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The Hawai'i Volcanic Smog Network: Tracking air quality and community engagement near a major emissions hotspot

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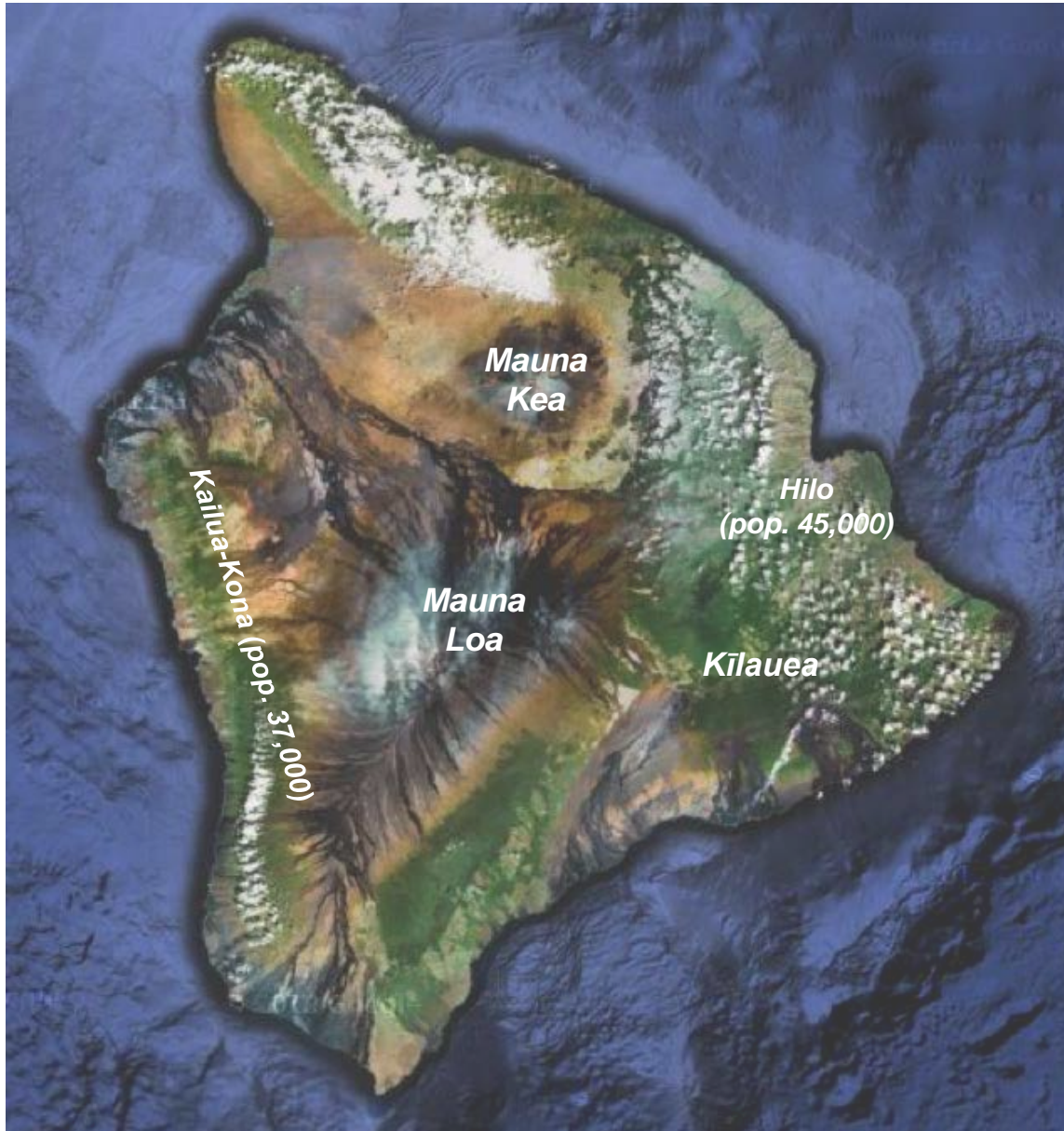


Outline



- 1) Background/motivation
- 2) Technical approach
- 3) Community partnership
- 4) Education
- 5) Preliminary results, next steps

Island of Hawai'i



pop. 198,000

30.2% White (Non-Hispanic)

21.6% Asian

0.8% Black or African American

0.6% Native American

12.6% Hispanic or Latino

13.0% Native Hawaiian

30.1% Two or more races

18.3% Persons in poverty

Air pollution

EPA's "Criteria Air Pollutants"

<https://www.epa.gov/criteria-air-pollutants>

- CO** carbon monoxide
- O₃** ground-level ozone
- NO₂** nitrogen dioxide
- SO₂** sulfur dioxide
- PM** particulate matter
- Pb** lead



Air pollution in Hawai'i (“vog”)

Sulfur dioxide (SO₂): Associated with respiratory problems, difficulty breathing

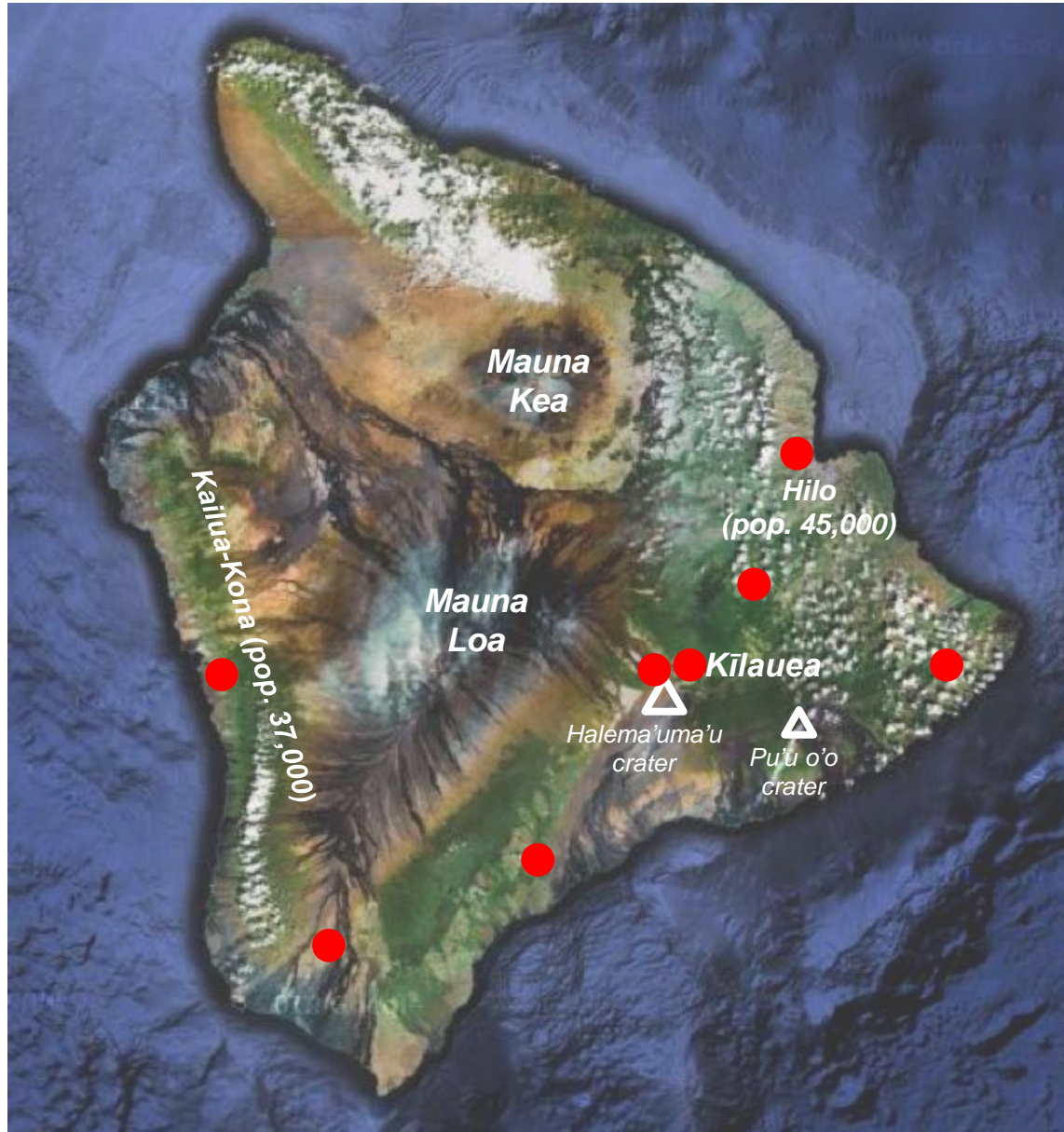
Oxidizes to form sulfuric acid (H₂SO₄), **particulate matter (PM)**

