Do-It-Yourself Air Sensors – Exploring the Atmosphere and Turning on Light Bulbs!

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U.S. EPA Office of Research and Development

Goals of this talk

1. Get you excited about the atmosphere and air quality science
2. Show you a few highlights of EPA research
3. Introduce you to a fun classroom activity

And…there is a give-away!

At the end of the talk, there is a survey to fill out. Please indicate if you are interested in a kit – we'll do a draw and one attendee will receive a free sensor kit in the mail!
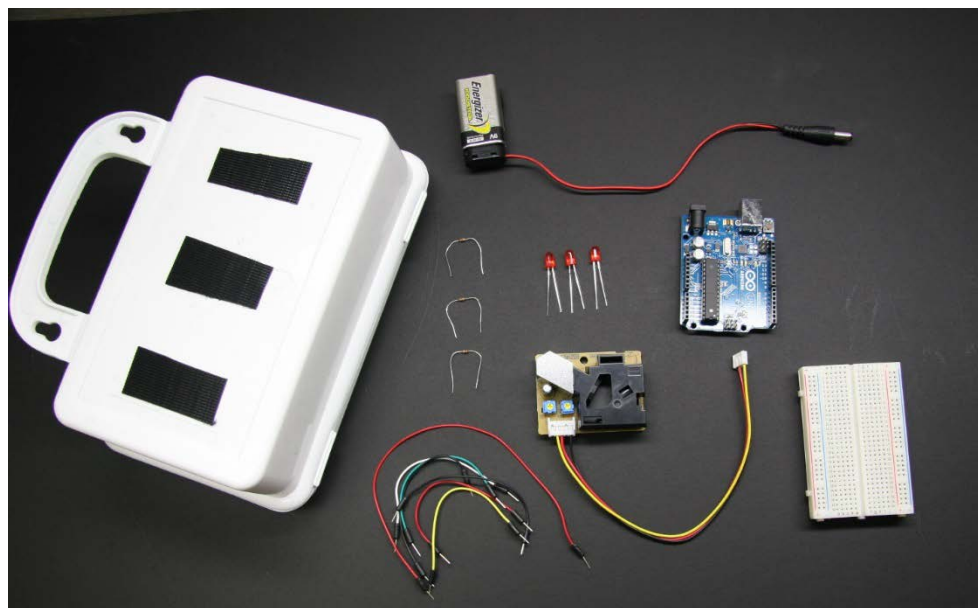
The air surrounding you: "All Things Air 101"

1. What is in the air?
2. Why does it matter?
3. Why it is a cool career?

Poll: Do you talk about the atmosphere much in your classes?

A. Not at all

B. It has come up briefly, but no focused lessons

C. I've taught entire lesson plans on the topic

D. I teach an entire class on the subject!

The atmosphere can seem endless, but it is really a thin layer in the big picture view
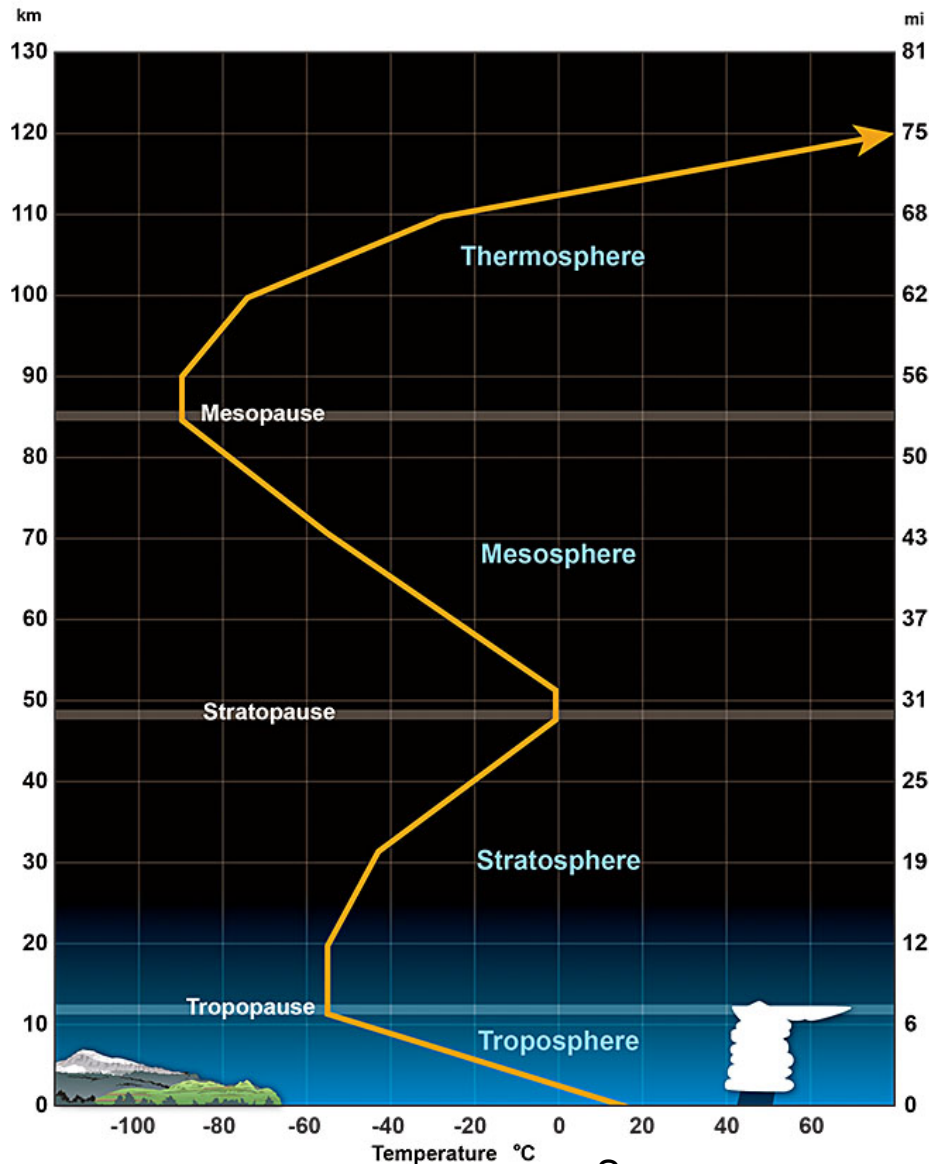

"If Earth were the size of a basketball, the atmosphere could be modeled as a thin sheet of plastic wrapped around the ball."
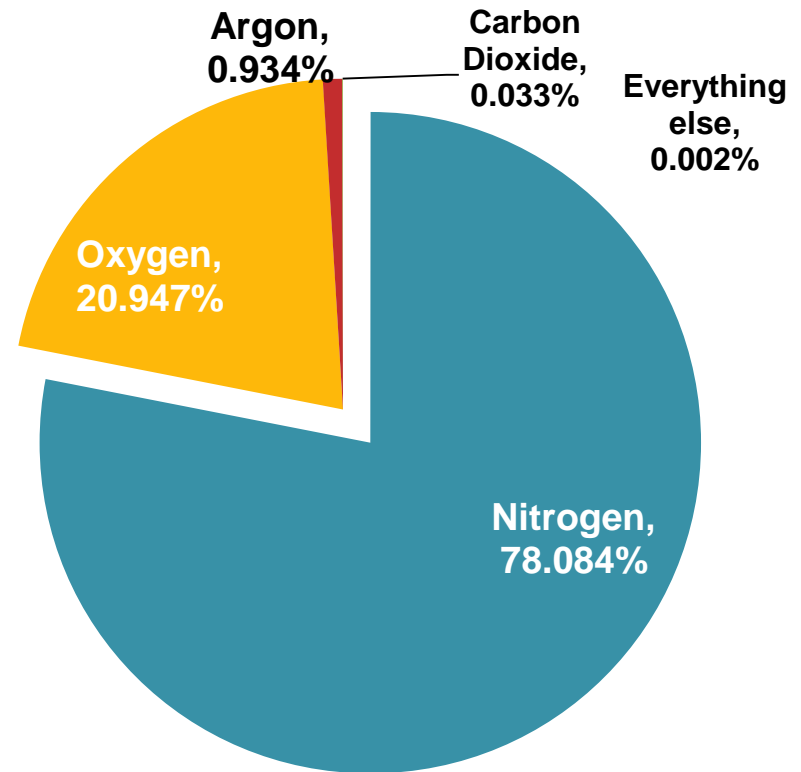*Glenn Research Center, NASA*

But…so essential to life!

(image: nasa.gov)

What is in our atmosphere?

Source: noaa.gov

Gases in the lower atmosphere:

- Argon, 0.934%
- Carbon Dioxide, 0.033%
- Everything else, 0.002%
- Oxygen, 20.947%
- Nitrogen, 78.084%

← UV-protective ozone layer located in the stratosphere

← Most of our emissions stay in the troposphere / "lower atmosphere"

And now, let's focus on the "everything else" – very small amounts of pollution can make a big impact

Free response in the chat window: Can you name an air pollutant?

