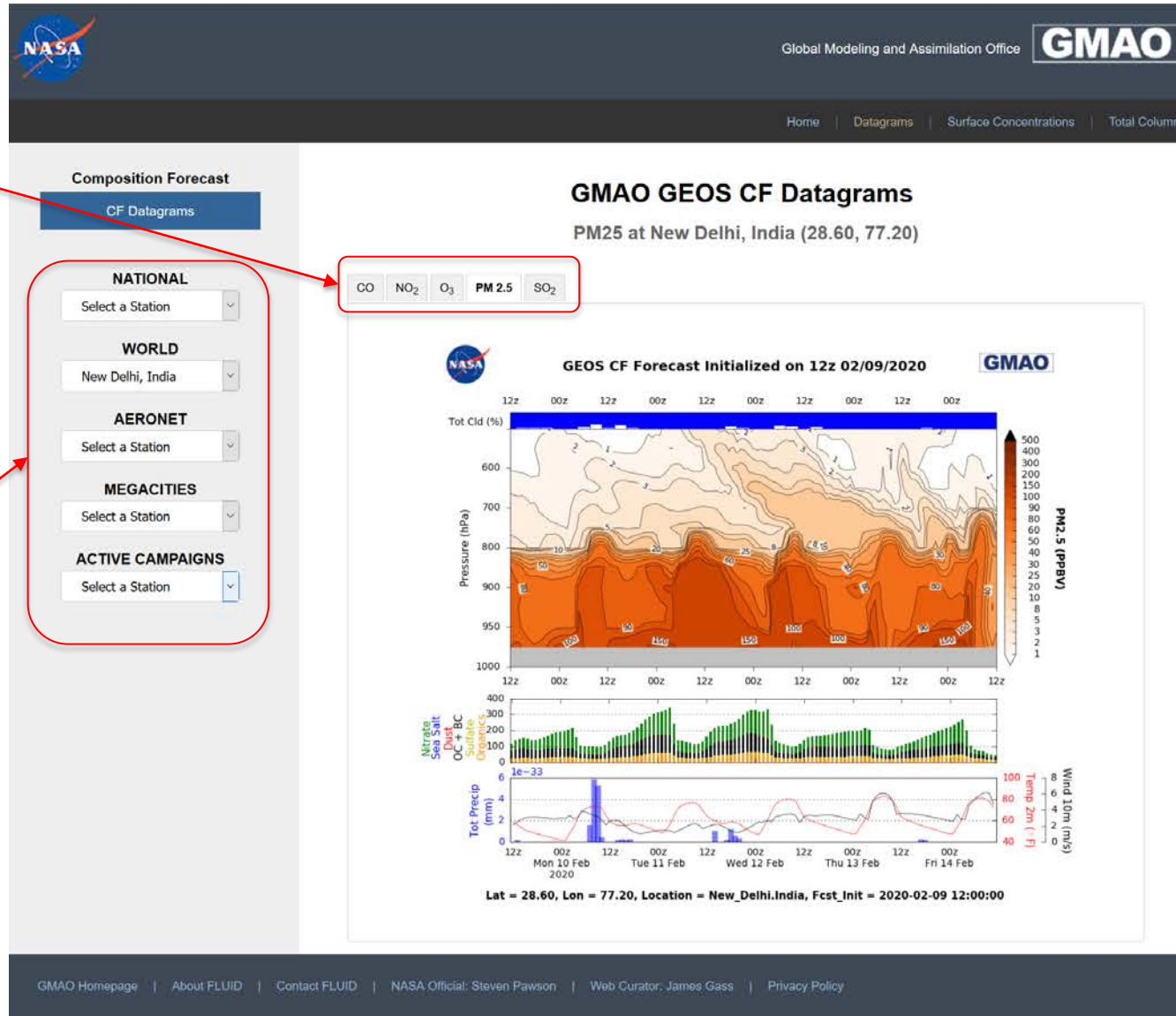
GMAO Homepage | About FLUID | Contact FLUID | NASA Official: Steven Pawson | Web Curator: James Gass | Privacy Policy

Access forecasted concentrations of pollutants using the FLUID visualization tool.

Step#3: AQ Forecasts (<https://fluid.nccs.nasa.gov/cf/>)

Pick a pollutant.