Kīlauea: ~3000 tonnes SO₂/day, ~1 megatonne SO₂/year

Anthropogenic emissions in U.S.: 5.7 megatonnes SO₂/year

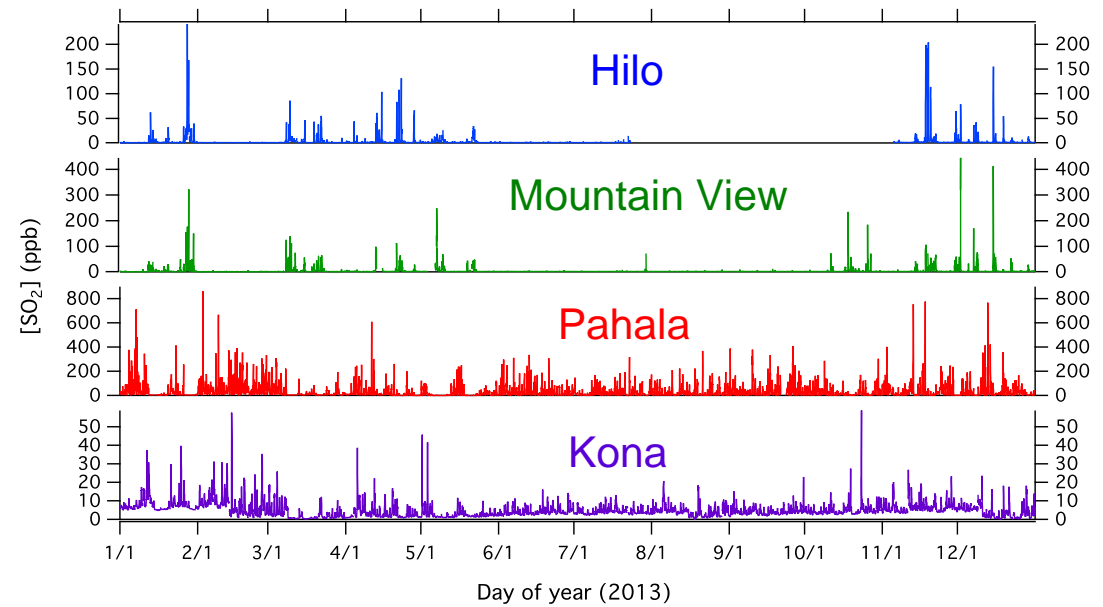
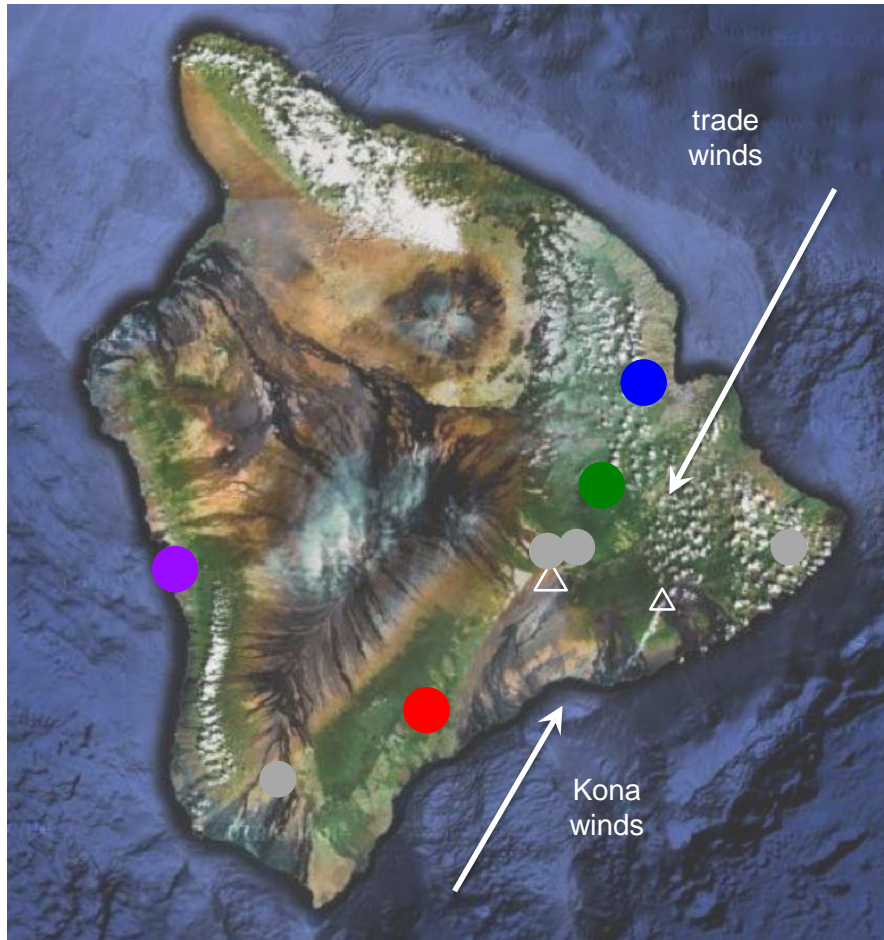


Current air quality monitoring



8 SO₂/PM monitoring sites
(6 Hawai'i Department of Health, 2 NPS/USGS)

Spatial, temporal variability



data from Hawaii Dept. of Health Air Quality stations

Current project: Hawai'i Island Vog Network

Develop, deploy sensor network for measuring volcanic SO₂, PM levels with high spatial, temporal resolution

