



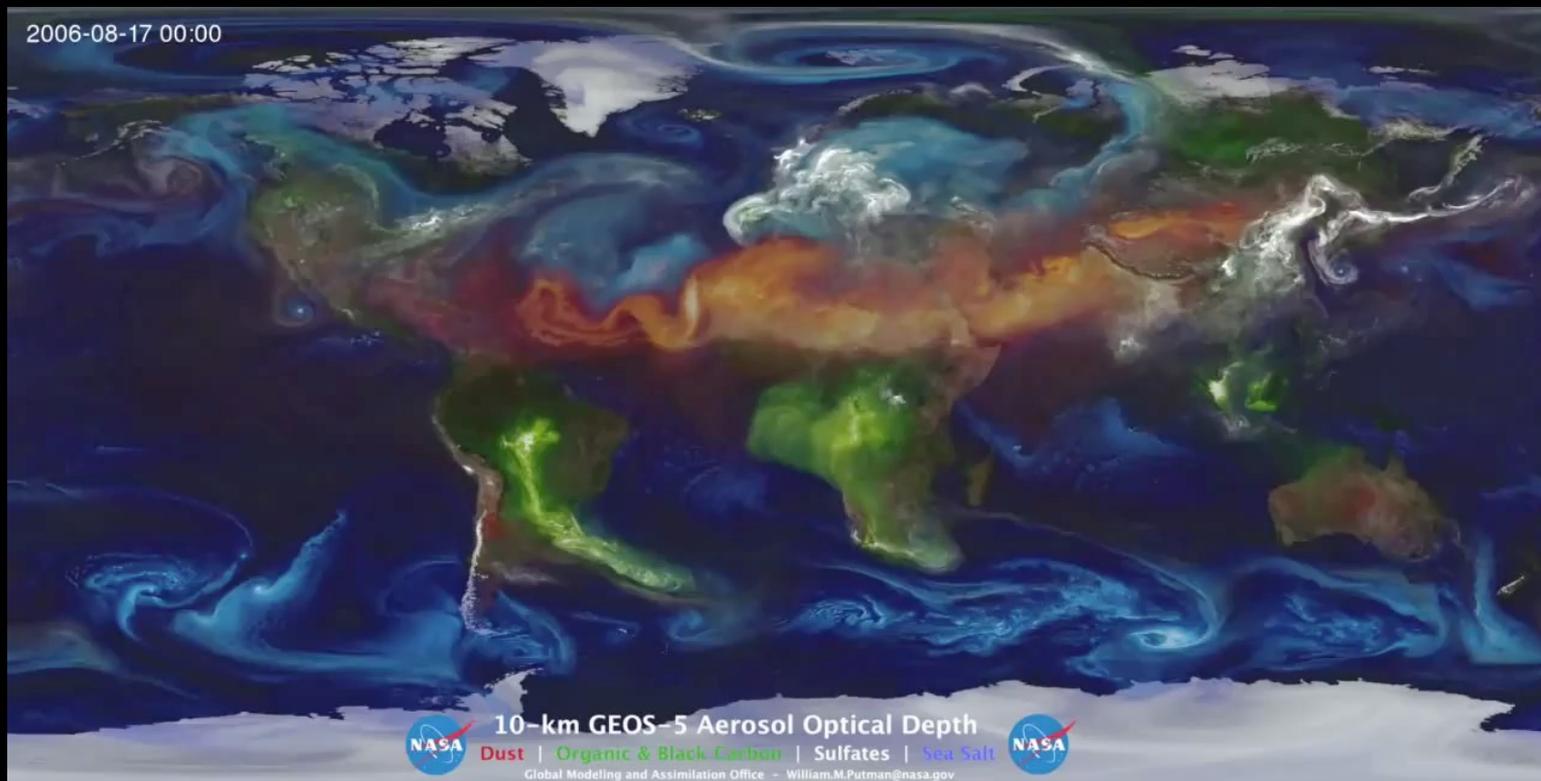
Jet Propulsion Laboratory
California Institute of Technology

A New Angle on Air Pollution: NASA's Multi-Angle Imager for Aerosols (MAIA)

Abigail Nastan, Dave Diner and the MAIA Team

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Government sponsorship acknowledged.

What are aerosols?



DUST

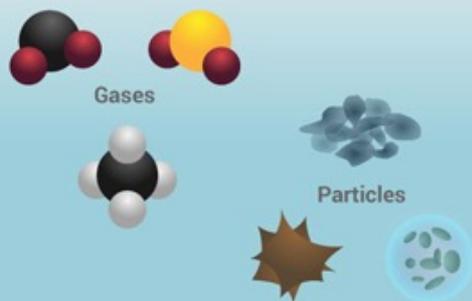
ORGANIC & BLACK CARBON

SULFATES

SEA SALT

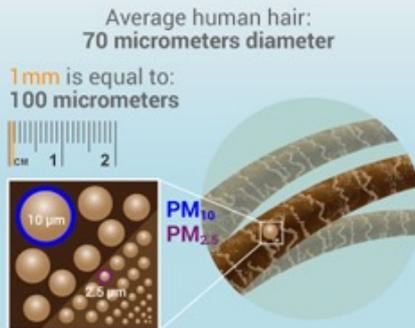
What is air pollution made of?

Gases vs particles



Gases vs. particles: Air pollution is anything in the atmosphere that is dangerous to people, animals, plants, or the environment as a whole. There are two major things that can pollute the air. The first is gases like ozone or sulfur dioxide. The second type of pollution is particulates - microscopic bits of solid or liquid particles that are light enough to become suspended in the atmosphere. The MAIA investigation focuses on particulate air pollution.

Size of particulates



Size of particulates: Particulate matter or PM is often grouped by the size of the individual particles. This is important because size determines how easily the particles interact with our bodies when they enter our lungs. PM is so small that it is usually measured in micrometers - one millionth of a meter. The two major size classes of PM are PM₁₀, particles under 10 micrometers in diameter, and PM_{2.5}, particles smaller than 2.5 micrometers in diameter.

Types of PM

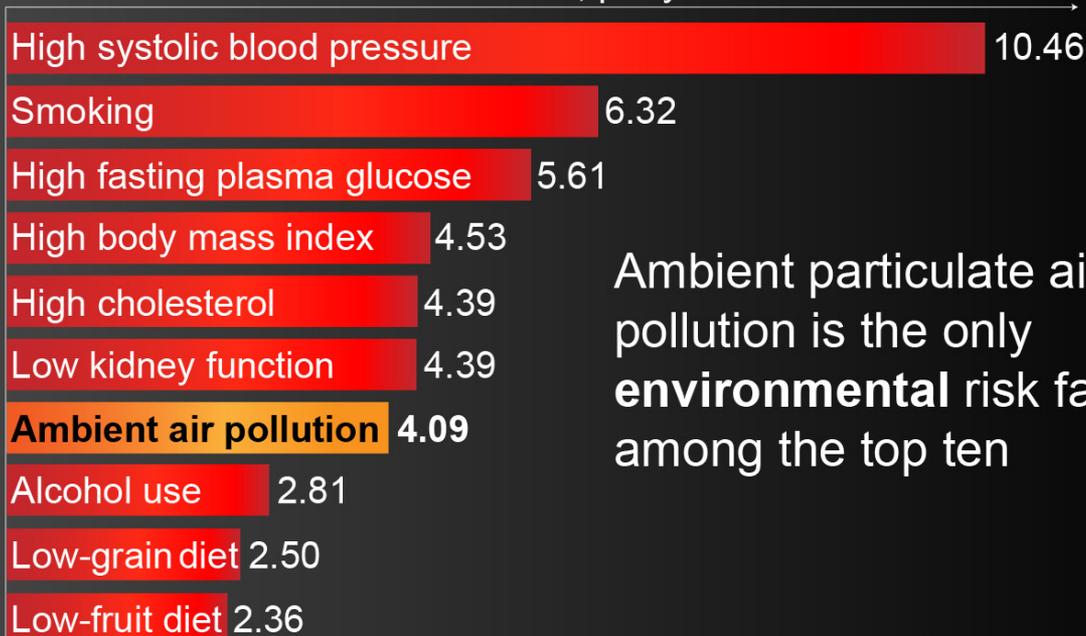


Types of PM: PM types include black carbon, mineral dust, and tiny liquid droplets containing sulfates, nitrates, and organic carbon. Black carbon, which makes up soot, is left over after something burns. Dust is made of tiny bits of soil. Most sulfate and nitrate aerosols come from chemical reactions between gas molecules. Organic carbon aerosols can also form this way, or they can be directly emitted into the air.