Pick a world city, surface monitor station, etc.

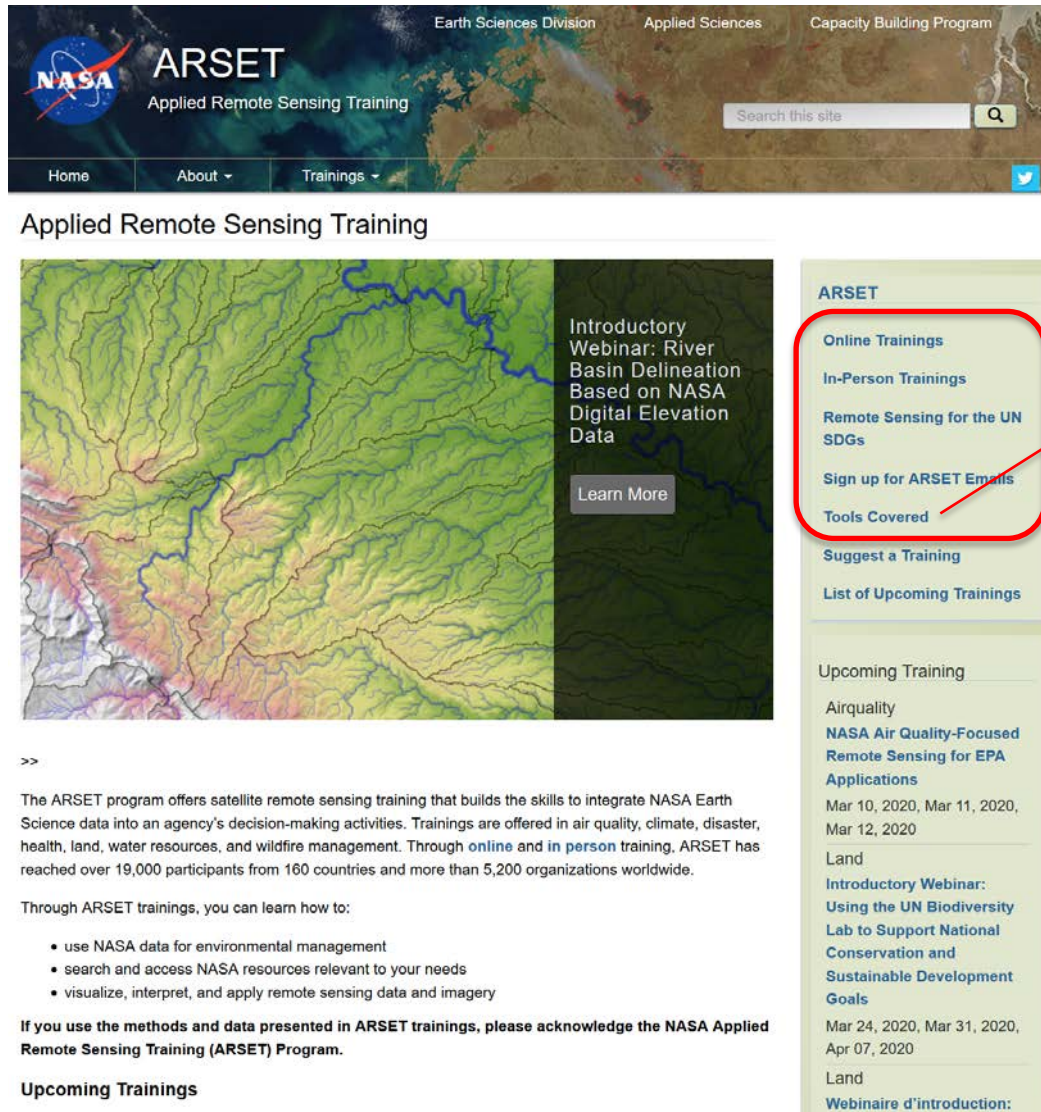


Access pre-made images of forecasts for selected world cities.

FLUID is currently undergoing further development to make available many other pollutants.