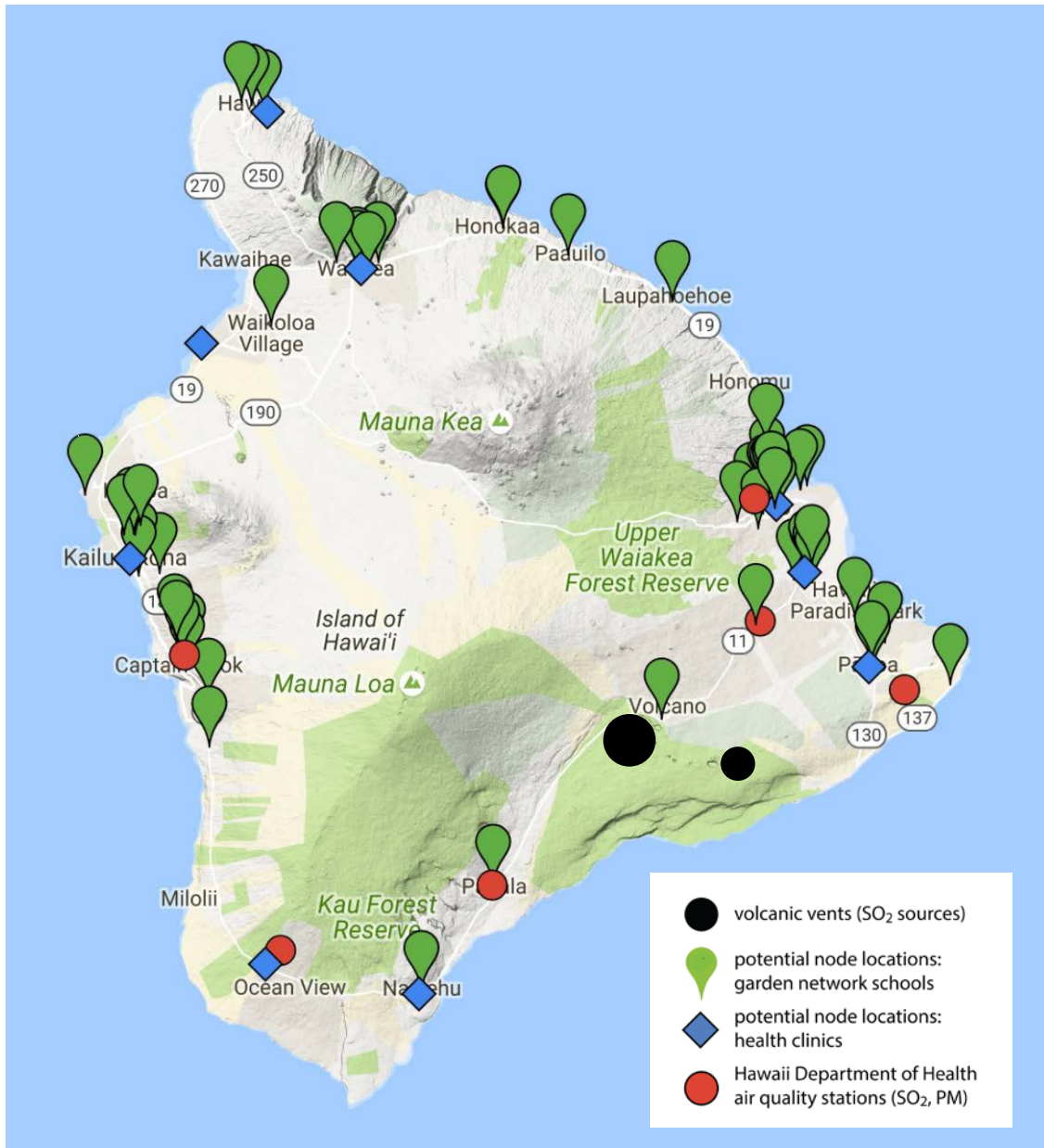
Real-time, web-based availability of data: for use by community members, educators, health professionals, researchers

Use of measurements for education: Hawai'i Island School Garden Network

Specific questions to address:

- how, when do people use air quality data?
- best-practices for sensor design, calibration, analysis?
- use of low-cost sensor networks be used as scientific, educational tools?

Hawai'i Island volcanic smog sensor network



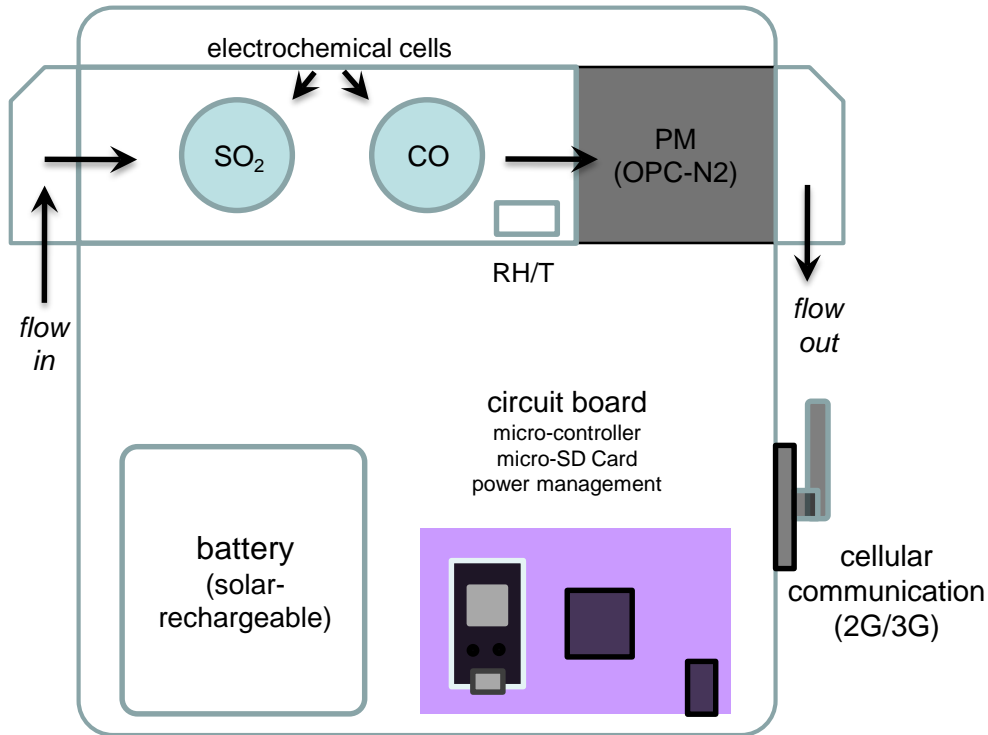
40 sensor nodes for measuring vog components and meteorological parameters

primarily located at schools (green pins), local health clinics (blue diamonds)

expected deployment: fall 2018

data sent in near-real-time to a server for access via a public web portal

Node design



Electrochemical cells for SO_2 and CO
(anthropogenic tracer)

Optical particle counter (OPC) for size-resolved
PM concentration (down to 380 nm)

Data sent via cellular network (2G/3G)
every 5 minutes

Solar panels, rechargeable battery: battery life
>1 day absent any recharge

Total cost (parts) ~\$1000

Calibration by co-location at Hawaii Dept. of
Health Air Quality Stations

Community partner: The Kohala Center

Independent, community-based center for research, conservation, and education (founded in 2000)