What else is in our atmosphere and where does it come from?
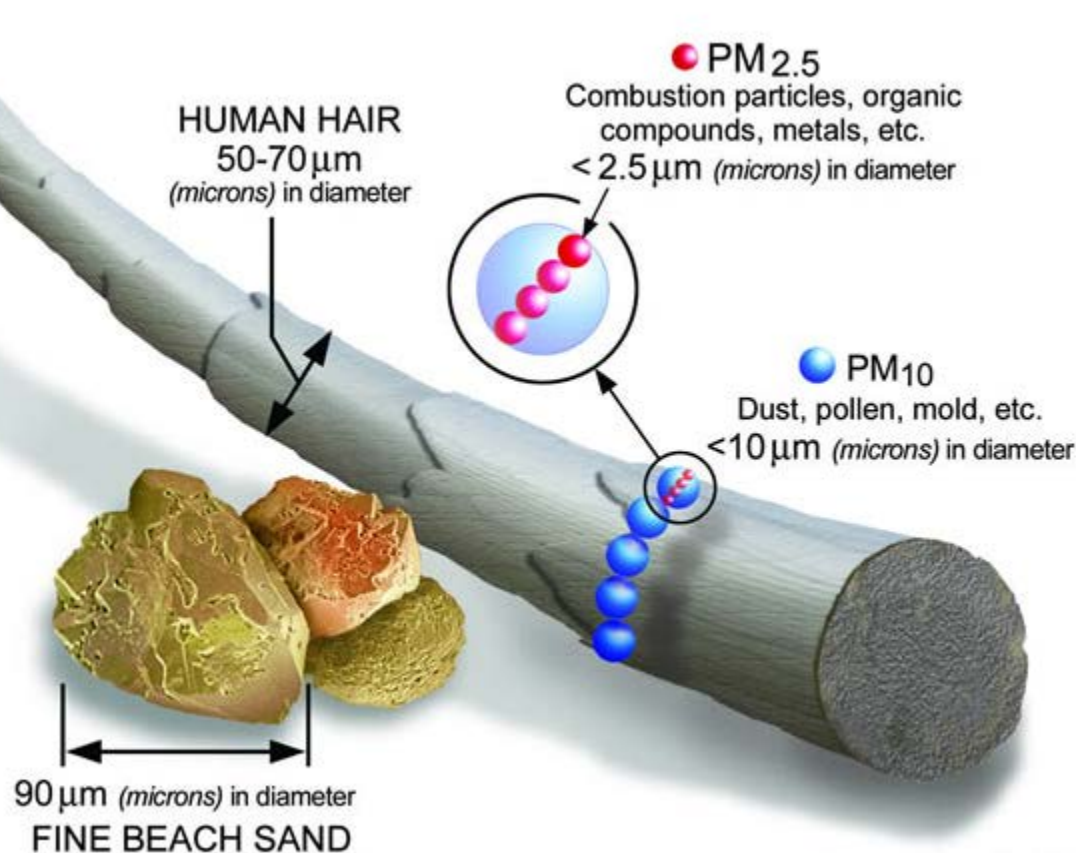
Particulate matter (PM)

HUMAN HAIR
50-70 μm
(microns) in diameter

● PM$_{2.5}$
Combustion particles, organic compounds, metals, etc.
< 2.5 μm *(microns)* in diameter

● PM$_{10}$
Dust, pollen, mold, etc.
< 10 μm *(microns)* in diameter

90 μm *(microns)* in diameter
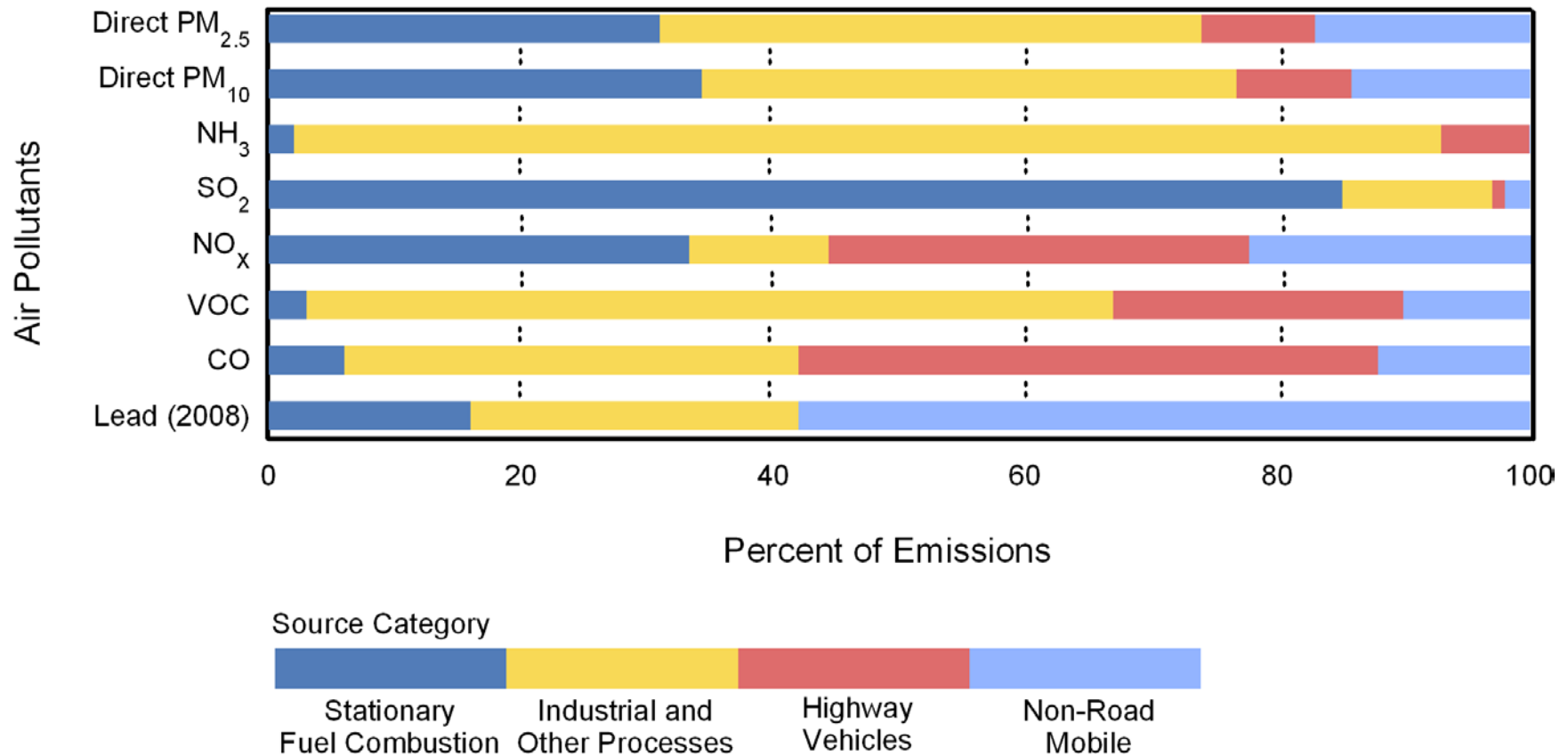FINE BEACH SAND

Image courtesy of the U.S. EPA

Gases

Ozone
Carbon monoxide
Nitrogen dioxide
Sulfur dioxide

Hazardous air pollutants (HAPs)

Gases (e.g., benzene)
Particles (e.g., mercury)

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What else is in our atmosphere and where does it come from?

A picture of emission types and pollutants in the United States, 2010.

Did you know there is "good" ozone and "bad" ozone?

"Good up high": Way up in the stratosphere (above where planes fly), the natural ozone layer absorbs UV radiation and lowers the amount reaching people on the ground

"Bad nearby": Down in the troposphere where people live, sunlight fuels a chemical reaction between two pollutants (VOCs and NOx) that creates ozone that causes respiratory effects.
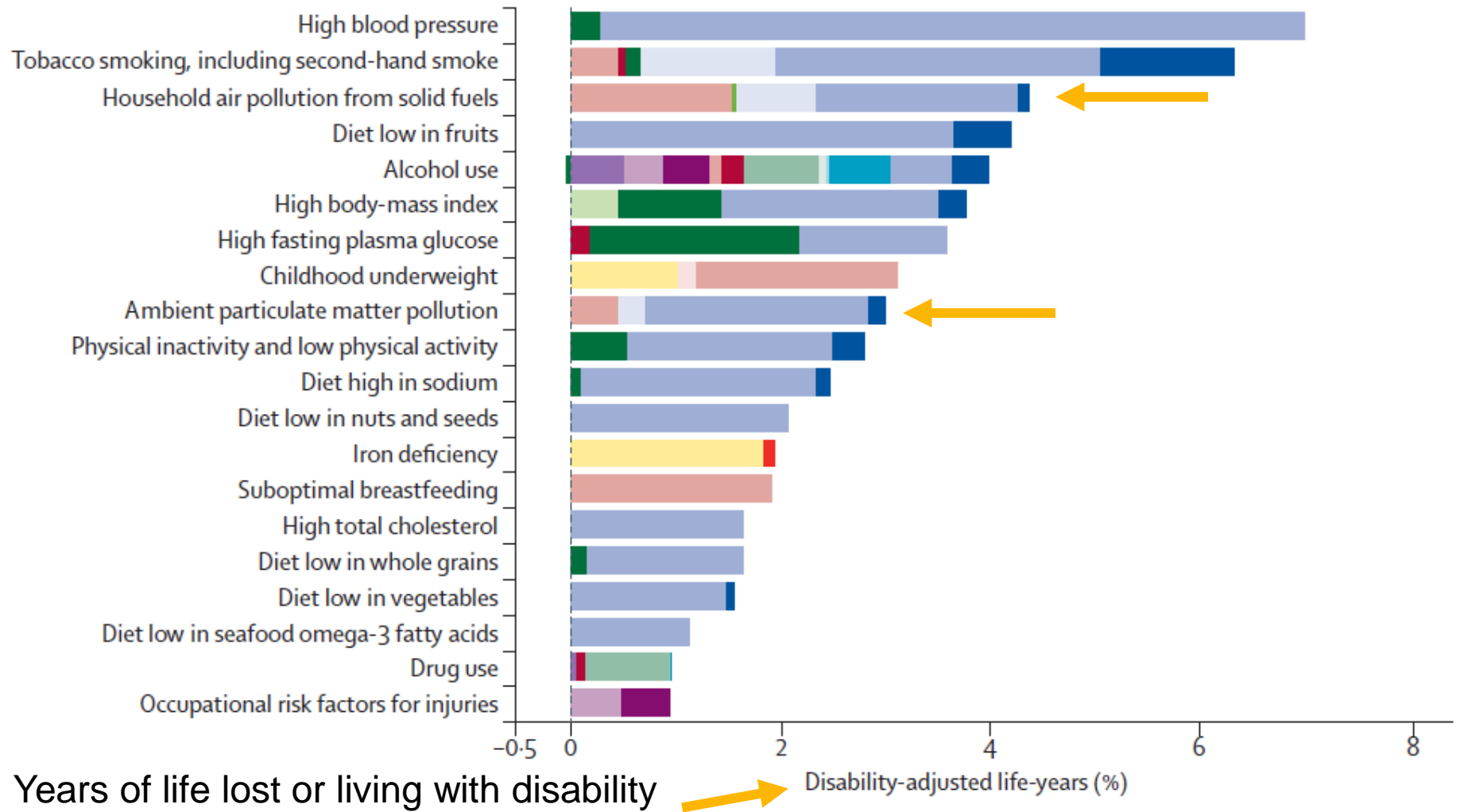
Why clean air matters

Poll: Can air pollution affect your lifespan?