Step#4: ARSET (<https://arset.gsfc.nasa.gov/>)

ARSET has many useful online trainings, tutorials, and other resources



Applied Remote Sensing Training

Introductory Webinar: River Basin Delineation Based on NASA Digital Elevation Data

[Learn More](#)

ARSET

- [Online Trainings](#)
- [In-Person Trainings](#)
- [Remote Sensing for the UN SDGs](#)
- [Sign up for ARSET Emails](#)
- [Tools Covered](#)
- [Suggest a Training](#)
- [List of Upcoming Trainings](#)

Upcoming Training

Airquality
NASA Air Quality-Focused Remote Sensing for EPA Applications
Mar 10, 2020, Mar 11, 2020, Mar 12, 2020

Land
Introductory Webinar: Using the UN Biodiversity Lab to Support National Conservation and Sustainable Development Goals
Mar 24, 2020, Mar 31, 2020, Apr 07, 2020

Land
Webinaire d'introduction:

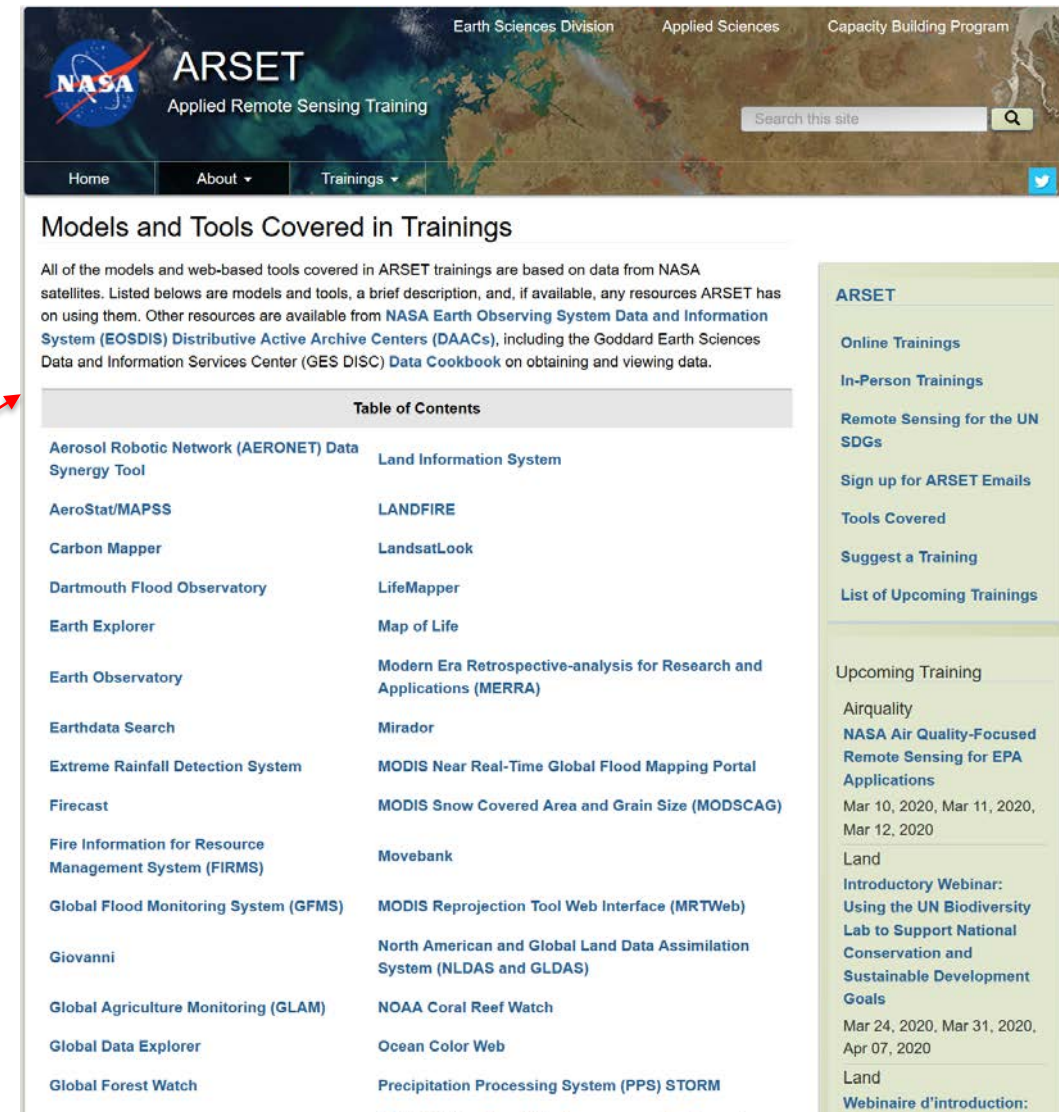
The ARSET program offers satellite remote sensing training that builds the skills to integrate NASA Earth Science data into an agency's decision-making activities. Trainings are offered in air quality, climate, disaster, health, land, water resources, and wildfire management. Through [online](#) and [in person](#) training, ARSET has reached over 19,000 participants from 160 countries and more than 5,200 organizations worldwide.