90% of the world's population lives in areas exceeding the World Health Organization's air quality guidelines

Top 10 risk factors for premature death, 2016

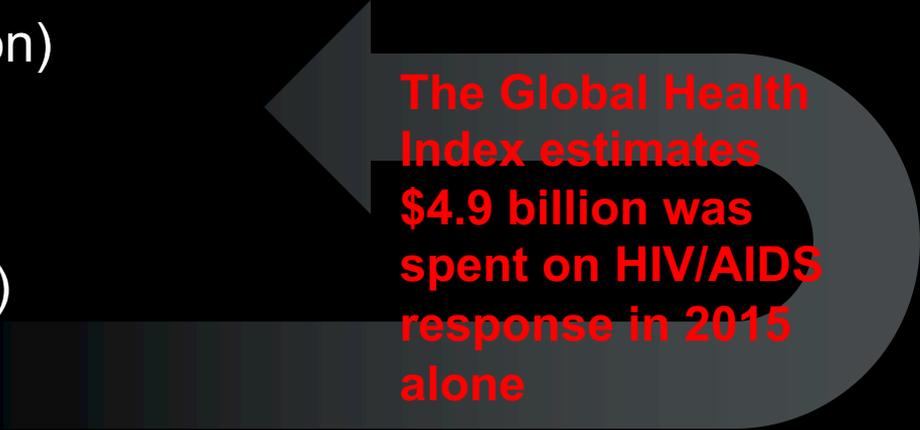
Deaths in millions, per year



Ambient particulate air pollution is the only **environmental** risk factor among the top ten

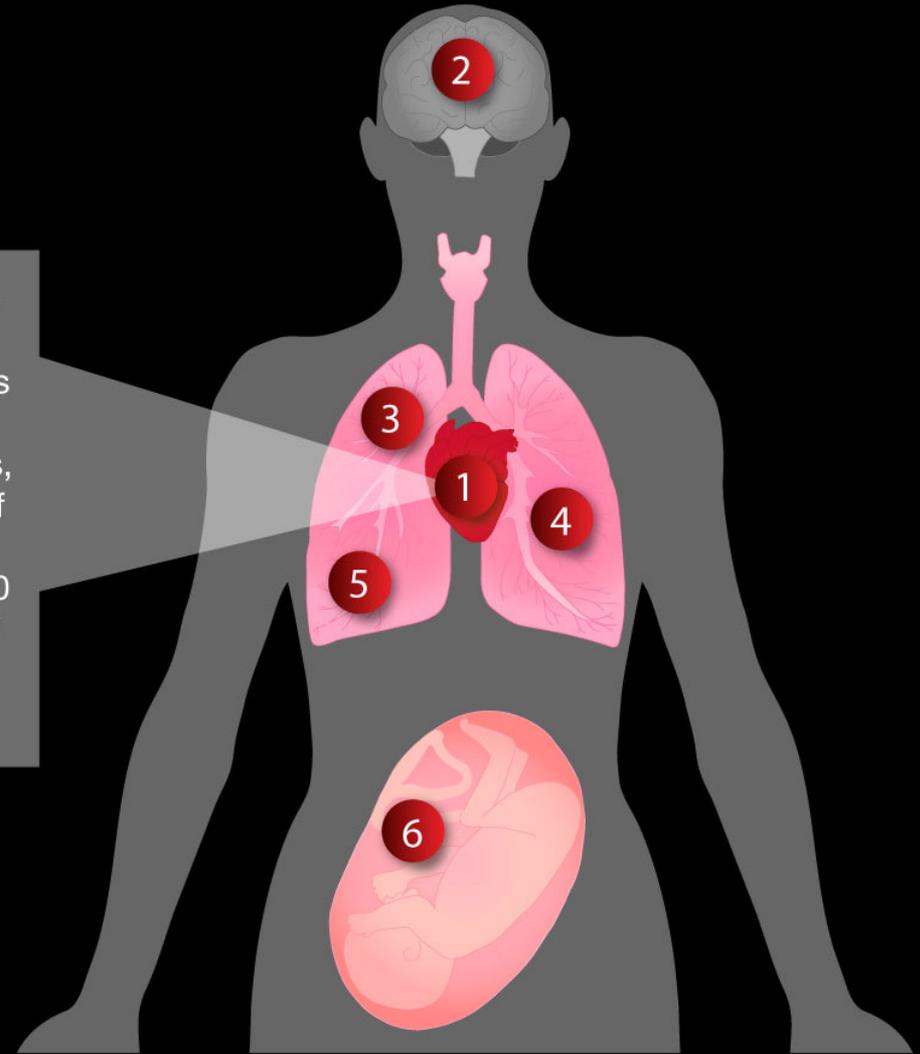
Deaths by various causes

1. All heart disease deaths (17.7 million)
2. All cancer deaths (8.93 million)
3. **Air pollution (4.06 million)**
4. Violent deaths (1.36 million)
5. Road accidents (1.34 million)
6. HIV/AIDS (1.03 million)
7. Drowning (303,000)
8. Fires (132,000)
9. All natural disasters (7,060)
10. Shark attacks (~10)

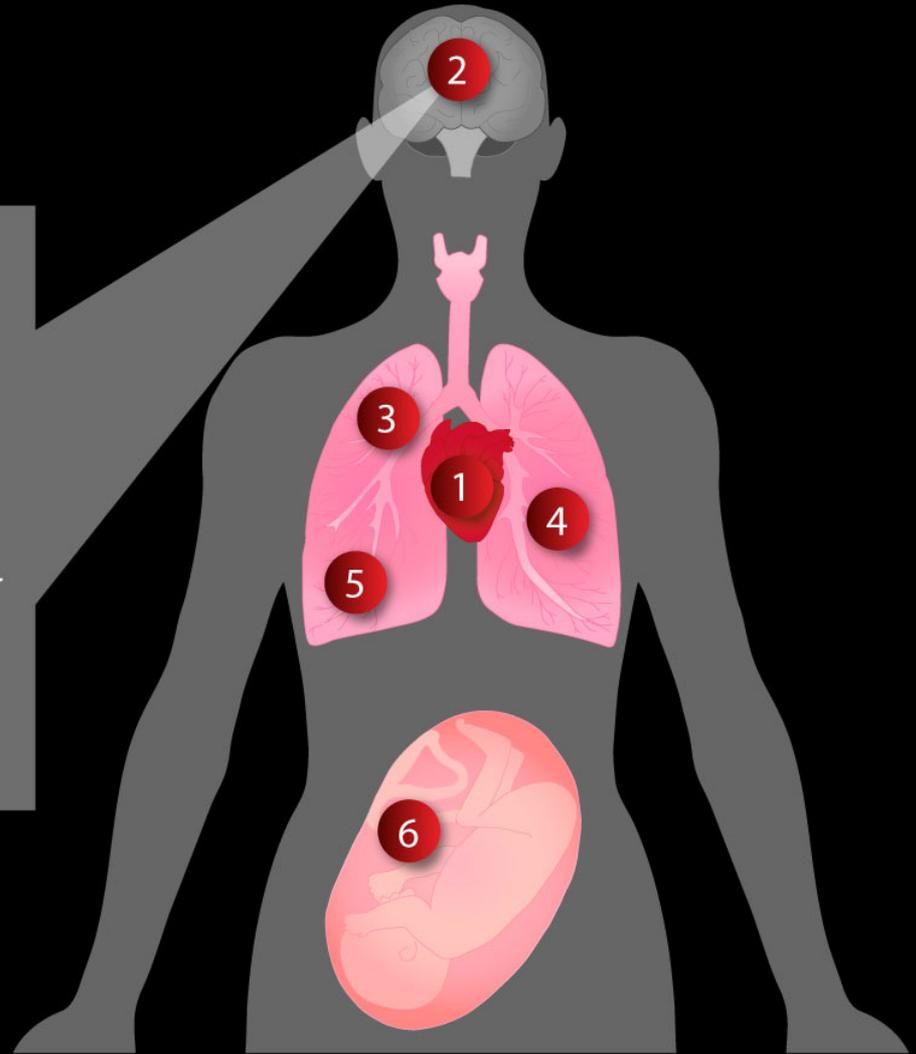


The Global Health Index estimates \$4.9 billion was spent on HIV/AIDS response in 2015 alone

Heart disease: Ischemic or coronary heart disease is a reduction in blood flow to the heart. This usually happens when the coronary arteries – the blood vessels that carry oxygen to the heart muscle itself – become constricted or blocked. This sometimes, but not always, leads to a heart attack and/or cardiac arrest. The risk of developing this type of heart disease is increased by 3-21% (depending on age) by long-term exposure to $10 \mu\text{g}/\text{m}^3$ of $\text{PM}_{2.5}$, according to the 2016 Global Burden of Disease. $10 \mu\text{g}/\text{m}^3$ is the World Health Organization's guideline for annual exposure to $\text{PM}_{2.5}$.