Main focus areas: food self-reliance, energy self-reliance, and ecosystem health

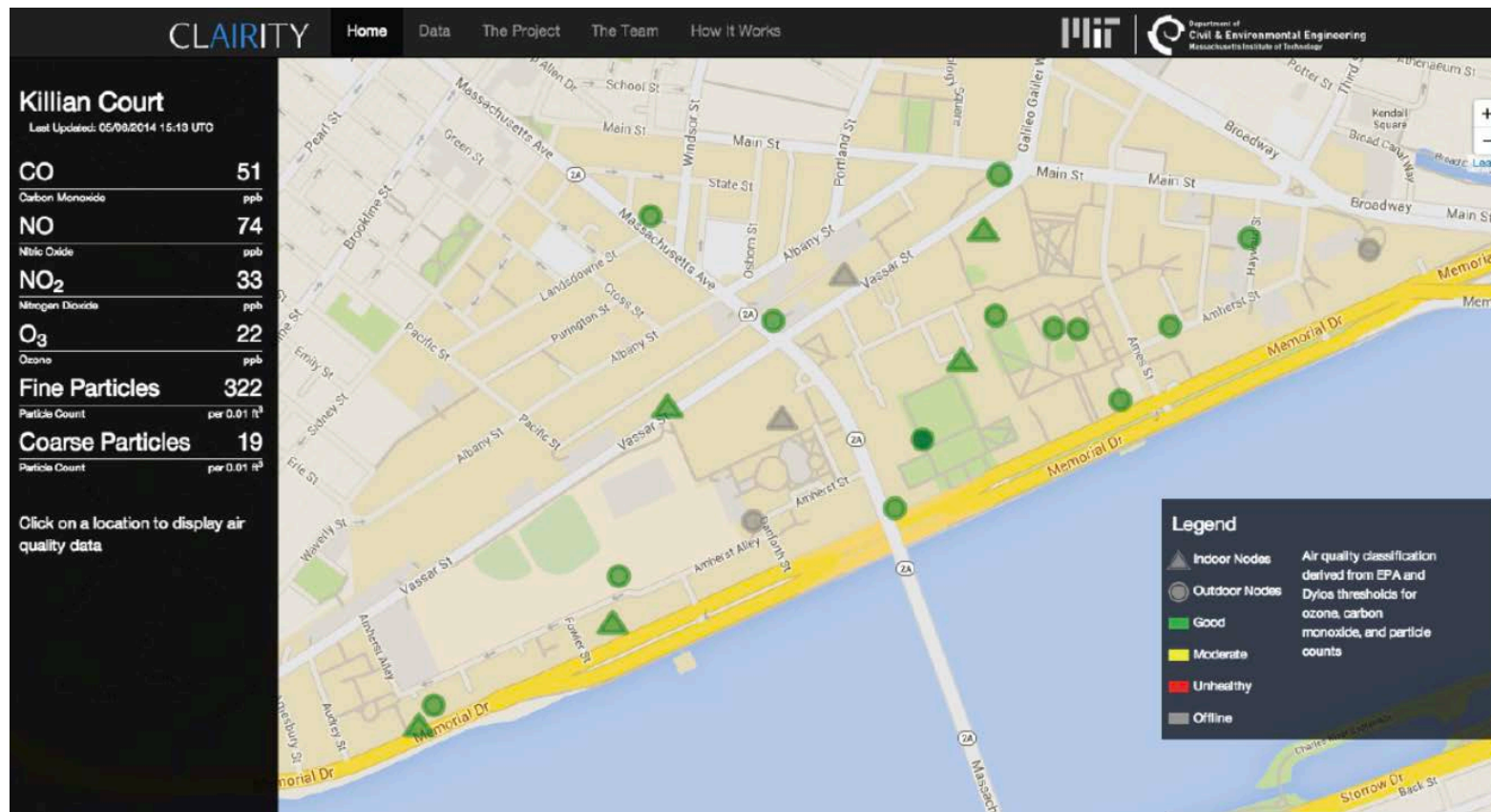
Efforts include: basic and applied research, policy research, conservation and restoration initiatives, public outreach and education; local, regional, national, and international partnerships.

Broad objective: development of a knowledge-based economy (research, ancestral knowledge), so that communities in Hawai'i and around the world can thrive ecologically, economically, culturally, and socially



Informing community members

Goal is to deliver quality information to the public so they can make decisions about the future of the island and its communities



example web portal: CLAIRITY network, Cambridge MA, 2014

TKC's Hawai'i Island School Garden Network

School garden program: participation of >60 schools (public, private, charter):
70 acres of gardens, ~15 tons food/yr

Students grow their own food, in turn helping them:

- develop a taste for healthy, fresh, locally grown fruits and vegetables
- learn about health and nutrition
- appreciate and practice environmental stewardship
- care for the island and its communities

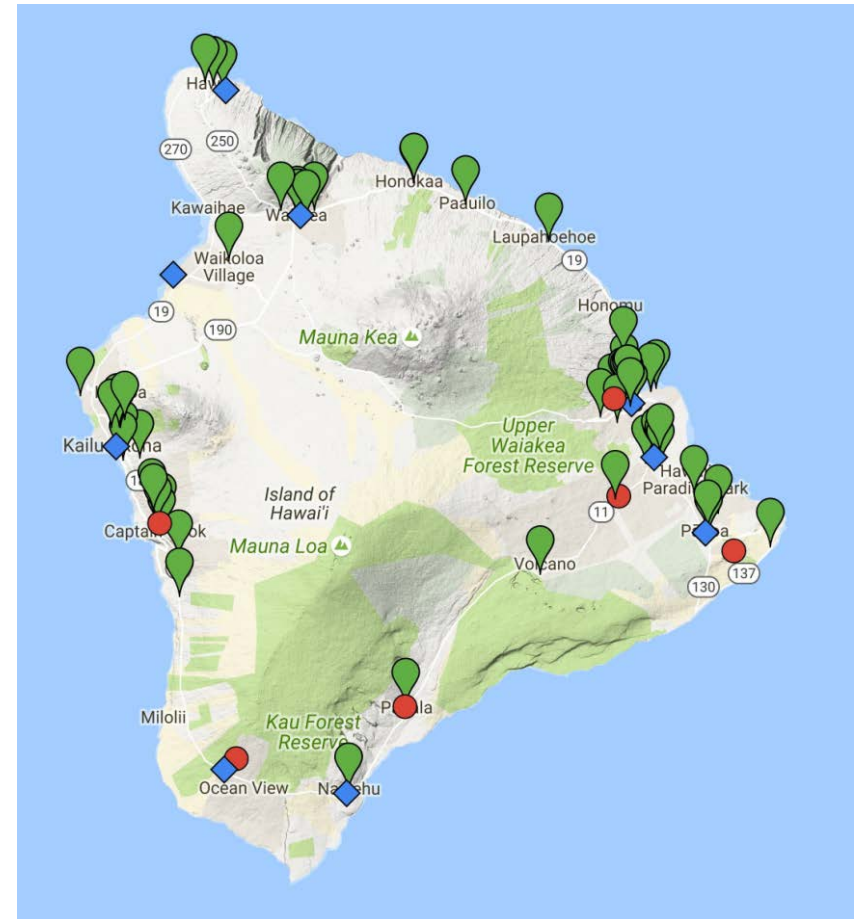


TKC-MIT partnership

The Kohala Center works closely with researchers in building partnerships with local communities and developing effective teaching and research programs