YES: It is a leading cause of years of life lost worldwide.

NO: It may make it more difficult to breath at times, but the effect is temporary.

What actions can shorten our life?

Global Burden of Disease, 2010 (Lim et al., 2012)

Years of life lost or living with disability

Human activities: local impacts

1948 – Donora, Pennsylvania, United States

Worst air pollution disaster in United States history. Five days of severe air pollution – 20 people died, over 7,000 were hospitalized or became ill.
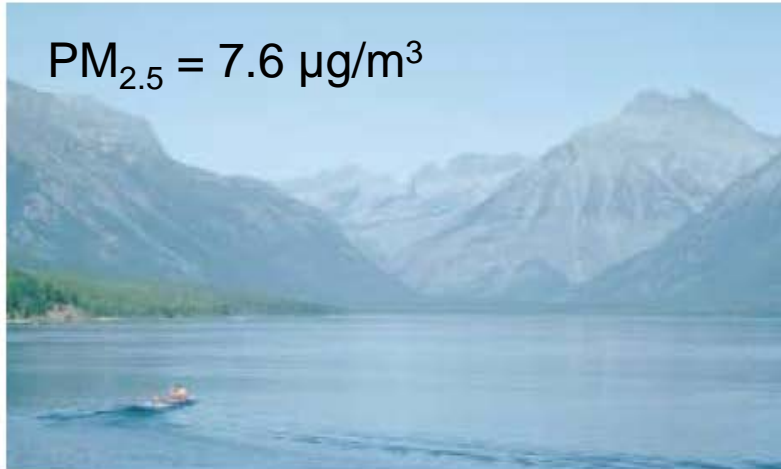

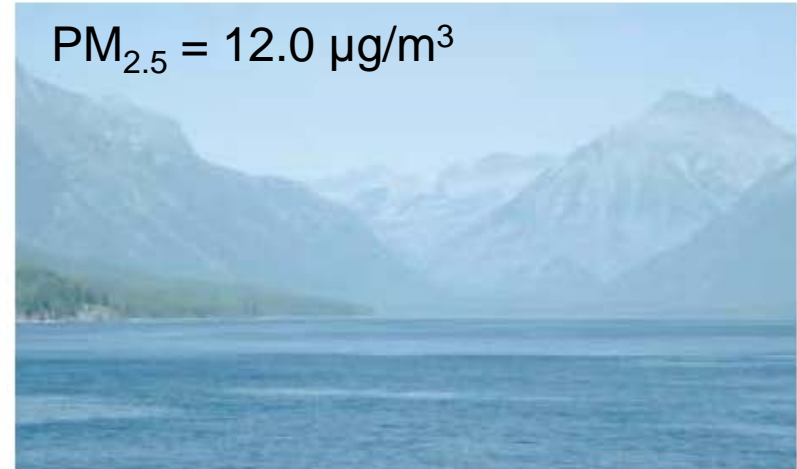Smog in Donora, PA, 1948 (photo: Pittsburgh Post Gazette)

Industrial emissions that usually dispersed were trapped in an inversion, forming a thick, yellowish smoke

EPACE
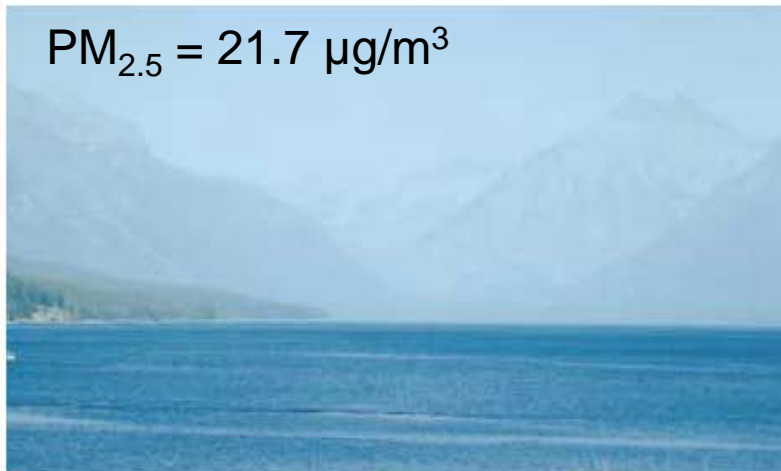
Not only a health impact, but visibility too

Glacier National Park (USA)

$PM_{2.5}$ = 7.6 µg/m³

(a)

$PM_{2.5}$ = 12.0 µg/m³
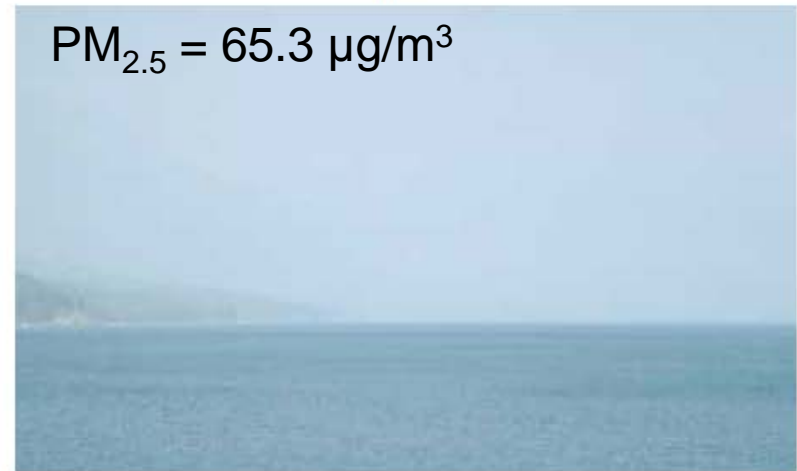
(b)

$PM_{2.5}$ = 21.7 µg/m³

(c)

$PM_{2.5}$ = 65.3 µg/m³

(d)

Reference: Introduction to Visibility, William Malm

Poll: Are common air pollutant emissions in the United States much different than 50 years ago?

A. We are emitting MORE – population has increased, we all have more cars, use more electricity, and that means more air pollution.

B. We are emitting ABOUT THE SAME – cleaner technologies compensate for us having more cars and use more electricity.

C. We are emitting LESS – cleaner technologies have more than made up for the difference in having more cars and using more electricity.

Air quality in the USA – we've come a long way
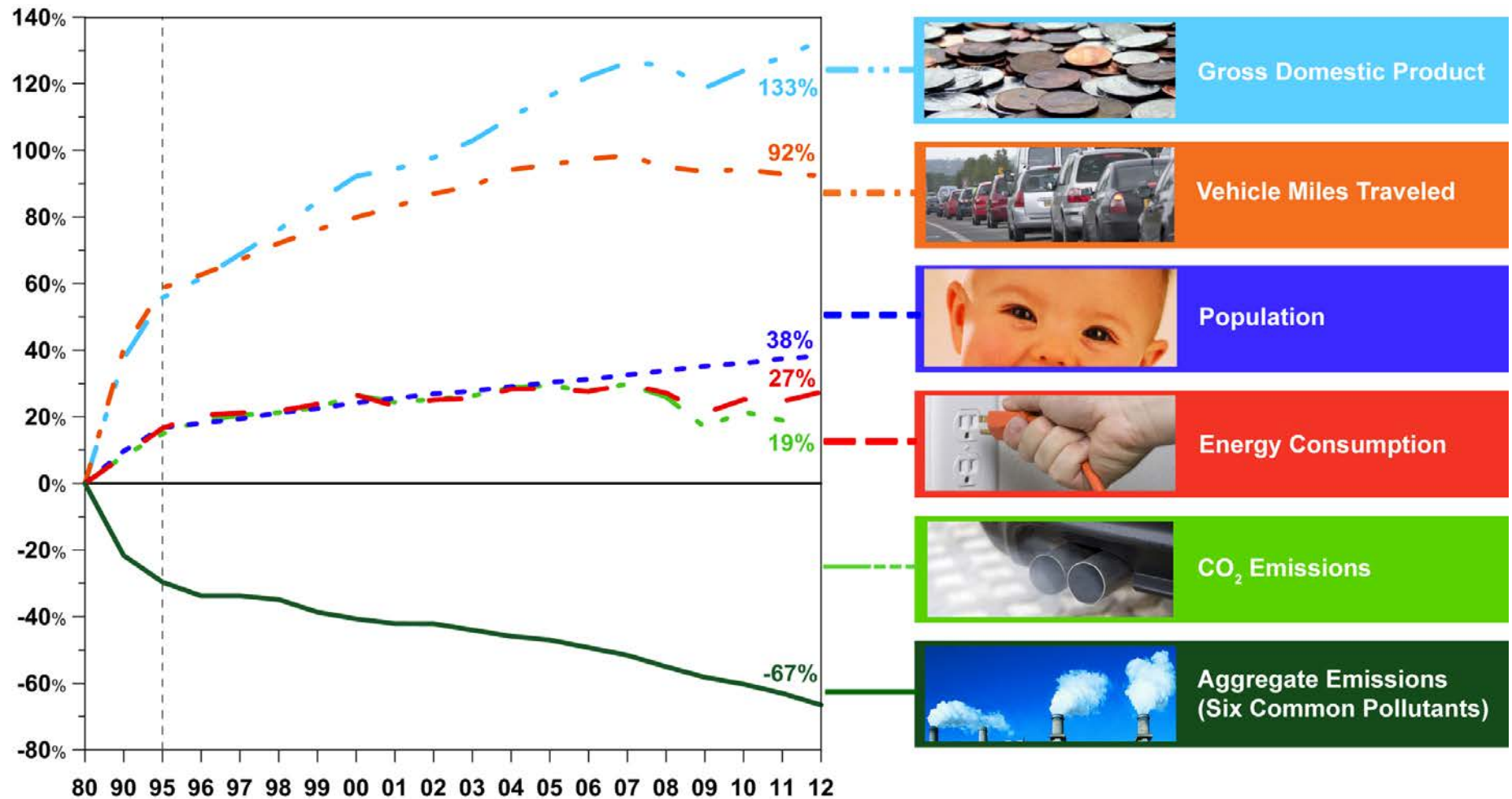
Source: EPA, Comparison of Growth Areas and Emissions, 1980-2012