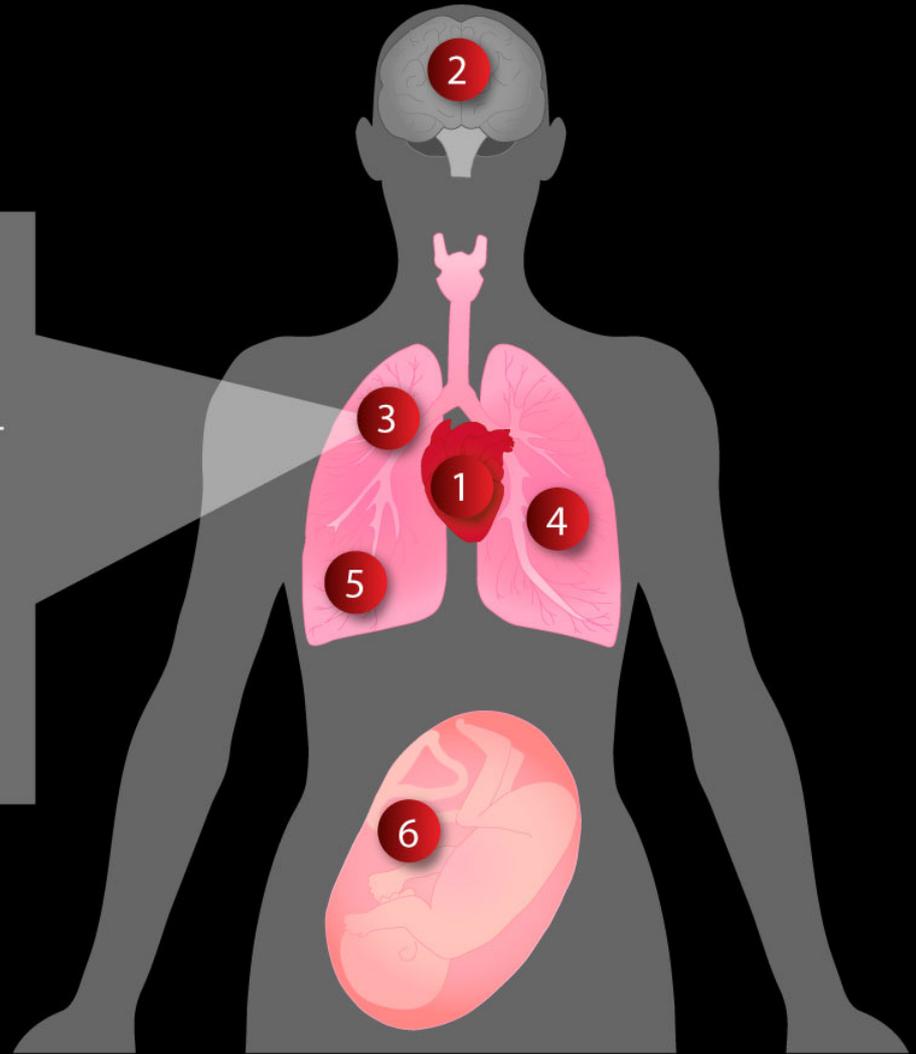


Stroke: A stroke happens when blood flow to the brain is reduced or lost. The lack of oxygen causes part or all of the brain tissue to die if blood flow is not quickly restored. Strokes occur either because a blood vessel in the brain bursts (hemorrhagic stroke) or because blood vessels in the brain become constricted or blocked (ischemic stroke). A person who survives a major stroke can suffer paralysis, pain, memory loss, and other symptoms, and is more likely to have another stroke in the future. The risk of having a stroke increases 3-43% (depending on age) when you are exposed to $10 \mu\text{g}/\text{m}^3$ of $\text{PM}_{2.5}$ over long periods, according to the 2016 Global Burden of Disease.

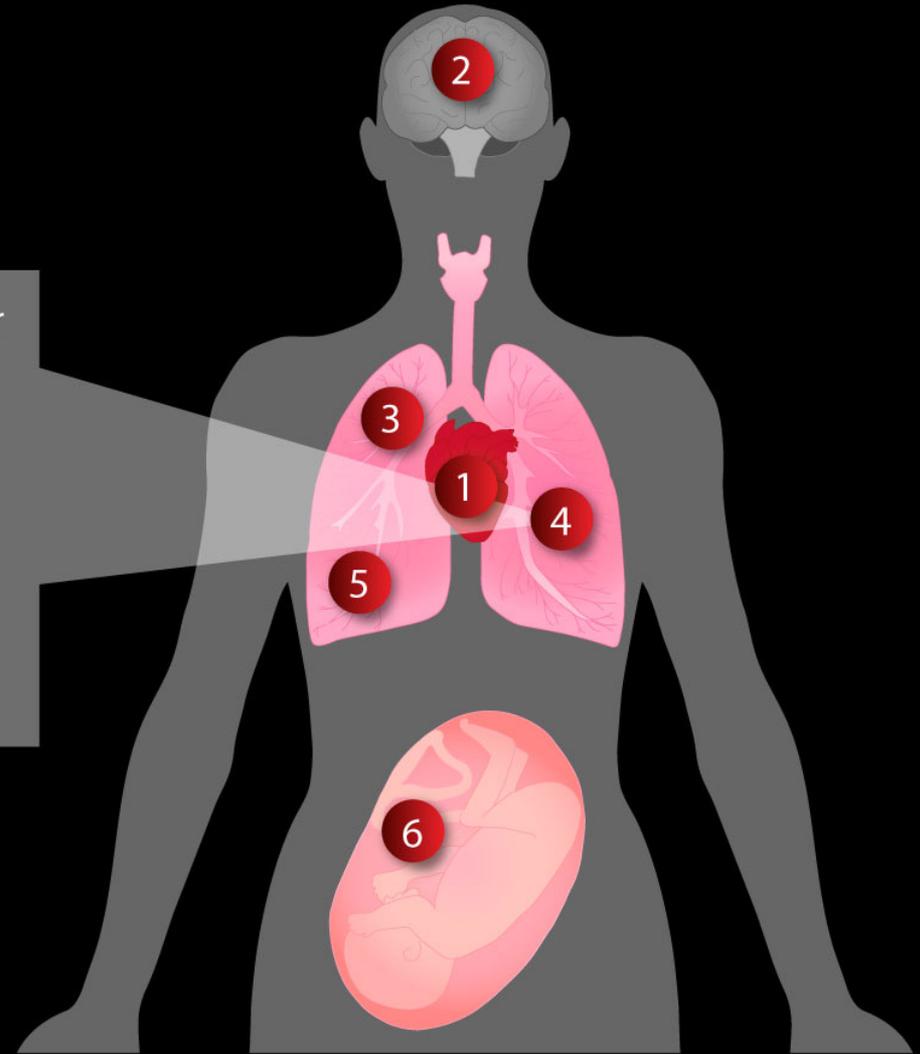


Chronic obstructive pulmonary disease (COPD):

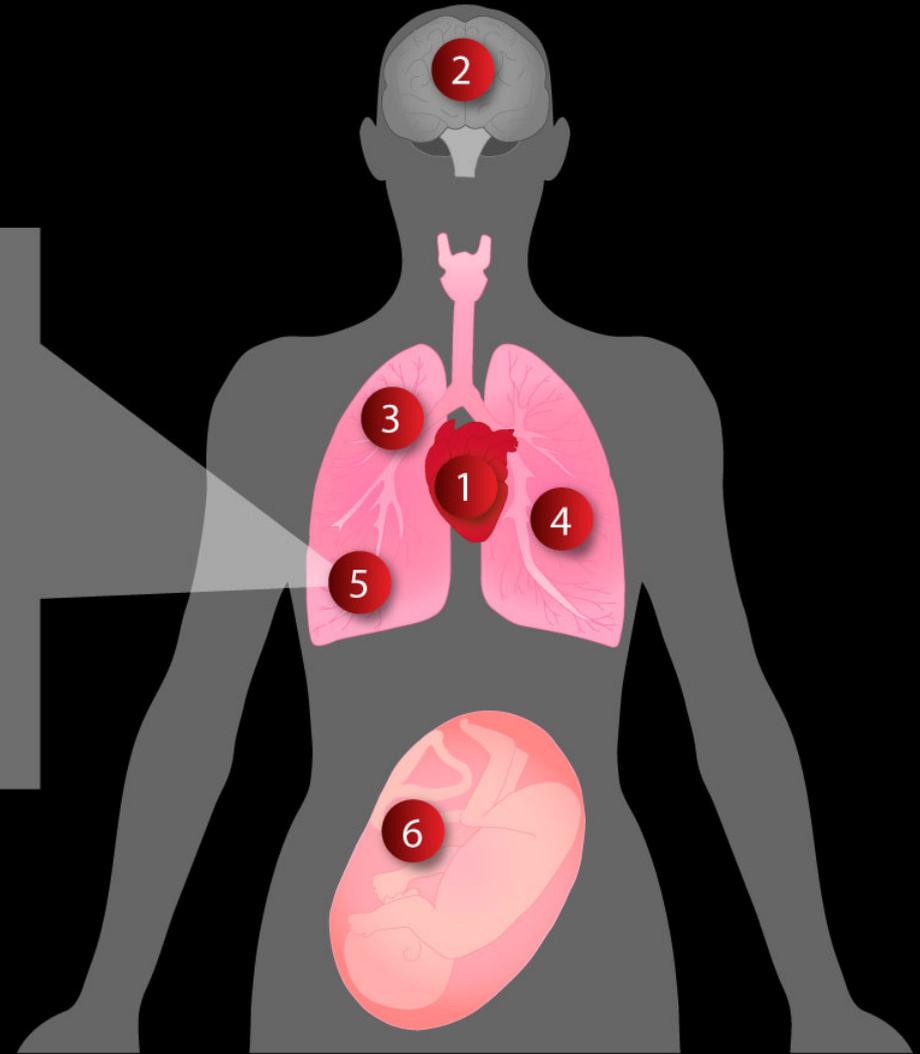
COPD is a disease in which the amount of air going in and out of the lungs is reduced, causing shortness of breath. COPD is a combination of emphysema, where the air sacs within the lungs are damaged, and obstructive bronchiolitis, in which the airways constrict and/or fill with mucus. COPD usually gets worse over time, though treatments exist to slow the progression. Because COPD reduces a person's ability to get enough oxygen, it increases the risk of developing heart disease. The Global Burden of Disease estimates that exposure to $10 \mu\text{g}/\text{m}^3$ of $\text{PM}_{2.5}$ increases the risk of developing COPD by 8.1%.