Partnership via School Garden Network:

- sensor nodes located in school gardens
- direct connection with educators, students
- local SO₂ measurements for schools (air quality alerts)
- data for educational purposes (air quality, agriculture, climate)



Science curriculum

MIT's Center for Environmental Health Sciences has extensive experience in science outreach and education:
Community Outreach Education and Engagement Core (COE²C),
Kathy Vandiver, Director



Activities include working alongside EPA's Region 1 Tribal Program (Michael Stover, program officer) with 5 federally recognized tribes in Maine

- tribal youth science programs
- professional development programs with teacher workshops
- talks, technical assistance for Tribal Environmental Conferences



MIT's "Atoms and Molecules" curriculum

Chemistry curriculum aimed at middle schoolers

Key concepts include: atoms, molecules, mixtures, chemical reactions, *important real-world chemical systems*










Aligns with Next Generation Science Standards

>500 sets distributed so far


<https://edgerton.mit.edu/molecule-set>


LEGO® Atom Key


Each LEGO brick is an atom:

Hydrogen (H)	=	
Sodium (Na)	=	
Calcium (Ca) or Magnesium (Mg)	=	
Iron (Fe) or Copper (Cu)	=	
Carbon (C)	=	
Nitrogen (N)	=	
Sulfur (S)	=	
Oxygen (O)	=	
Chlorine (Cl)	=	

Examples of LEGO molecules:


 CO_2


 H_2O


 N_2

LEGO® Atoms and Molecules: Atom Key and Layout Mat 2.0
More info at: <http://mindandhand.mit.edu/>

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Atoms and Molecules: Photosynthesis

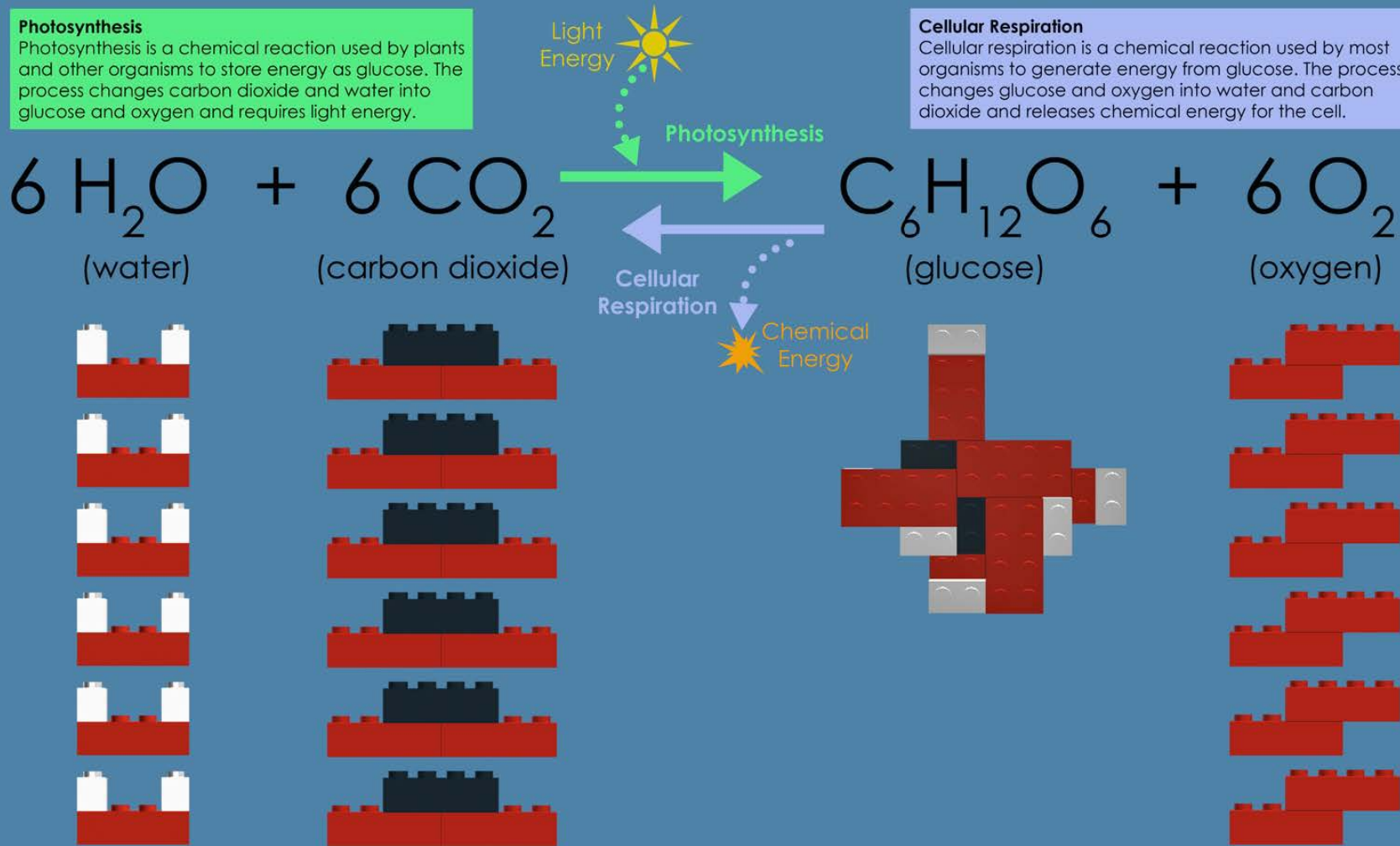
Photosynthesis and Cellular Respiration

Photosynthesis

Photosynthesis is a chemical reaction used by plants and other organisms to store energy as glucose. The process changes carbon dioxide and water into glucose and oxygen and requires light energy.

Cellular Respiration

Cellular respiration is a chemical reaction used by most organisms to generate energy from glucose. The process changes glucose and oxygen into water and carbon dioxide and releases chemical energy for the cell.



Atoms and Molecules: Understanding Air

Model the Molecules in Air

Build all the LEGO molecules and place them on their pictures:

20% O₂
oxygen

80% N₂
nitrogen

<1%
other gases, such as:

H₂O
water

CO₂
carbon dioxide
390 parts per million (ppm)

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Atoms and Molecules: Understanding Air

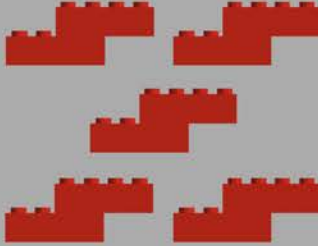
Burning Fuel
Complete Combustion

Side 1
Reactants


Combustion is a chemical reaction.
Build the fuel and oxygen molecules with LEGO bricks. Place them on their pictures.