Some areas of the world still struggle with air pollution challenges

New York Times, April 1, 2013

Air Pollution Linked to 1.2 Million Premature Deaths in China

TheTelegraph, Oct 22, 2013

Chinese city of Harbin shrouded in smog as air pollution soars

Chinese city paralysed by smog as Beijing announces new measures to tackle air pollution in the capital
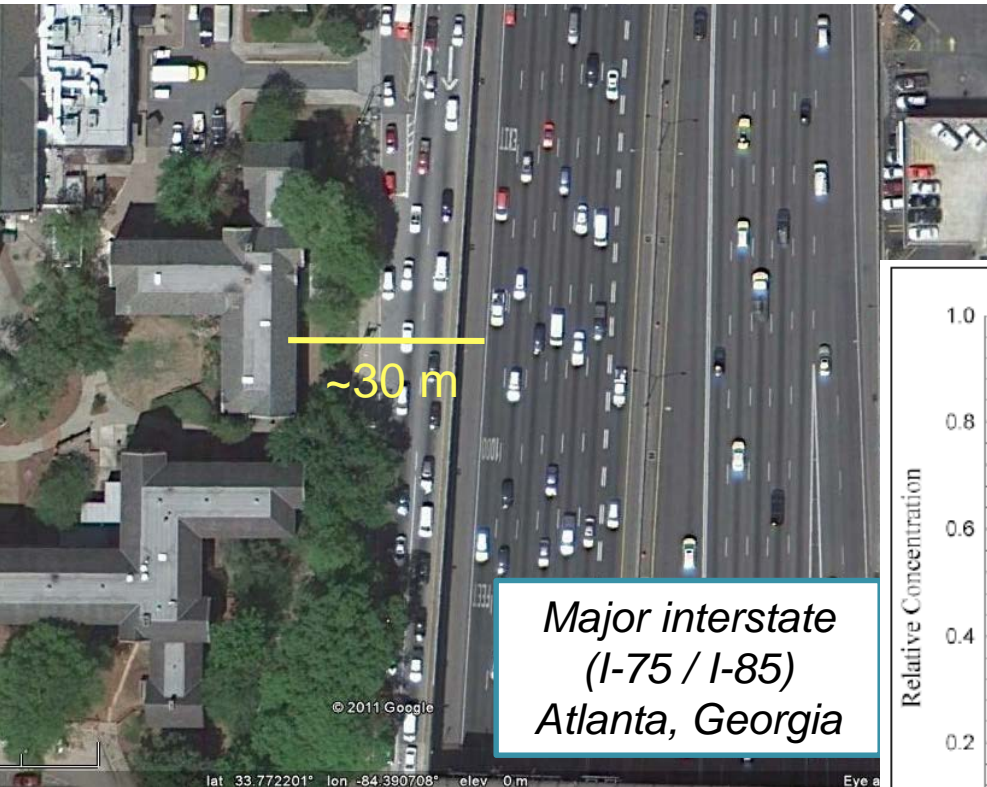

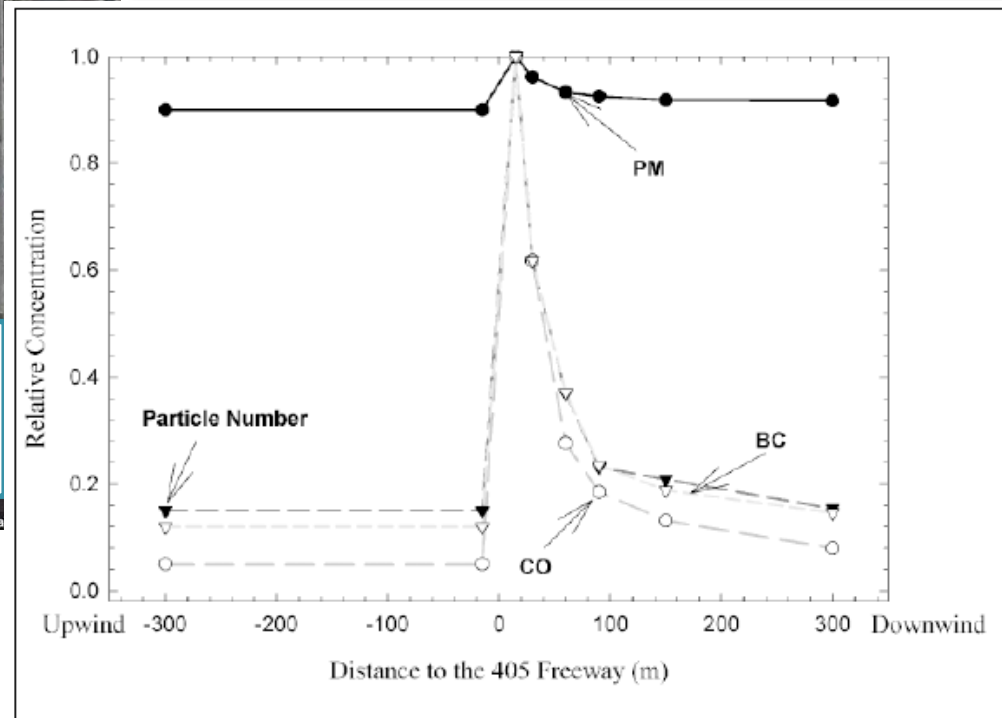Shanghai in January. Researchers said the toll from China's pollution meant the loss of 25 2010.

People ride along a street on a smoggy day in Daqing, Heilongjiang province, China   Photo: REUTERS

EPACE

And we also have emerging issues of concern for air quality in the USA

Modern day concerns – "near-source exposure"

Over 45 million people in the United States live within 100 meters of a major transportation system.

~30 m

Major interstate (I-75 / I-85) Atlanta, Georgia

Zhu et al (2002)

Current concern for "near-road" air pollution

Special Report 17

Health Effects Institute

January 2010

Traffic-Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure, and Health Effects