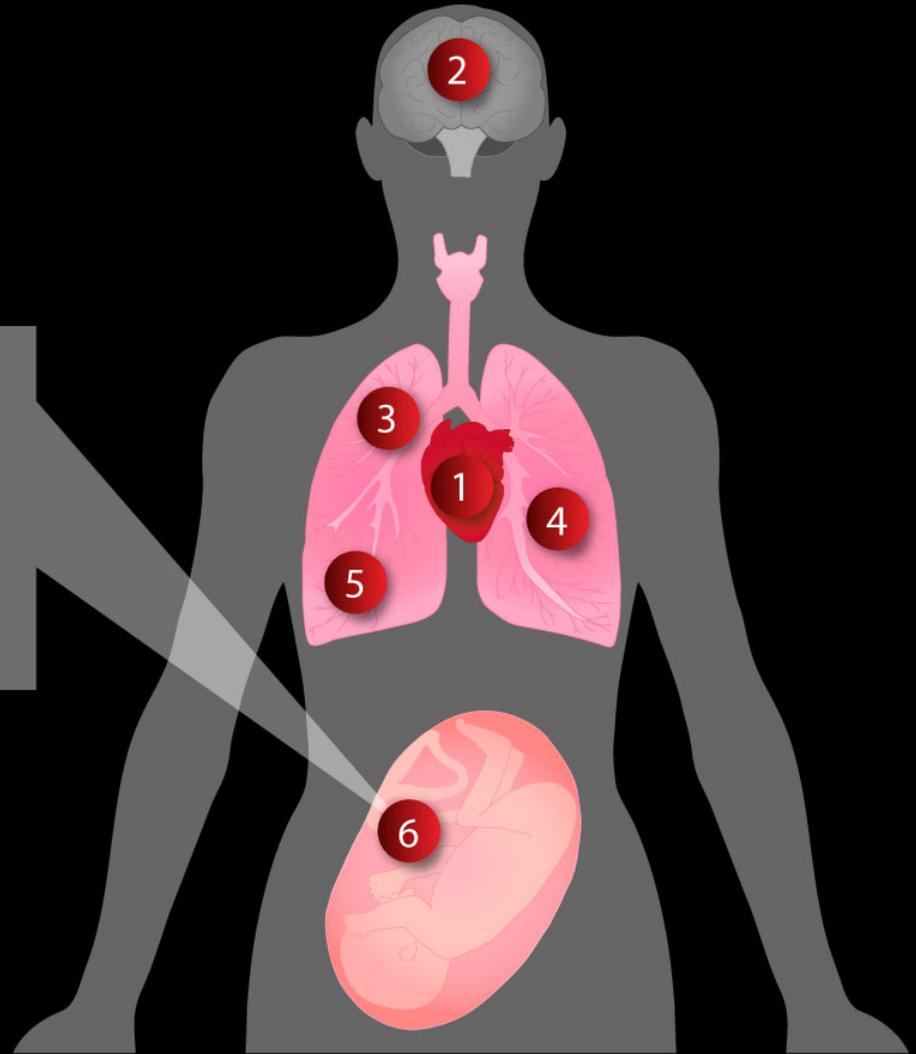
Lung cancer: While smoking is the major risk factor for lung cancer, air pollution has also been demonstrated to increase risk. Lung cancer is one of the most common and deadliest cancers, in part because it usually does not cause symptoms until it is at an advanced stage. In the United States, the overall five-year survival rate of lung cancer is 17%. The 2016 Global Burden of Disease estimates that the risk of developing lung cancer increases by 3.4% when a person is exposed to $10 \mu\text{g}/\text{m}^3$ of $\text{PM}_{2.5}$.



Lower respiratory infections: This is a viral, bacterial, or fungal infection of the windpipe or lungs. Lower respiratory infections include pneumonia (which is an infection of the air sacs within the lungs), certain types of flu, as well as bronchitis and bronchiolitis, which are infections of the bronchia and bronchioles in the lungs. These infections can be very dangerous to young children, the elderly, and those with respiratory and immune conditions. Exposure to $10 \mu\text{g}/\text{m}^3$ of $\text{PM}_{2.5}$ has been shown to increase risk of developing a lower respiratory infection by 6.3%, according to the 2016 Global Burden of Disease.



Adverse birth outcomes: Exposure to PM pollution during pregnancy has been shown to increase the likelihood of complications, known as adverse birth outcomes. Specifically, PM exposure increases the risk of pre-term delivery, low birth weight, and intrauterine growth retardation, where the fetus's weight is below the tenth percentile for gestational age.



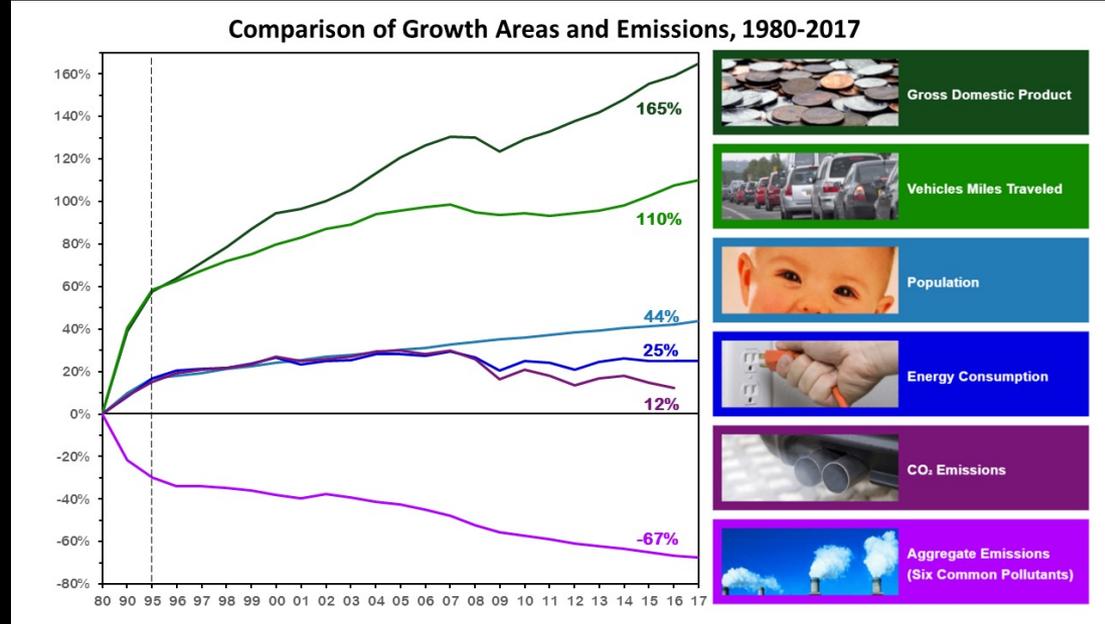
2019 State of the Air (American Lung Association)



Radcliffe Dacanay, LA smog, CC BY 2.0

1. **Fresno-Madera-Hanford**
2. **Bakersfield**
3. Fairbanks (AK)
4. **Visalia**
5. **Los Angeles-Long Beach**
6. **San Jose-San Francisco-Oakland**
7. Pittsburgh (PA)
8. **El Centro**
9. Cleveland (OH)
10. Medford (OR)

How do we improve?



2019 Air Quality National Summary, EPA

What sources of air pollution are most dangerous?