C_3H_8
(propane)



$5 O_2$
(oxygen)



LEGO® Atoms and Molecules: Understanding Air
More info at: <http://www.chemistry.mt.edu/>

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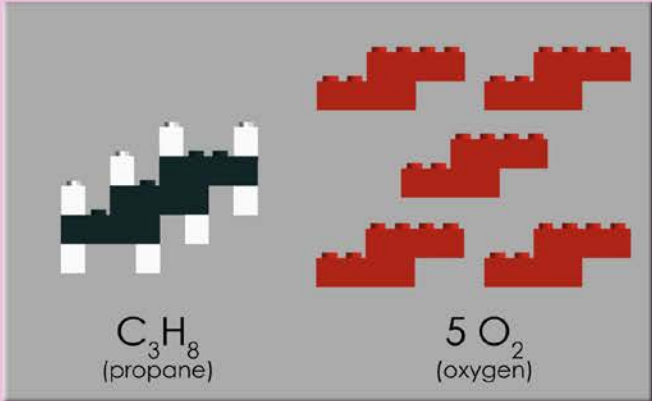
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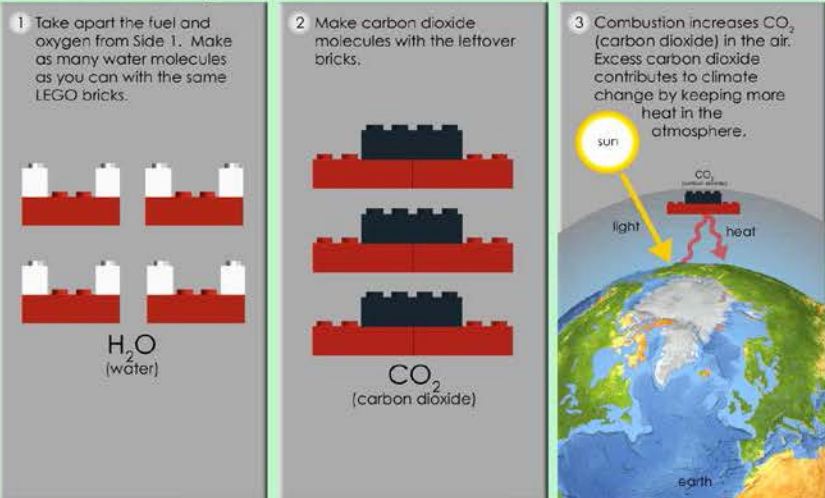
Burning Fuel

Complete Combustion

Side 2
Products

When there is plenty of oxygen available, fuel burns completely, producing only carbon dioxide and water.
This reaction is called **complete combustion**.

- 1 Take apart the fuel and oxygen from Side 1. Make as many water molecules as you can with the same LEGO bricks.
- 2 Make carbon dioxide molecules with the leftover bricks.
- 3 Combustion increases CO_2 (carbon dioxide) in the air. Excess carbon dioxide contributes to climate change by keeping more heat in the atmosphere.



H_2O
(water)

CO_2
(carbon dioxide)

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Atoms and Molecules: Understanding Air

Burning Fuel

Complete Combustion

Side 1
Reactants

Combustion is a chemical reaction.
Build the fuel and oxygen molecules with LEGO bricks. Place them on their pictures.

C_3H_8
(propane)

$5 O_2$
(oxygen)

→ (TURN OVER)

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Burning Fuel

Complete Combustion

Side 2
Products

When there is plenty of oxygen available, fuel burns completely, producing only carbon dioxide and water. This reaction is called **complete combustion**.

1 Take apart the fuel and oxygen from Side 1. Make as many water molecules as you can with the same LEGO bricks.

H_2O
(water)

2 Make carbon dioxide molecules with the leftover bricks.

CO_2
(carbon dioxide)

3 Combustion increases CO_2 (carbon dioxide) in the air. Excess carbon dioxide contributes to climate change by keeping more heat in the atmosphere.

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Burning Fuel

Incomplete Combustion

Side 1
Reactants

There are fewer oxygen molecules for this reaction.
Build the fuel and oxygen molecules with LEGO bricks. Place them on their pictures.

C_3H_8
(propane)

$4 O_2$
(oxygen)

→ (TURN OVER)

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Burning Fuel

Incomplete Combustion

Side 2
Products

When there is not enough oxygen available, fuel doesn't burn completely, producing not only carbon dioxide and water, but other products. This reaction is called **incomplete combustion**.

1 Take apart the fuel and oxygen from Side 1. Make as many water molecules as you can with the same LEGO bricks.

H_2O
(water)

2 Choose one box below and make the molecules with the remaining bricks.

$2 CO_2$ and C
(carbon dioxide and soot)

CO_2 and 2 CO
(carbon dioxide and carbon monoxide)

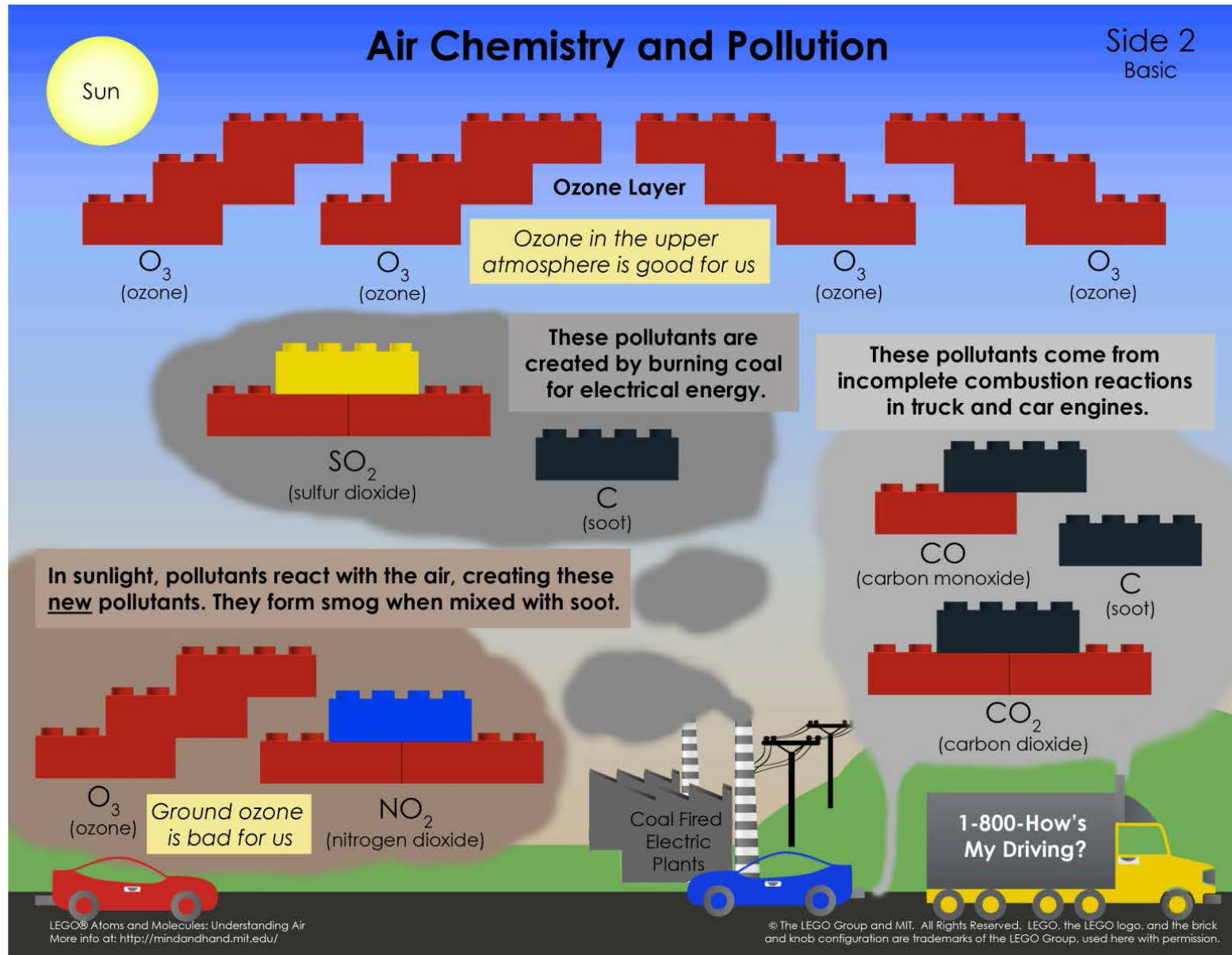
3 Incomplete combustion makes C (soot) or CO (carbon monoxide). Both are air pollutants and are bad for your health.