HEI Panel on the Health Effects of Traffic-Related Air Pollution

<u>Sufficient evidence</u>

Exacerbation of childhood asthma

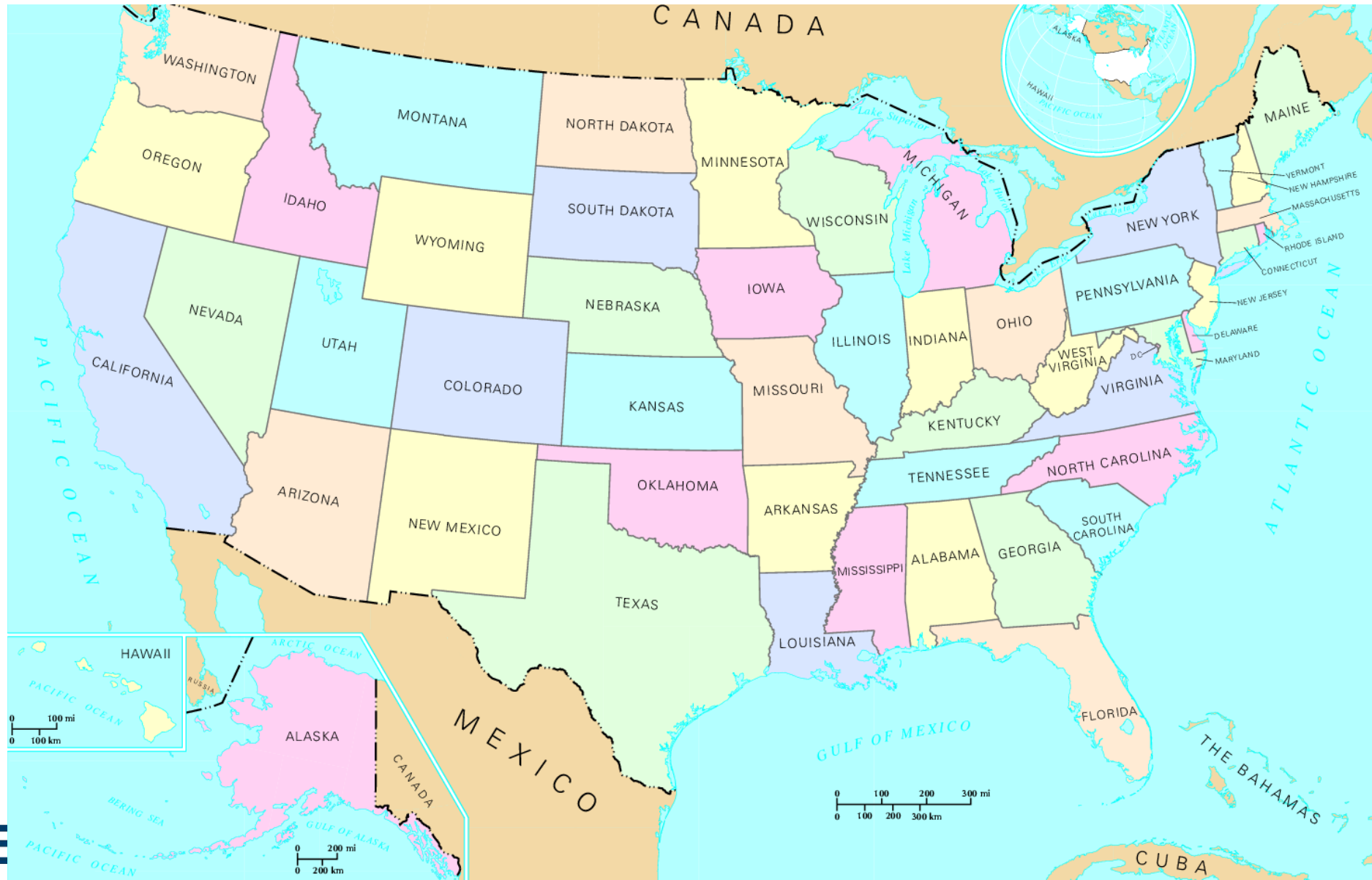<u>Suggestive, but more evidence needed</u>

Onset of childhood asthma

All-cause and cardiovascular mortality from long-term exposure

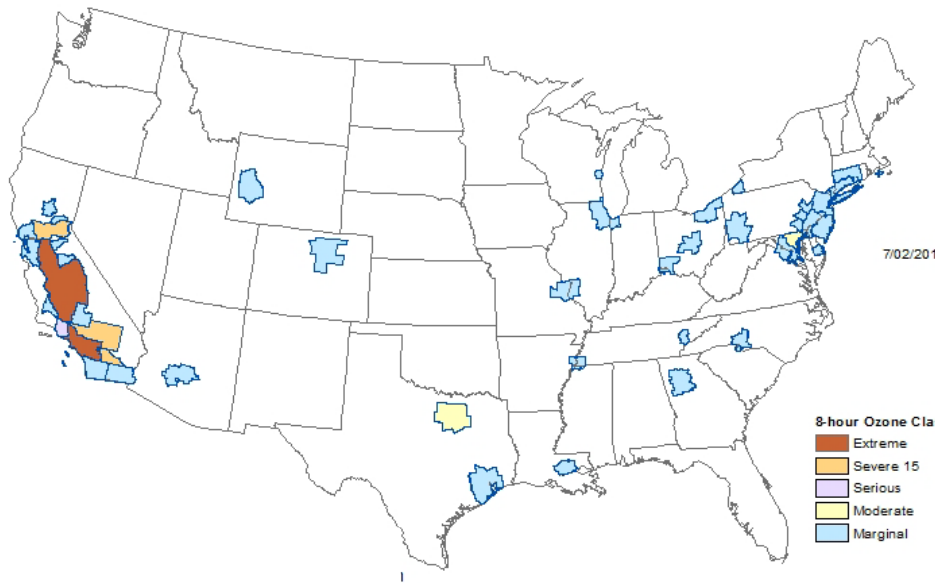Cardiovascular morbidity

Impaired lung function

Nonasthma respiratory symptoms

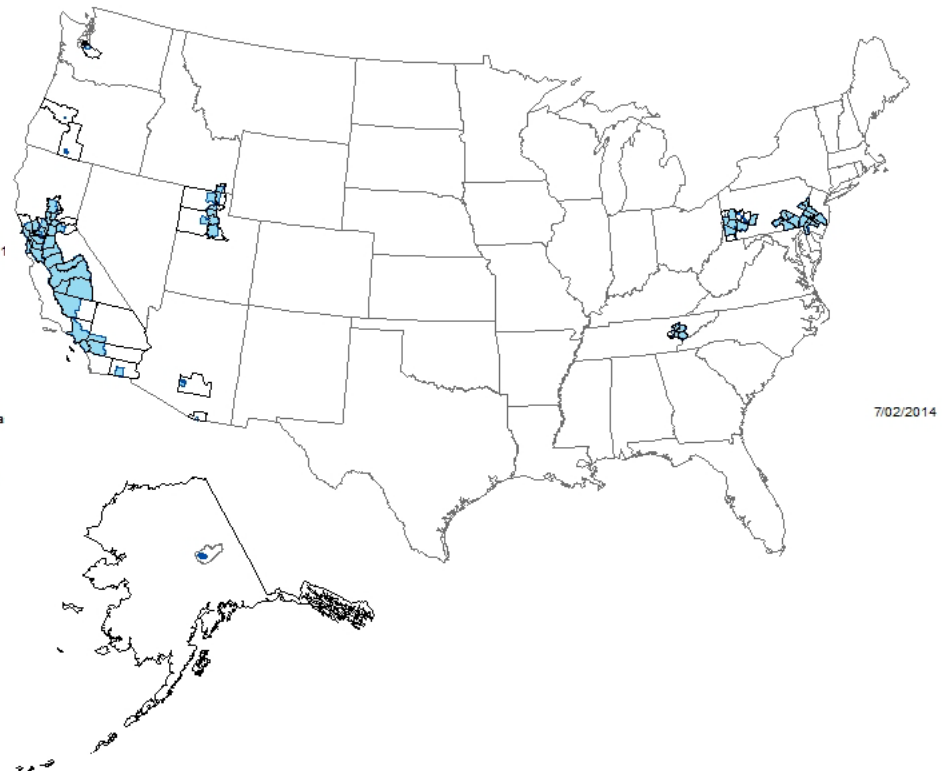# What are three areas you would predict where air pollution is an ongoing challenge? (add a marker)

Areas still struggling to meet national standards for ozone and PM$_{2.5}$

8-Hour Ozone Nonattainment Areas (2008 Standard)

PM-2.5 Nonattainment Areas (2006 Standard)

8-hour Ozone Cla
- Extreme
- Severe 15
- Serious
- Moderate
- Marginal

7/02/201

7/02/2014

Why studying the air can be an exciting career

("when am I ever going to use this?")

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Will I ever use this? Many fields study air quality, climate, and health

Meteorology

Chemistry

Engineering

Physics

Statistics / math

Computer science

Electronics

Environmental policy

Health (epidemiology, toxicology, public health)

(YES, you can tell your students, you CAN use this information when you grow up!!)

Love adventure? Field research has much in store

University project: Studying air pollution in southeast China

University project: Studying air pollution on the pristine Greenland Ice Sheet

Job qualifications: Open to learning, enjoys team work, likes the outdoors, and patience.

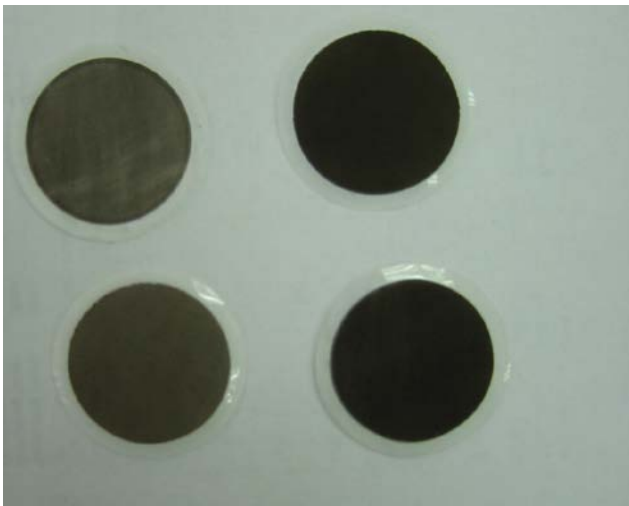# Other avenues – air quality modeling, laboratory research
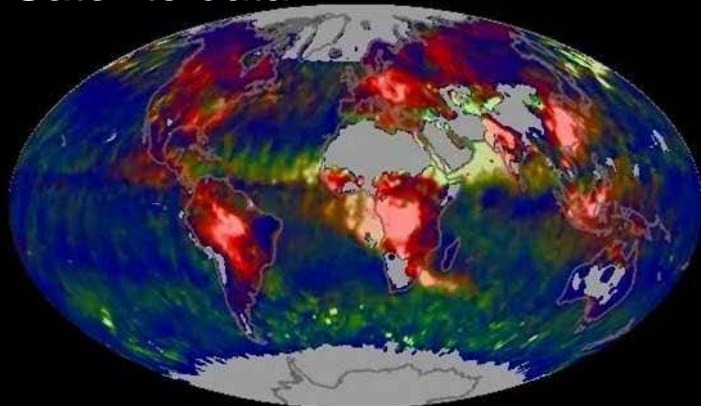
Satellite data | Model estimate
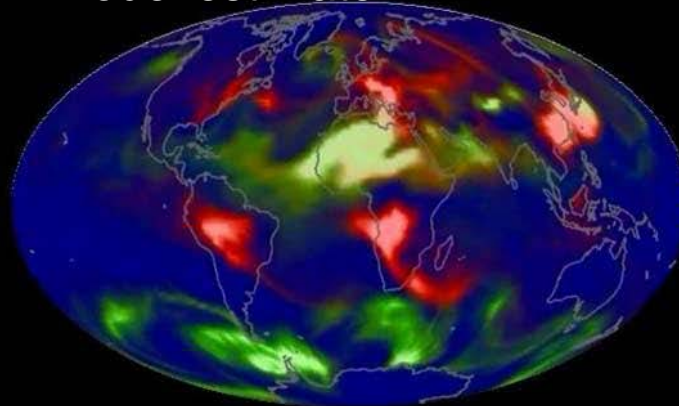
Image left: Aerosols in Earth's atmosphere can be a major source of pollution worldwide, and include fine aerosols such as pollution and smoke (red) and coarse aerosols such as dust and sea-salt (green). Credit: NASA

Lab analysis of particles collected onto filters to study where they came from.