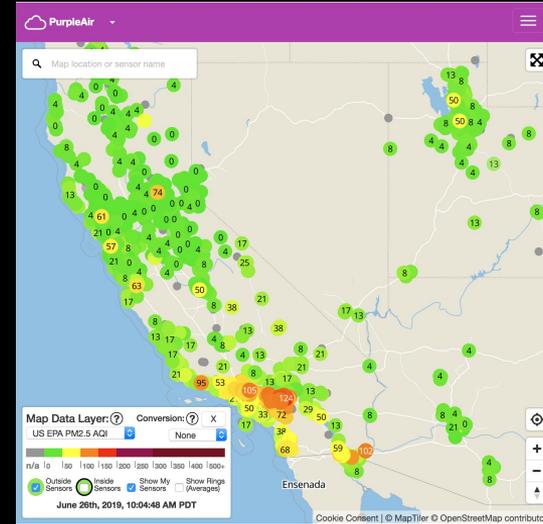


Regulatory monitors



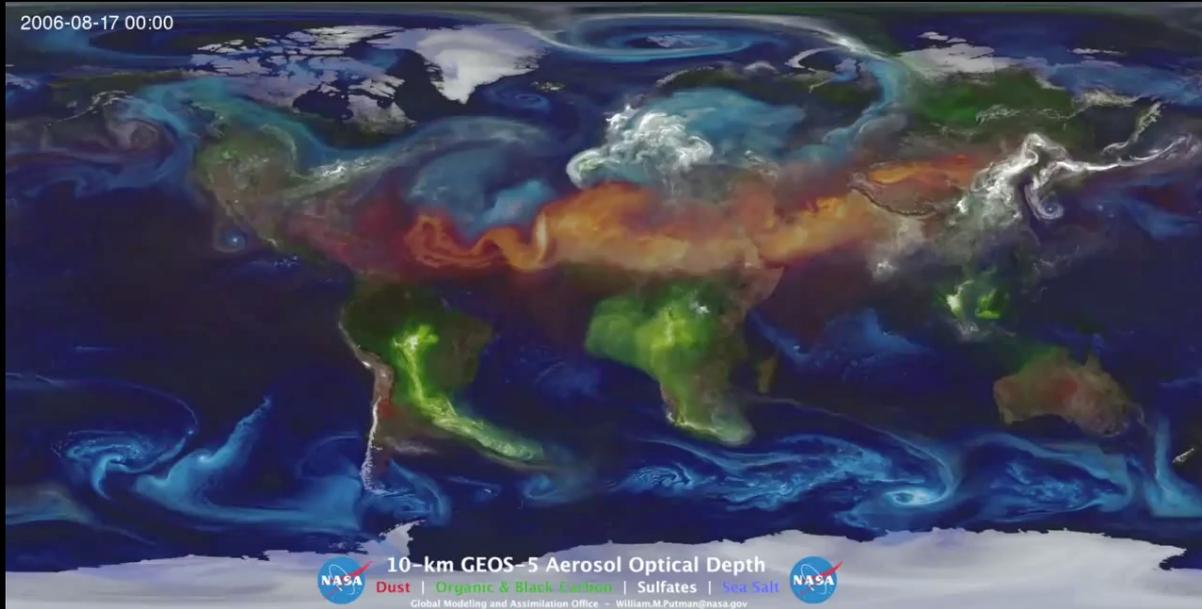
- +Reliable
- +Well-regulated;
data is curated
- Expensive
- Too scarce to
capture all spatial
changes

Low-cost sensors



- +Affordable
- +Can deploy
many to capture
spatial changes
- Not reliable
- Data is low
quality
- Can't tell us
about different
types

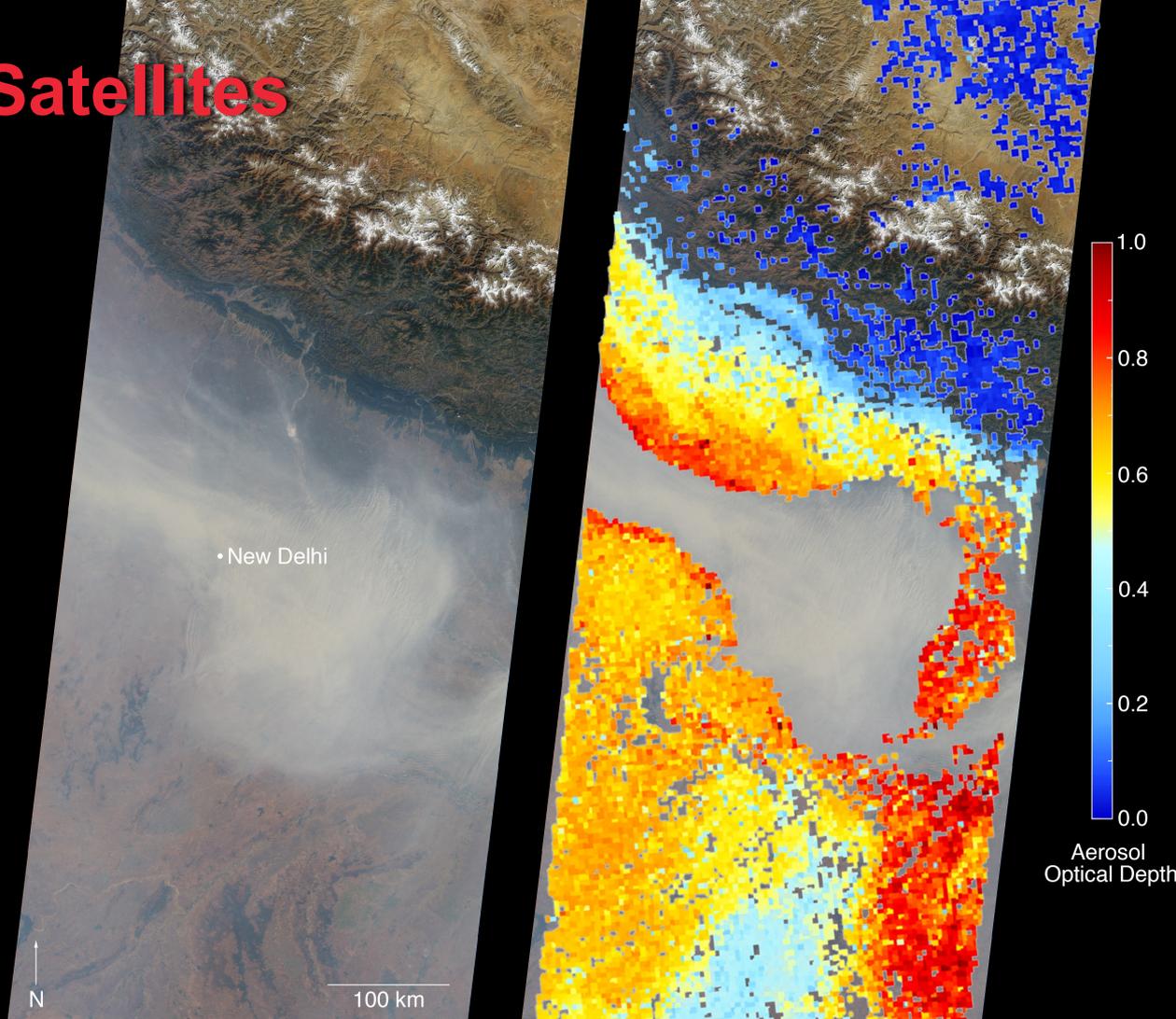
Chemical transport models



- +Cover entire area
- +Relatively affordable
- +Tells us about aerosol types

- Very sensitive to errors in emissions database
- Not based on observations

Satellites



- +Better coverage
- +Relatively affordable
- +Can tell us about aerosol types

- Can't be used when cloudy
- Must remove effects due to Earth's surface and upper atmosphere

Terra (NASA)

PARASOL (CNES)

Aura (NASA)



MODIS (US)

POLDER (France)

OMI (Netherlands)

MISR (US)