Through ARSET trainings, you can learn how to:

- use NASA data for environmental management
- search and access NASA resources relevant to your needs
- visualize, interpret, and apply remote sensing data and imagery

If you use the methods and data presented in ARSET trainings, please acknowledge the NASA Applied Remote Sensing Training (ARSET) Program.

Upcoming Trainings



Models and Tools Covered in Trainings

All of the models and web-based tools covered in ARSET trainings are based on data from NASA satellites. Listed below are models and tools, a brief description, and, if available, any resources ARSET has on using them. Other resources are available from NASA Earth Observing System Data and Information System (EOSDIS) Distributive Active Archive Centers (DAACs), including the Goddard Earth Sciences Data and Information Services Center (GES DISC) Data Cookbook on obtaining and viewing data.

Table of Contents

Aerosol Robotic Network (AERONET) Data Synergy Tool	Land Information System
AeroStat/MAPSS	LANDFIRE
Carbon Mapper	LandsatLook
Dartmouth Flood Observatory	LifeMapper
Earth Explorer	Map of Life
Earth Observatory	Modern Era Retrospective-analysis for Research and Applications (MERRA)
Earthdata Search	Mirador
Extreme Rainfall Detection System	MODIS Near Real-Time Global Flood Mapping Portal
Firecast	MODIS Snow Covered Area and Grain Size (MODSCAG)
Fire Information for Resource Management System (FIRMS)	Movebank
Global Flood Monitoring System (GFMS)	MODIS Reprojection Tool Web Interface (MRTWeb)
Giovanni	North American and Global Land Data Assimilation System (NLDAS and GLDAS)
Global Agriculture Monitoring (GLAM)	NOAA Coral Reef Watch
Global Data Explorer	Ocean Color Web
Global Forest Watch	Precipitation Processing System (PPS) STORM

ARSET

- [Online Trainings](#)
- [In-Person Trainings](#)
- [Remote Sensing for the UN SDGs](#)
- [Sign up for ARSET Emails](#)
- [Tools Covered](#)
- [Suggest a Training](#)
- [List of Upcoming Trainings](#)

Upcoming Training

Airquality
NASA Air Quality-Focused Remote Sensing for EPA Applications
Mar 10, 2020, Mar 11, 2020, Mar 12, 2020

Land
Introductory Webinar: Using the UN Biodiversity Lab to Support National Conservation and Sustainable Development Goals
Mar 24, 2020, Mar 31, 2020, Apr 07, 2020

Land
Webinaire d'introduction:



Step#5: HAQAST (<https://haqast.org/>)

Work directly with scientists to use NASA satellite data and AQ models on your health and AQ applications.

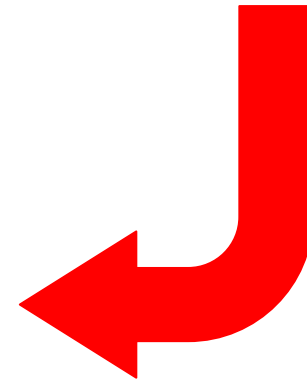




Questions?

Use the question function at the lower right of your screen

A screenshot of a web interface for asking questions. At the top, there is a tab labeled 'Q&A' with a dropdown arrow and a close button 'x'. Below the tab, it says 'All(0)'. The main area is empty. At the bottom, there is a text input field containing the text 'Hi--I have a question!'. Below the input field are two buttons: 'Send' and 'Send Privately'.



Be sure to check out our upcoming webinars. For all info, visit haqast.org/haqast2020

HAQAST2020

WEBINAR SERIES