Studying air quality at the EPA

Our mission: Protect human health and the environment.

Air pollution and health

US EPA regulates 6 common air pollutants via National Ambient Air Quality Standards:

Ozone (O_3)
Carbon monoxide (CO)
Nitrogen dioxide (NO_2)
Sulfur dioxide (SO_2)
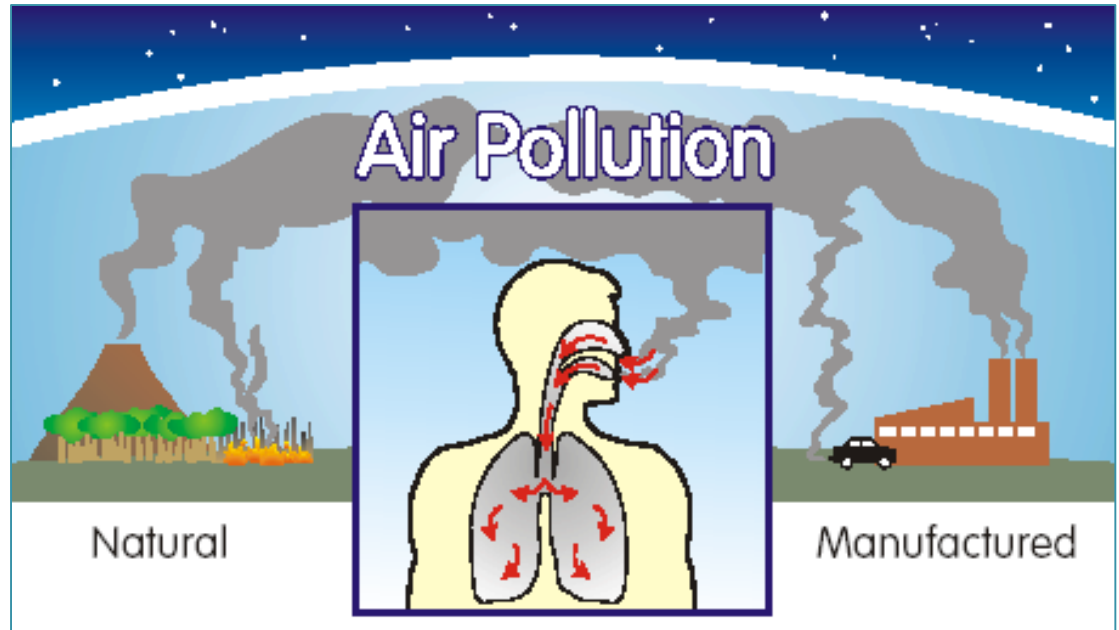Lead (Pb)
PM ($PM_{2.5}$, PM_{10})

Image source: astdr.cdc.gov

Health effects:

• premature death in people with heart or lung disease (PM)

• nonfatal heart attacks (PM)

• irregular heartbeat (PM)

• aggravated asthma (PM, O_3, NO_2, SO_2)

• increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing (PM, O_3, NO_2, SO_2)

• reduction of oxygen-carrying capacity of blood (CO, Pb)

• neurological effects (Pb)

Poll: What is your experience with air pollution monitoring?

A. I have never seen it.

B. I've seen equipment measuring the air, but haven't tried it.

C. I've taken measurements myself or with my students.

D. I've been part of a research study measuring air pollution.

Some example air quality projects in EPA's Office of Research and Development

- The Village Green Project: Engineering new ways to measure air pollution in communities

- Studying air pollution from forest fires – what is in the smoke and how does it effect us?

- DISCOVER-AQ: Measuring air pollution from satellites

The Village Green Project

Solar-powered, air and meteorology monitoring bench:

- Sustainable materials: manufactured from recycled milk jugs

- Tamper-proof: Instruments secured in bench or base of play structure

- Designed to add value to public environments

The Village Green Project

Air instruments (PM, ozone), power system and communications components stored securely behind bench

Website: villagegreen.epa.gov

Forest fire study

The US military is the 2nd largest landowner in the United States. They have large forests to maintain; each forest is burned periodically for ecology and wildfire prevention.

Research questions:
1. What are the pollutant concentrations in smoke from prescribed fires?
2. How does the pollution change from "flaming" fire to "smoldering" fire?

Forest fire study

Approach

- Measure air pollution levels in "real-time" (measurements every second) during fires
- Measurement platforms:
    - Measurements on the ground – measurements upwind and downwind of fire
    - Airborne measurements on a plane that flies through the plume

DISCOVER-AQ

EPA-NASA partnership to advance our ability to detect ground-level air pollution from outer space

https://www.youtube.com
/watch?v=UJxQFJ5cEog
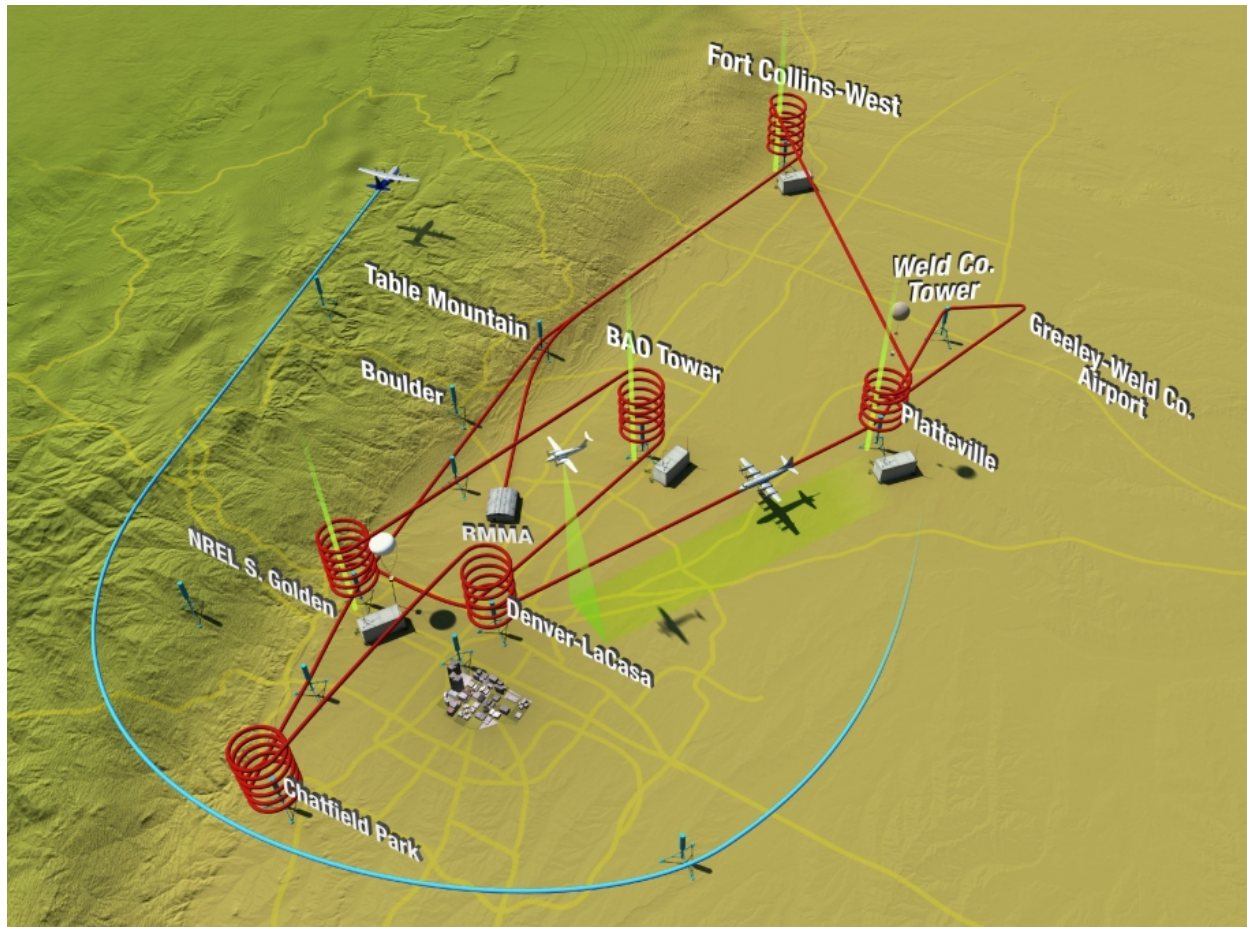
DISCOVER-AQ

DISCOVER-AQ Study Houston, TX (Sept. 2013)

- Citizen science: small NO_2/O_3 and NO_2 sensors deployed at 7 schools
- Sensor data compared to reference analyzer data
- Low-cost sensors performed well