1995

2000

2005

2010

2015

2020

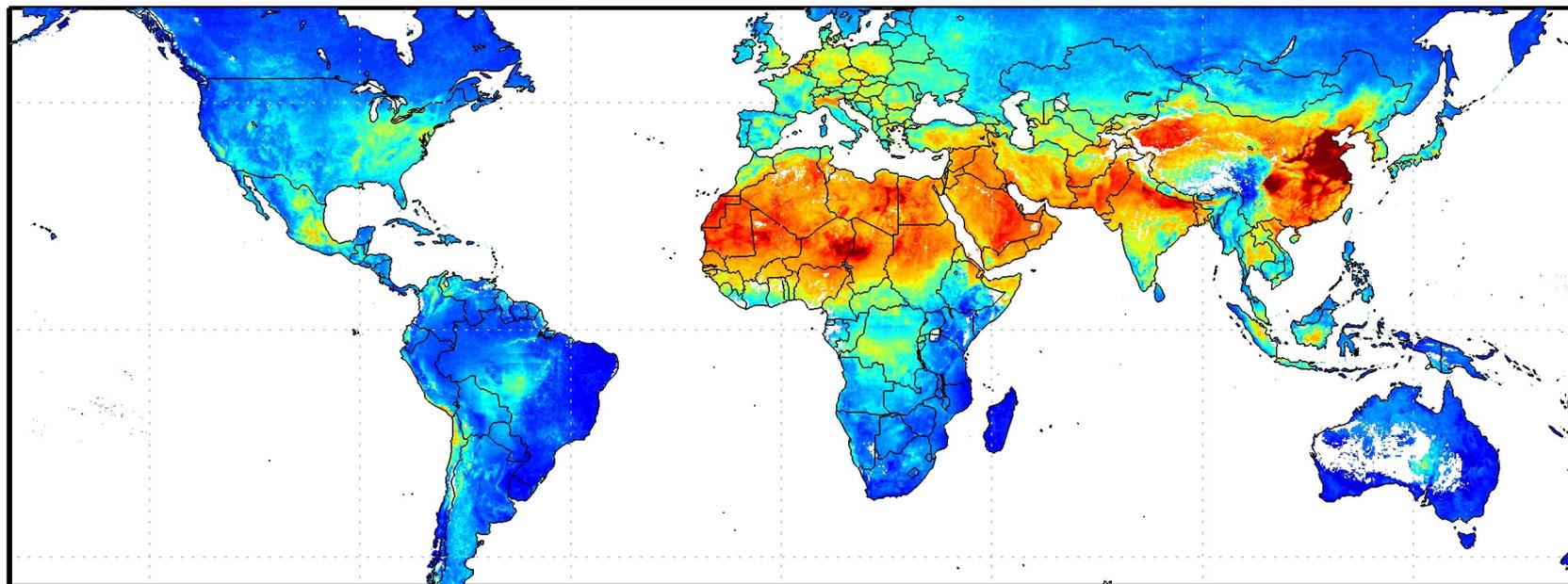
2025

Terra

PARASOL

Aura

Satellite AOD + surface monitors + chemical transport model:

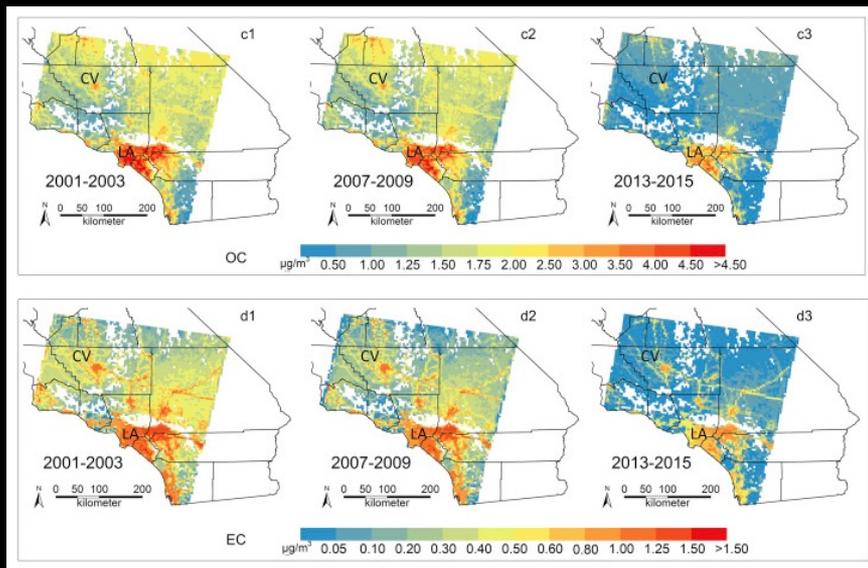


Satellite-Derived PM_{2.5} [$\mu\text{g}/\text{m}^3$]

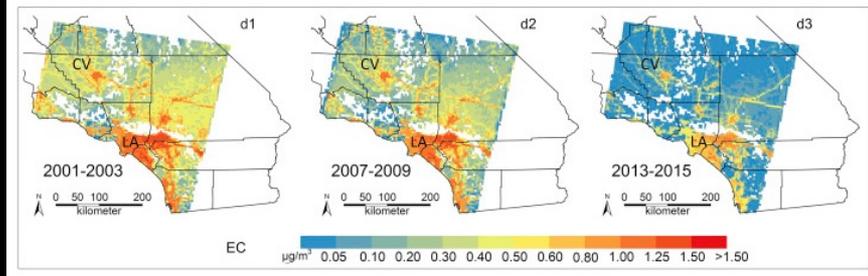
van Donkelaar et al. (2010, 2015)

MISR fractional AOD + surface monitors + chemical transport model:

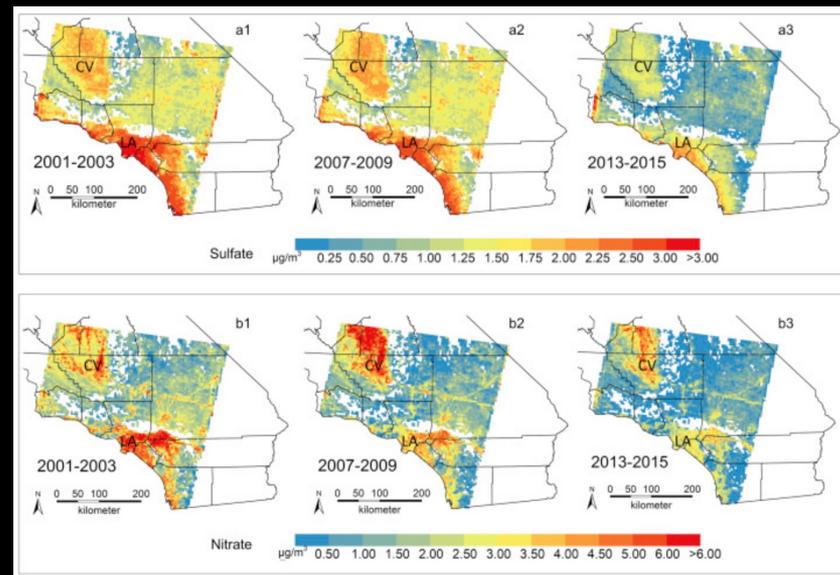
Organic Carbon



Elemental Carbon

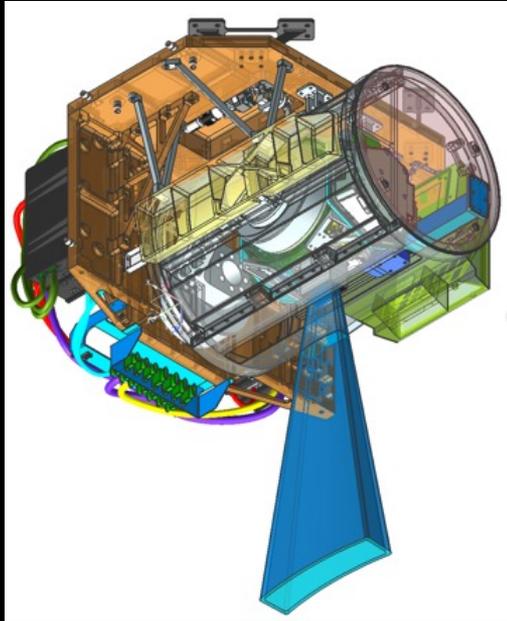


Sulfates

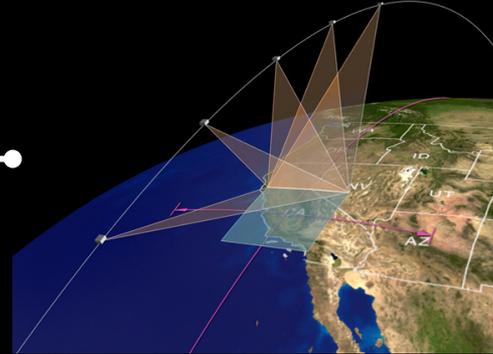


Nitrates

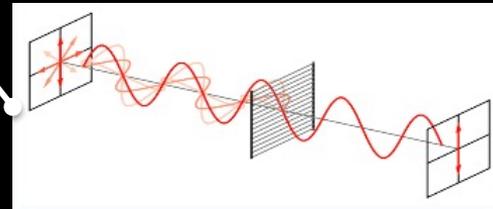
Multi-Angle Imager for Aerosols (MAIA)



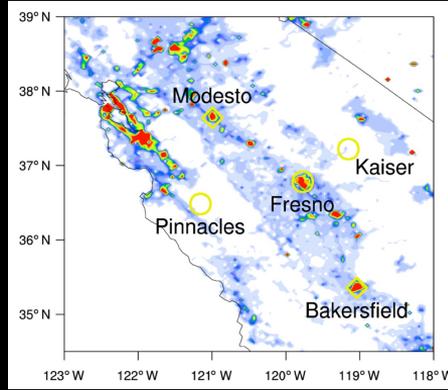
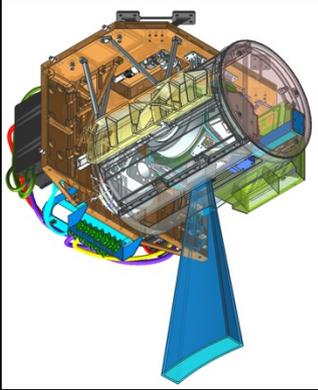
Multispectral