lungs

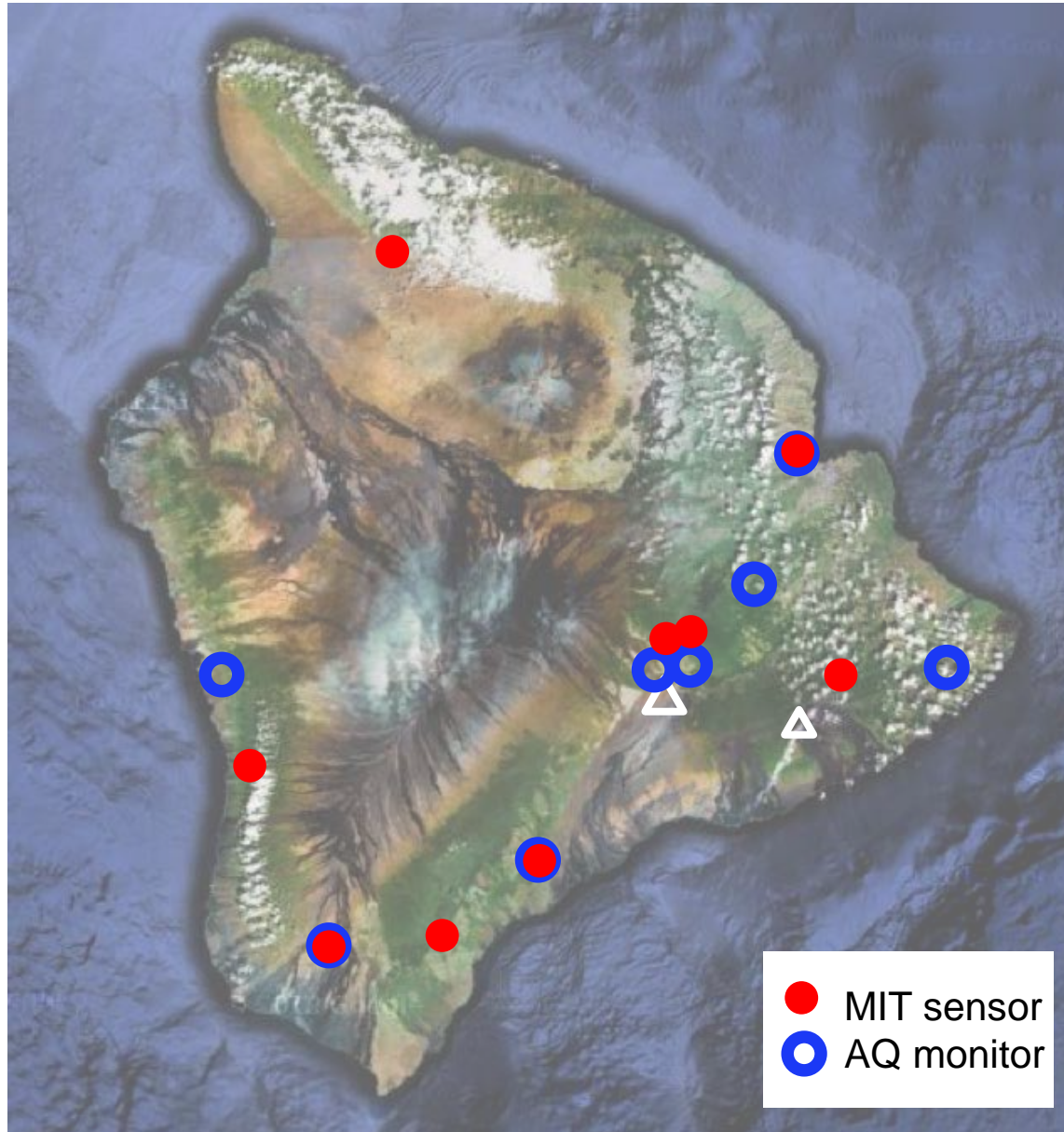
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Atoms and Molecules: Understanding Air