CairClip Sensor

Point of Contact: Russell Long, Rachelle Duvall

Sensor Data from Schools

Classroom activity: Air Sensor Kit

The emerging world of low cost sensors and electronics – an opportunity for STEM outreach and air science

A growing world of electronics supporting creative projects:
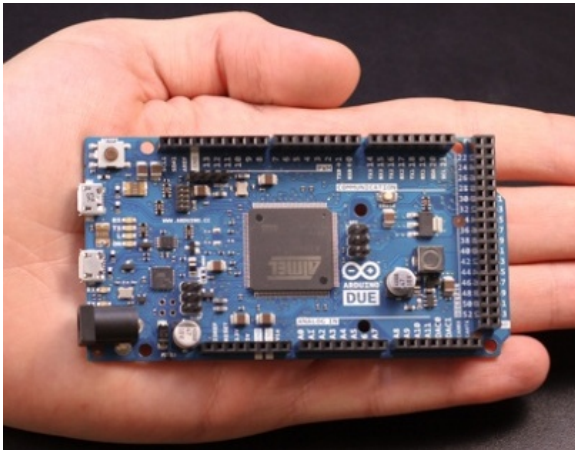
Arduino microprocessor – a simple computer

Lilypad Arduino – electronics meets home ec!
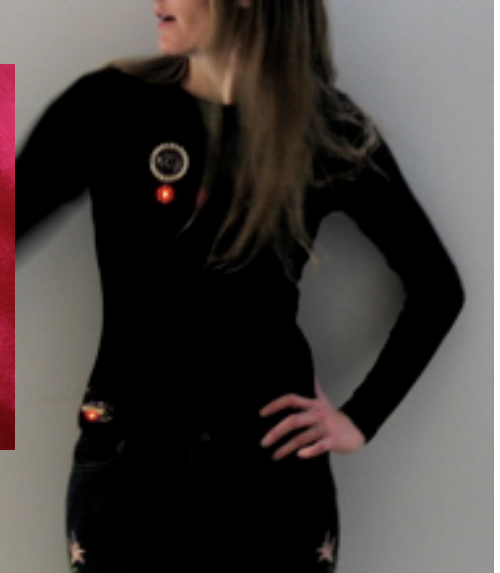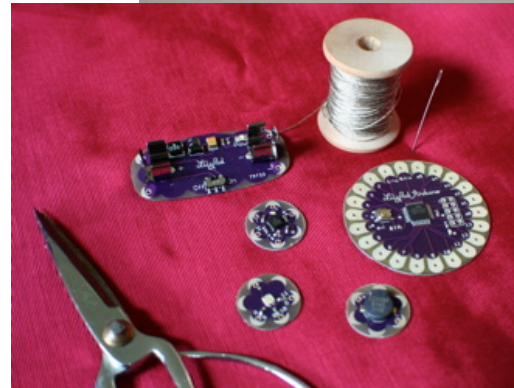
Image: http://web.media.mit.edu/

The emerging world of low cost sensors and electronics – an opportunity for STEM outreach and air science

Example air sensor components:

Nitrogen dioxide sensor
(Images courtesy of Ron Williams)

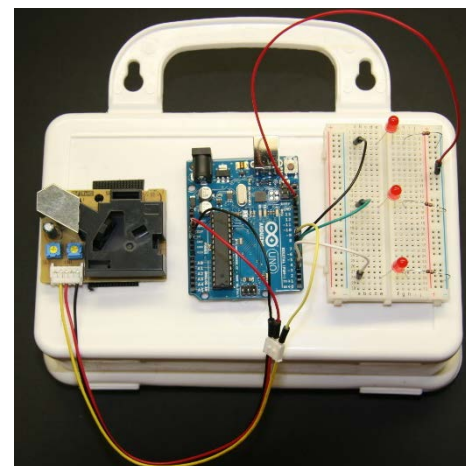Carbon dioxide sensor

Particle sensor

Particle sensor

- Some are "raw" components that need additional electronics work (an opportunity to build and learn!)
- Some are ready to turn on and collect data (an opportunity to measure!)
- All are portable, data quality is variable

Air sensor kit for outreach

Air sensor → Computer ("data in, display out") → Data display
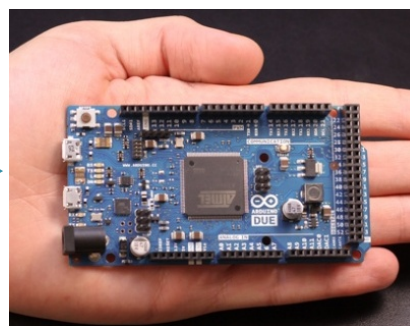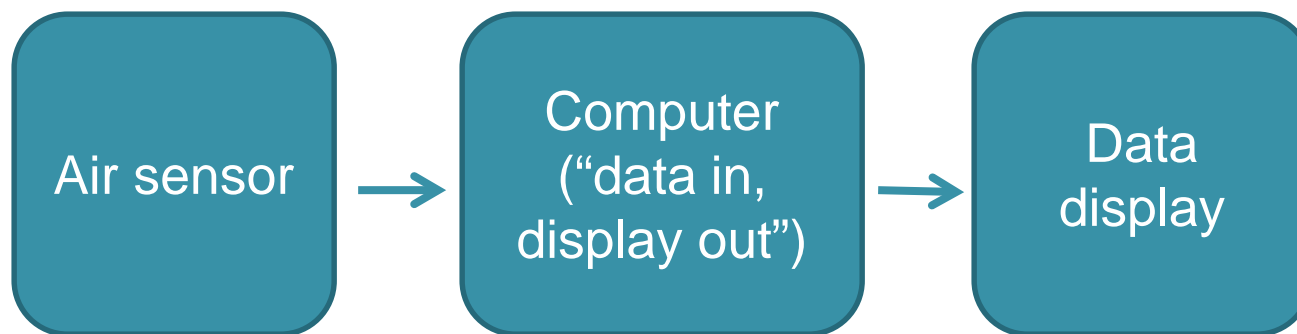
Arduino board

Portable "particle monitor" with LEDs lighting up to indicate concentration
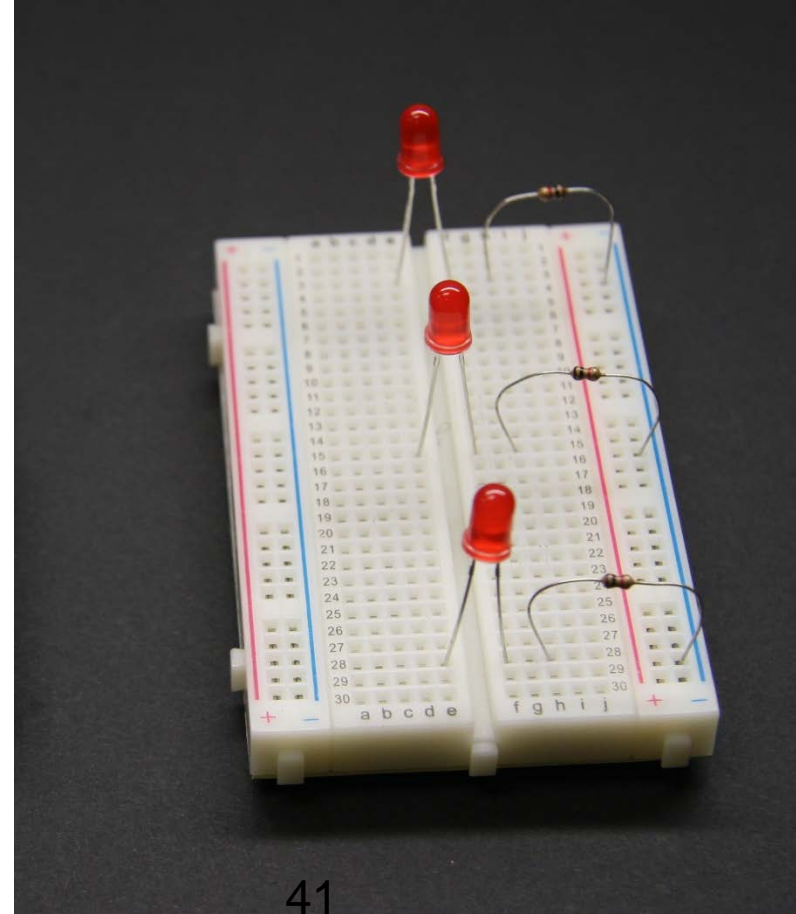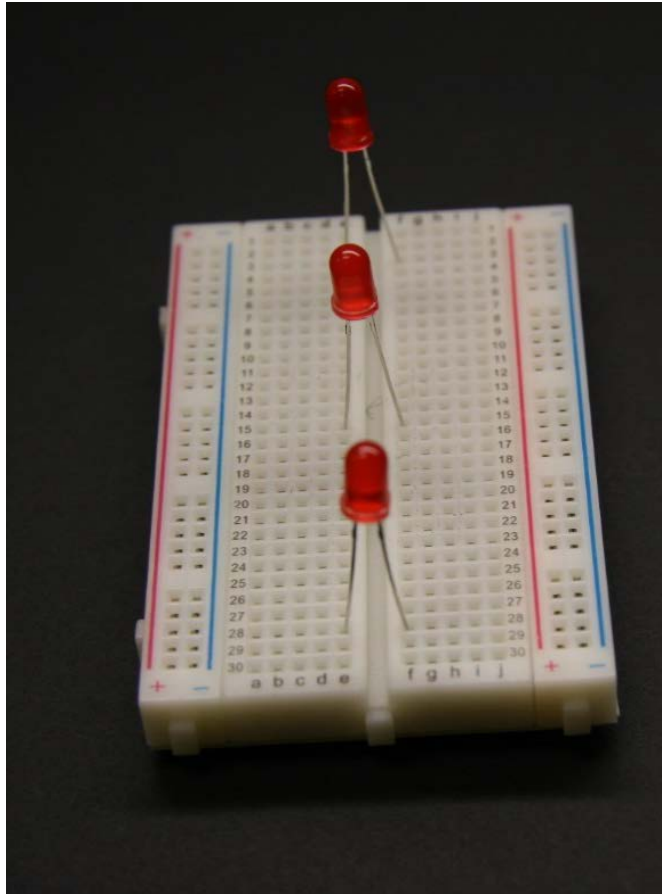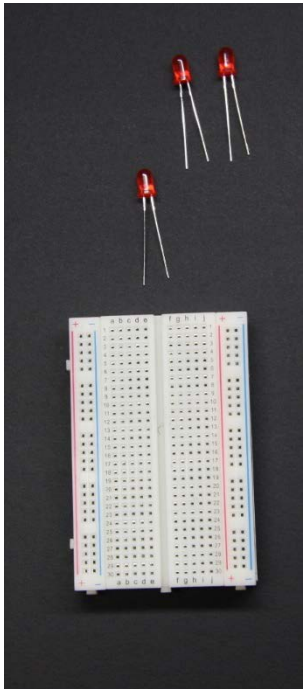
Additional components:
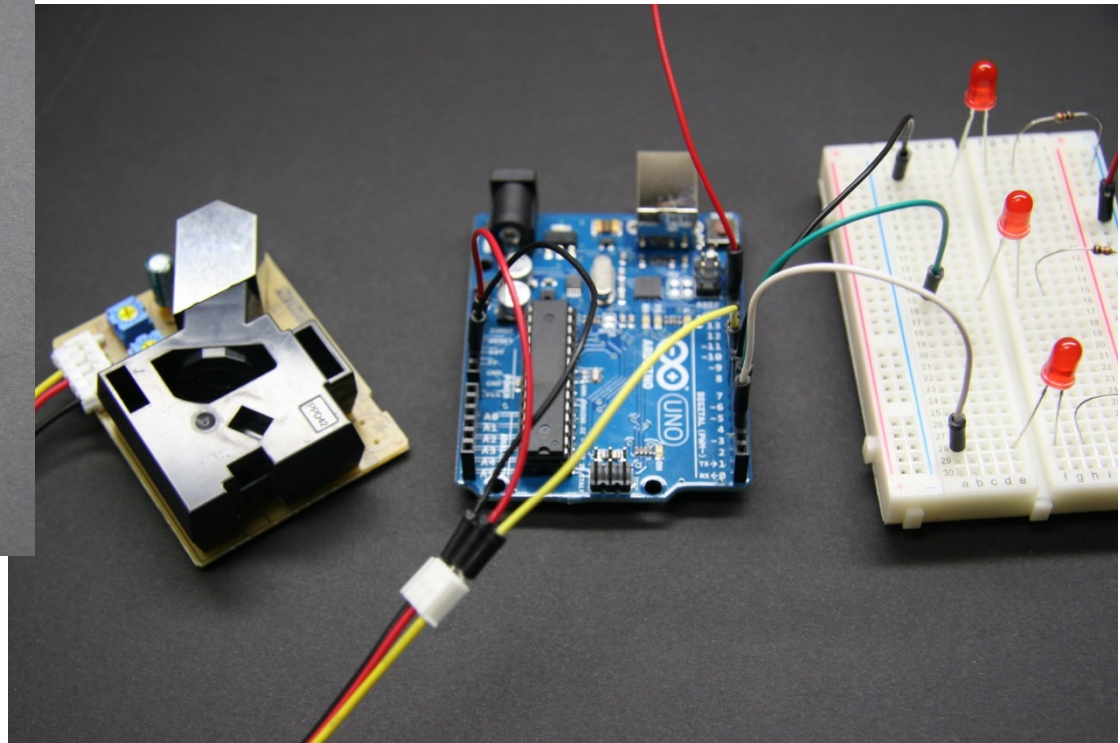- Resistors and wires
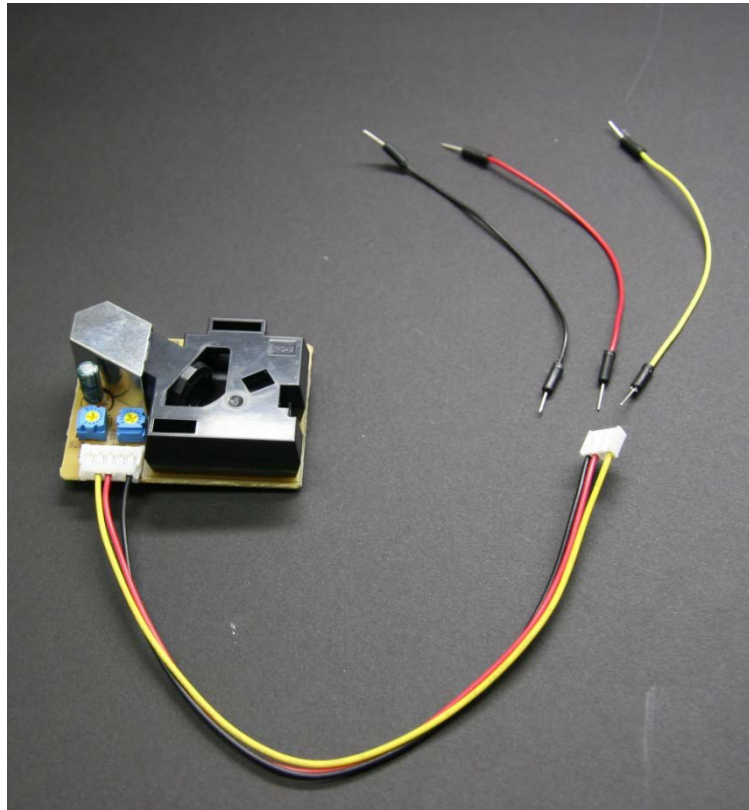- Small battery
- 3 LEDs

Total kit cost:
~$65

Reuseable!

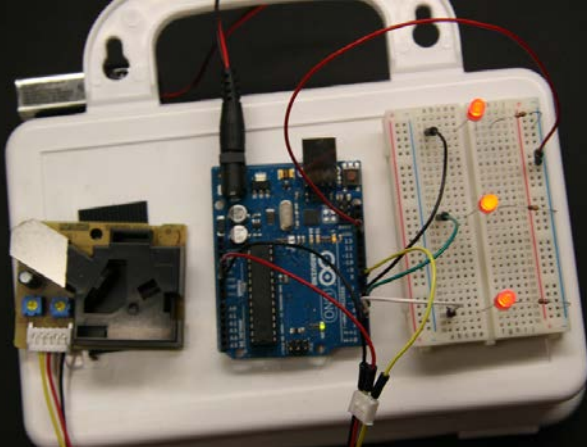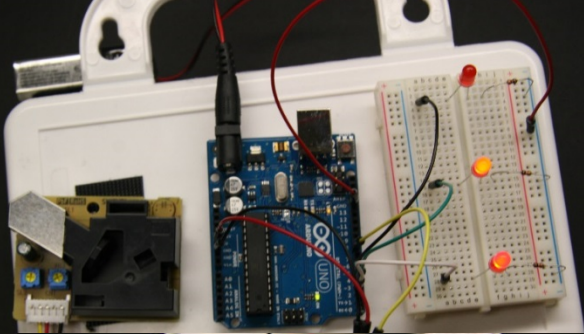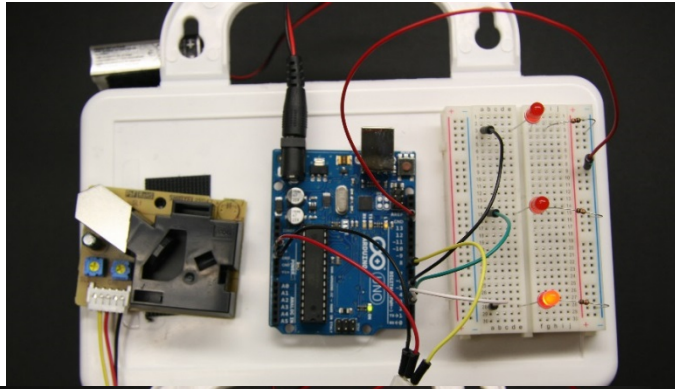# Step by step instructions: Put the 3 red LED lights on the breadboard, then add resistors

Step by step instructions: Attach wires to the particle sensor, then connect to the small Arduino computer

Attach to the box…now, can you make the lights change?

More lights on indicates higher PM levels

Do you want to incorporate this into your class?

We have:
- Instructions
- Arduino code ready to go
- Shopping list for parts
- Classroom handout

    For more information:
        Gayle Hagler:
   hagler.gayle@epa.gov

Build Your Own Particle Sensor

Target Age Range: 5th -12th grades

Estimated Time: 1 hour
Additional ideas for lengthening the activity provided at the end. In addition, older high school age students can complete this activity in as little as 30 minutes with an abbreviated introduction.

Objective:
Teach basics about particulate matter air pollution and electronics. In addition work on problem solving and other science, technology, engineering, and math (STEM) skills.
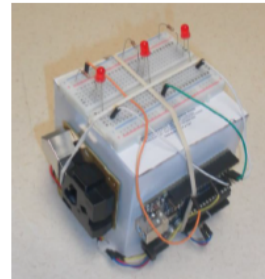
Figure 1. Sensor kit componetns assembled with materials you can find at home (rubber bands, cardboard box)

Figure 2. Sensor kit components assembled using a children's building toy pieces and velcro

http://www.epa.gov/research/airscience/next-generation-air-measuring.htm

Thank you – any questions?

Gayle Hagler
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