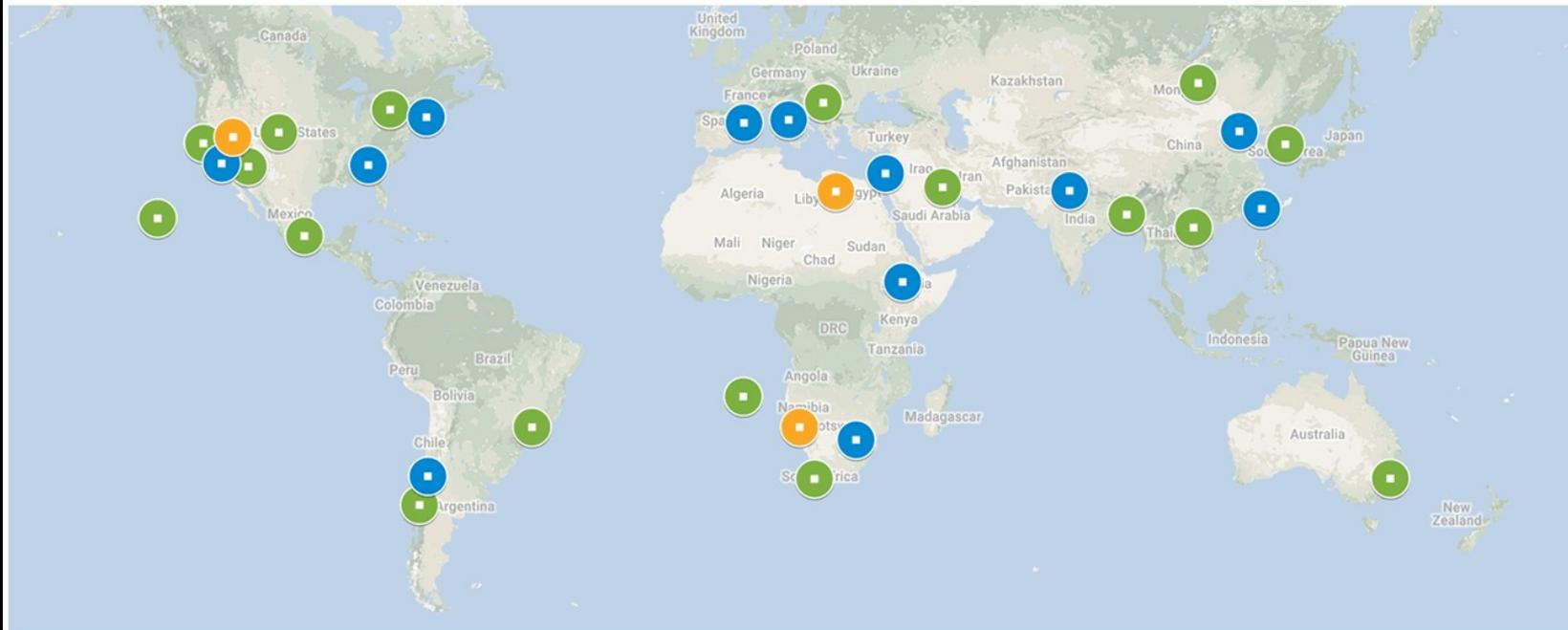


Multiangular



Polarimetric





Primary Target Areas

- USA_LosAngeles
- USA_Atlanta
- USA_Boston
- CHL_Santiago
- ESP_Barcelona
- ITA_Rome
- ZAF_Johannesburg
- ISR_TelAviv
- ETH_AddisAbaba
- IND_Delhi
- CHN_Beijing
- TWN_Taipei

Secondary Target Areas

- PAC_OceanStCu
- USA_SanFrancisco
- USA_Phoenix
- USA_Denver
- MEX_MexicoCity
- CAN_Toronto
- CHL_Temuco
- BRA_SãoPaulo
- ATL_OceanStCu
- ZAF_CapeTown
- SRB_Belgrade
- KWT_KuwaitCity
- BGD_Dhaka
- VNM_Hanoi
- MNG_Ulaanbaatar
- KOR_Seoul
- AUS_Sydney

Calibration/Validation Target Areas

- USA_RailroadValley
- LBY_Libya4
- NAM_Gobabeb

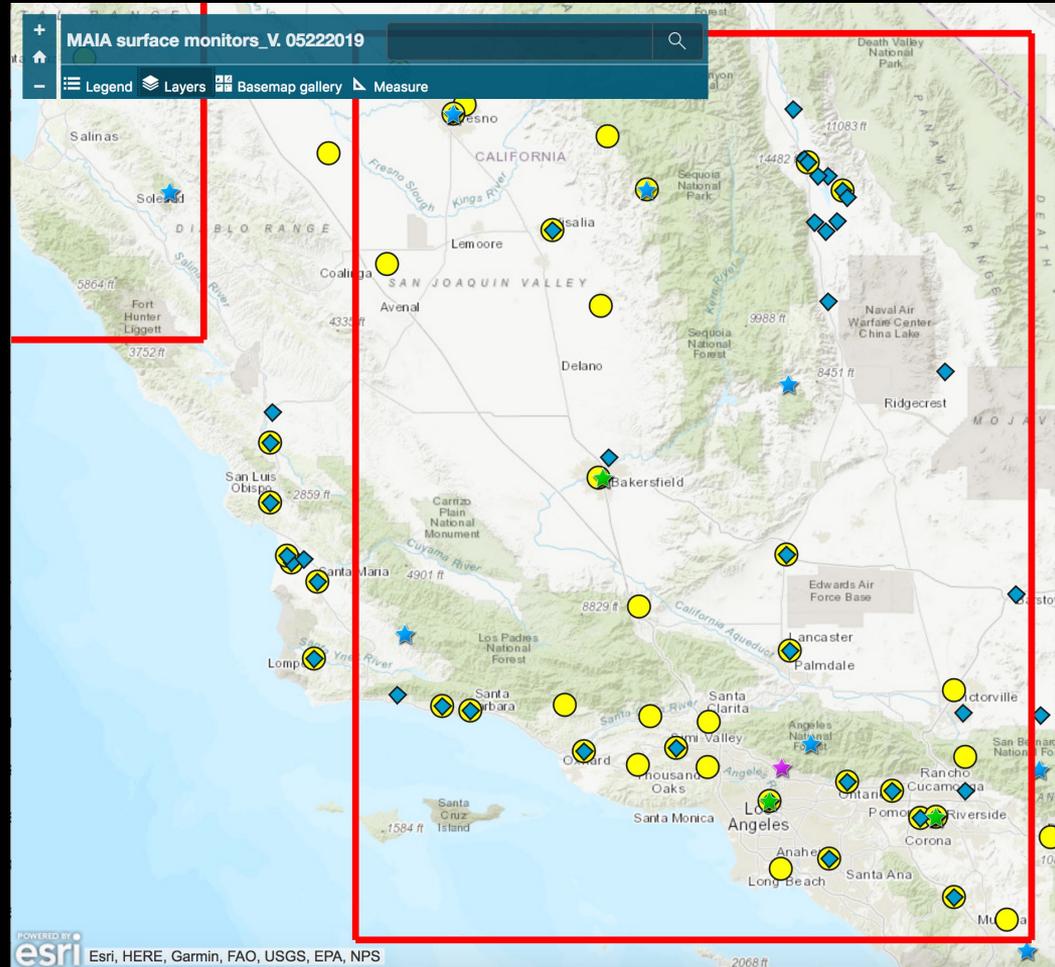
Southern California

Local Collaborators

- SCAQMD
- CARB
- UCLA
- UC Davis

Planned health studies

- Short-term mortality
- Birth outcomes



What can you do?

MAIA website

<https://maia.jpl.nasa.gov>



Home Science Objectives MAIA and Your Health

New NASA Instrument
to Study Air Pollution

Frequently Asked Questions

When will MAIA launch?

MAIA is scheduled to launch in 2022 (to be confirmed). The mission is planned to last for at least three years.

What is an aerosol? I thought that meant hairspray.

In everyday terms, an aerosol is a substance – like hairspray or spray paint – under pressure in some kind of container, which is released as a fine spray. In atmospheric science, though, the term aerosol refers to tiny particles, such as dust or smoke, floating in the air.

If I live in an [area](#) MAIA will study, will my health data be used? How do I know my privacy will be protected?

Health providers and epidemiologists take the privacy of health records very seriously. Before epidemiologists receive funding to conduct a study, they must prove that they will protect the privacy of the health records they will use. NASA will not store health data used in the investigation; all health records will be protected by the epidemiologist conducting the study. When epidemiologists conduct a cohort health study, all the patients agree to participate beforehand. When general health data are collected for use in a study, personal information like names and addresses are kept confidential. Therefore, if your health data are used in the MAIA investigation, your name and other identifying information would never appear in the data sets that are being analyzed or in the published results.

Will wearing a mask protect me from air pollution?

According to the EPA, most masks will not protect you from particulate matter air pollution. Surgical masks or ordinary dust masks do not protect you against tiny PM particles. You must purchase a mask rated by NIOSH as N95 or P100 (this is printed on the mask) in order to screen out PM, and even then it is difficult to fit these masks correctly. Those with beards and children cannot be protected by these masks due to fit problems. Therefore, the EPA [indicates](#) that moving indoors during high pollution events is a much more effective strategy than wearing a mask.