Initial SO₂ measurements

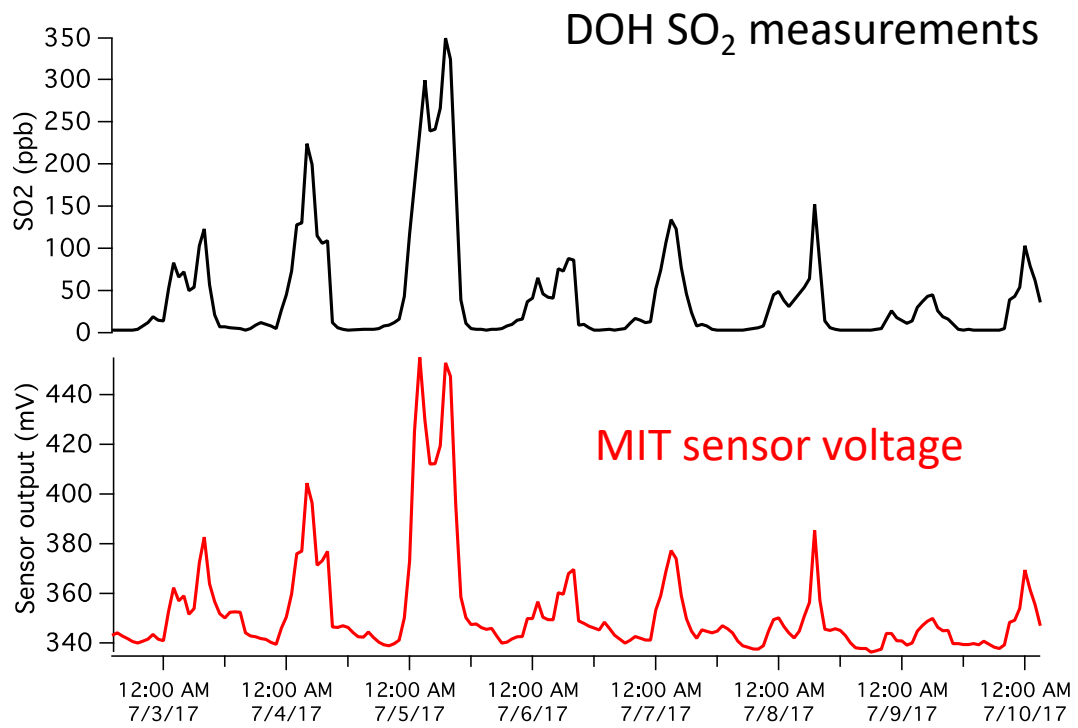


12 1st-generation nodes (SO₂ only) deployed starting Jan 2017

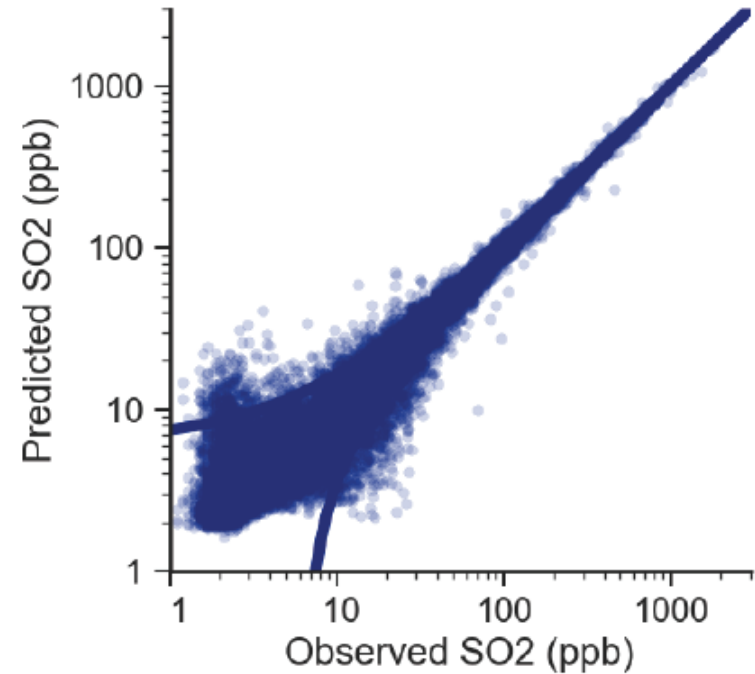
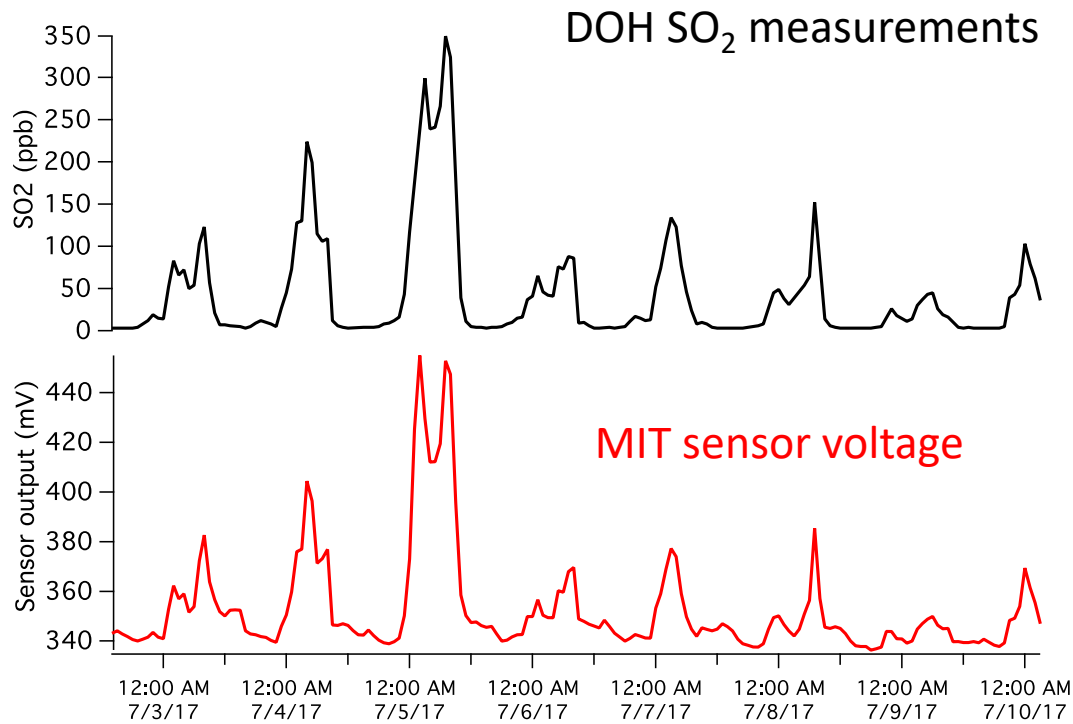
All were first co-located with DOH station; then distributed to various schools and DOH stations

Most are still running, providing info on sensor calibration and long-term performance

Sample SO₂ data



Sample SO₂ data



Excellent predictive power (to within 7 ppb SO₂)

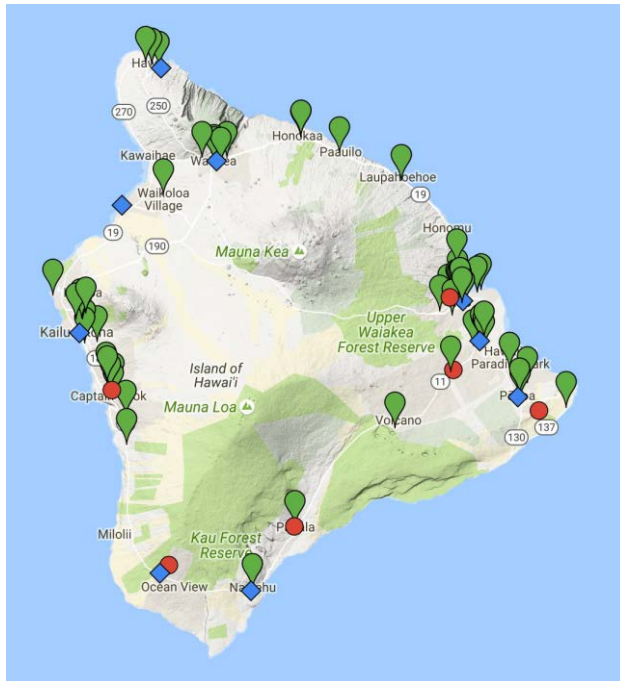
No evidence of degradation over ~6 months

Next steps

Fall 2017-spring 2018: Design next generation node (CO, PM, improved power management)

First formal teacher training in June 2018

Summer-Fall 2018: deployment of network, website launch



Summary/overview

- Volcanic smog (vog) is a major (natural) form of air pollution in the US
- High spatial, temporal variability; need for distributed sensing



- Planned sensor network will serve as a community resource, educational tool, testbed for air quality sensing
- Preliminary results: SO_2 measurements of high enough quality for such objectives

Acknowledgements/collaborators



MIT CEE: Colette Heald, David Hagan
Jon Franklin, Gabriel Isaacman-VanWertz



MIT CEHS: Kathy Vandiver



TKC: Betsy Cole, Donna Mitts, Nancy Redfeather



Hawaii Dept. of Health: Lisa Wallace

Teachers/Principals: Wendy Baker, Kalima Cayir, Ben Duke, Steve Hirakami, Darlene Javar, Chris King-Gates, Cindy Watarida