What can I do to protect myself from air pollution?

Want to tell me a new FAQ?

abigail.m.nastan@jpl.nasa.gov

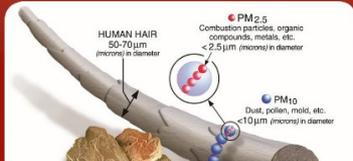
What can you do?

Earth Observatory for Kids

<https://earthobservatory.nasa.gov/blogs/eokids/>

Air Pollution Seeing Small Specks from Space

Air pollution causes health problems for millions of people every year. A particularly dangerous kind of pollution is called particulate matter. These particles come from cars, factories, power plants, wildfires, and other sources. The size is what makes them so harmful. Some are small enough to get into our lungs and pass into the bloodstream. Many scientific studies have shown that this type of air pollution can lead to heart attacks, strokes, lung cancer, and many other diseases, and can increase the chance of having an asthma attack.



DIY Science How Clean Is Your Air?

It can be pretty hard to tell what is floating around in the air because most airborne particles are too small for the naked eye to see. Here is an easy way to collect and observe some of the larger particles in your air. How clean is your air?



You will need:

- 4 white paper plates
- petroleum jelly
- duct tape
- 4 wooden blocks/bricks
- camera

Directions:

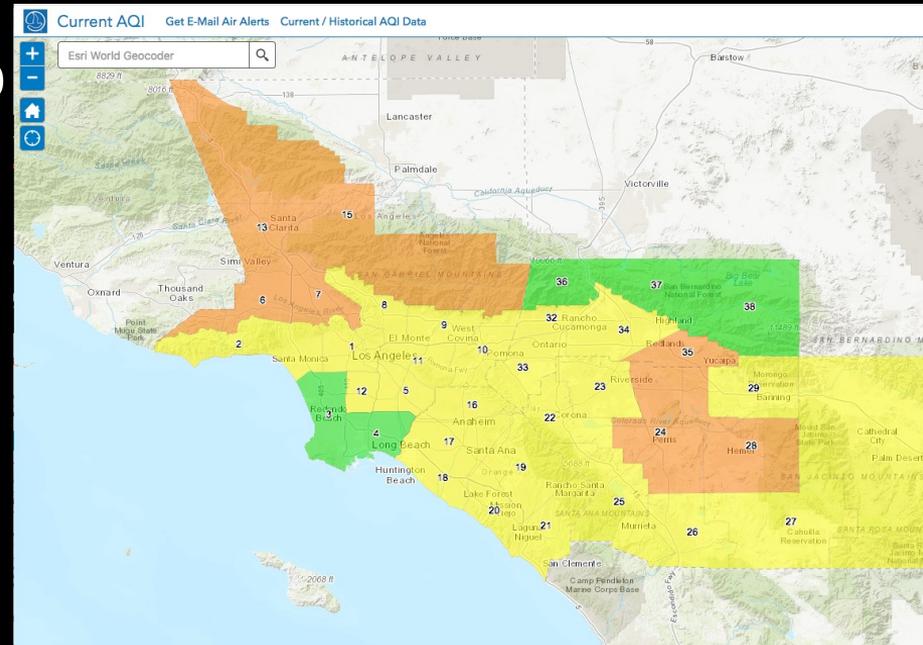
1. Find four locations you would like to test including an indoor and an outdoor location. List the locations in the table below.
2. Create four sensors. Use the duct tape to securely attach a paper plate to a block/brick. Then coat the top of the paper plate with petroleum jelly.
3. Place a sensor in each of the four locations.
4. Take photos of the plates and their locations.
5. Let these particle sensors sit for at least 24 hours. Make sure you test a time period during which there is no rain or snow.
6. After 24 hours, take photos of the plates and compare with the pictures from step 4. Rank the locations from cleanest (1) to dirtiest (4) in the table.

Location	Inside / Outside	Rank

What can you do?

Sign up for air alerts from SCAQMD

<http://www.aqmd.gov/home/air-quality/air-alerts>



SCAQMD complaint line:

1-800-CUT-SMOG

- Unusual odors
- Smoke and dust

Información en español

AirAlerts.org South Coast AQMD is helping Southern California residents learn to make clean air choices that will help reduce air pollution, including knowing when it's important to curtail use of wood-burning fireplaces.

Bad air quality can contribute to harmful diseases like asthma, lung disease and cancer in some cases. Smoke from residential wood-burning can aggravate health conditions. Check below for more information on how seasons affect air quality and steps you can take to help reduce air pollution, and to sign up to start receiving your air quality forecast and notifications today.

Wintertime - Check Before You Burn Program

When colder weather arrives, using your fireplace seems cozy. But, did you know that wood smoke contains gases and tiny particles known as PM 2.5 that lodge deep in your lungs and contribute to a variety of respiratory health problems, such as asthma or lung disease? Young children and the elderly are especially vulnerable.

From November 1 through the end of February, protect your family and community by pledging to participate in South Coast AQMD's "Check Before You Burn" program by not burning wood in fireplaces when unhealthy air quality is forecast, and by signing up to receive daily Air Alert and No-Burn day notification emails.

[Take the Check Before You Burn pledge!](#)

Summertime - Smog Season

High pollution levels can affect your health and the health of your loved ones and it happens more often than you might think. In fact, during the 2017 smog season, Southern California had more than 140 days of unhealthy air quality!

The more you know, the better you can protect yourself and your family. Learn how to participate in helping to clean the air, and sign up for Air Alerts to stay informed of the air quality in your area. Daily e-mail alerts are color-coded for easy reading, and are customizable for the city and pollution level you want to keep an eye on.

[Check out our Clean Air Choices page!](#)

Sign up today to receive Air Alerts customized to you!

[Subscribe](#)

[Manage Account](#)

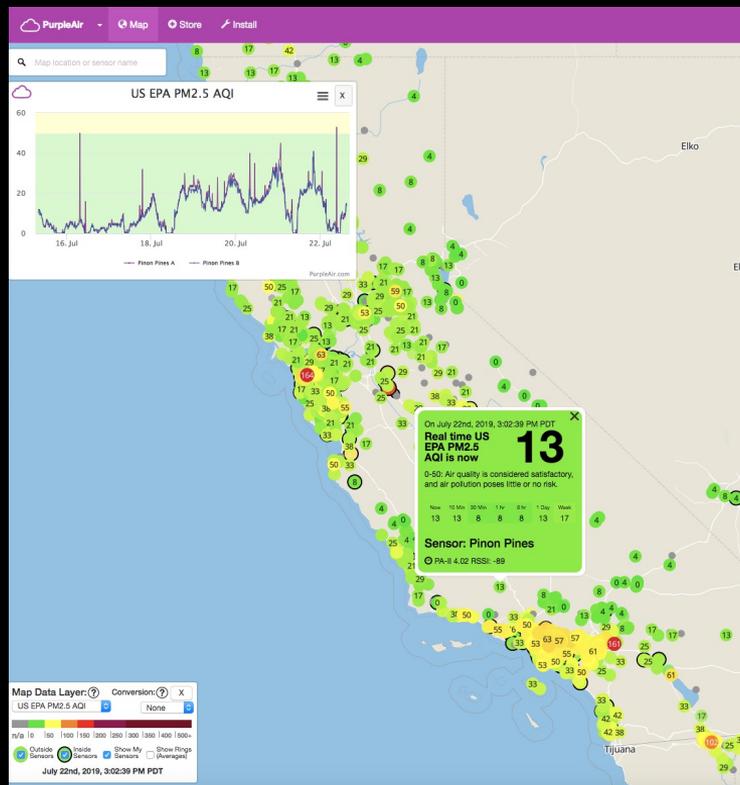
Air Alerts are powered by South Coast AQMD and U.S. EPA's Envirofact system (PDF).

What can you do?

Host a low-cost sensor

<http://www.aqmd.gov/aq-spec>

PM Sensors						
Sensor Image	Make (Model)	Est. Cost (USD)	Pollutant(s)	*Field R ²	*Lab R ²	Summary Report
	Aeroqual (AQY) Ver. 0.5	\$3,000	PM _{2.5}	0.84 to 0.87	0.99	PDF (1,178 KB)
	AethLabs (microAeth)	\$6,500	BC (Black Carbon)	0.79 to 0.94		
	Air Quality Egg (2018 Model)	\$249	PM _{1.0}	0.86 to 0.88	0.99	PDF (771 KB)
			PM _{2.5}	0.84 to 0.85	0.99	
			PM ₁₀	0.12 to 0.13		
	Air Quality Egg (Version 1)	\$200	PM	~ 0.0		
	Air Quality Egg (Version 2)		PM	PM _{2.5} : 0.79 to 0.85 PM ₁₀ : 0.31 to 0.40		
			PM _{1.0}	0.68 to		



Also consider:

- Power/internet/shelter needs
- Ease of data access



MAIA
Multi-Angle Imager
for Aerosols



Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov

