The 2020 State of Air Sensors

TD ENVIRONMENTAL SERVICES

Air quality sensing, analytics, and insights

About Tim Dye

Tim Dye

Air Quality Sensor Expert

- Meteorologist
- Thought leader in air sensors and Internet of Things (IoT) technologies
- Visionary that's created innovative air quality applications both domestically and internationally

Our Solutions

- Market insights
- Study design
- Data management
- Analytics
- Training & mentoring
- Capacity building

Clients

EDF Environmental Defense Fund – Finding the ways that work

Bay Area Air Quality Management District

Bloomberg Philanthropies

World Resources Institute

Denver – The Mile High City

NGK Spark Plugs / NTK Technical Ceramics – NGK Spark Plugs (U.S.A.), Inc.

OKAPI

SHAKTI Sustainable Energy Foundation

United States Environmental Protection Agency

ADB

intel

C40 Cities – Climate Leadership Group

The State of Air Sensors 2020

Outline

1. Background on Measurements
2. 2020 Events and State of the Market
3. Projects
4. Predictions

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Localized air information is powerful

Health

Personal, localized data provide information and insights that enable individuals, cities, and government to make informed decisions.

Policy

More local data helps implement better policy to improve public health. Research using sensor data discovers new insights that affect public policy.

Economic

A new source of data saves money (lower manufacturing costs), generates revenue (insurance savings), incubates new companies (sensor startups), and creates new data & information companies.

Types of Measurement Systems

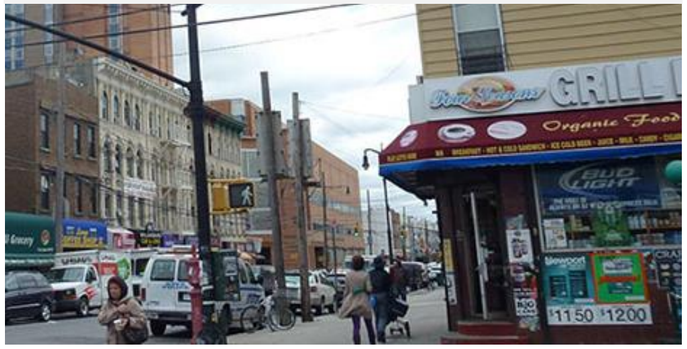
	Reference Instruments	Portable Instruments	Air Sensors
Cost	$20,000 +	$5,000 - 15,000	$200 – 3,000
Ease of use	Expert	Expert	Anyone
Accuracy	Very accurate	Accurate	Varies
Data produced	Little	Moderate	Lots

Modes of Monitoring

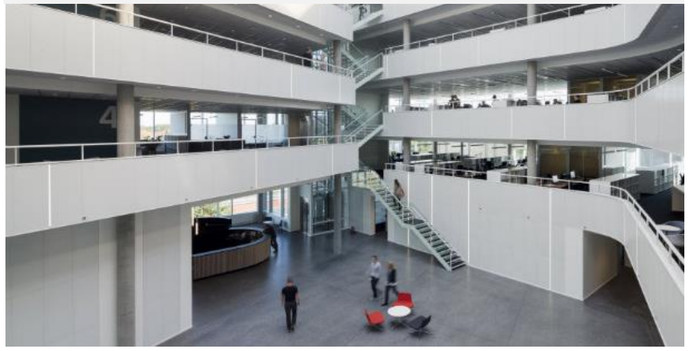
Type	Coverage	Location

Fixed

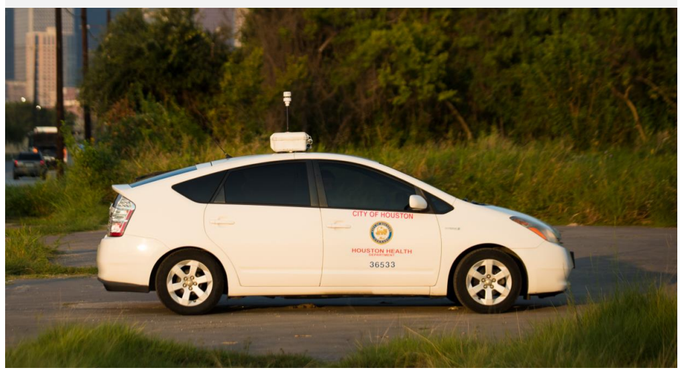
Area



Indoor



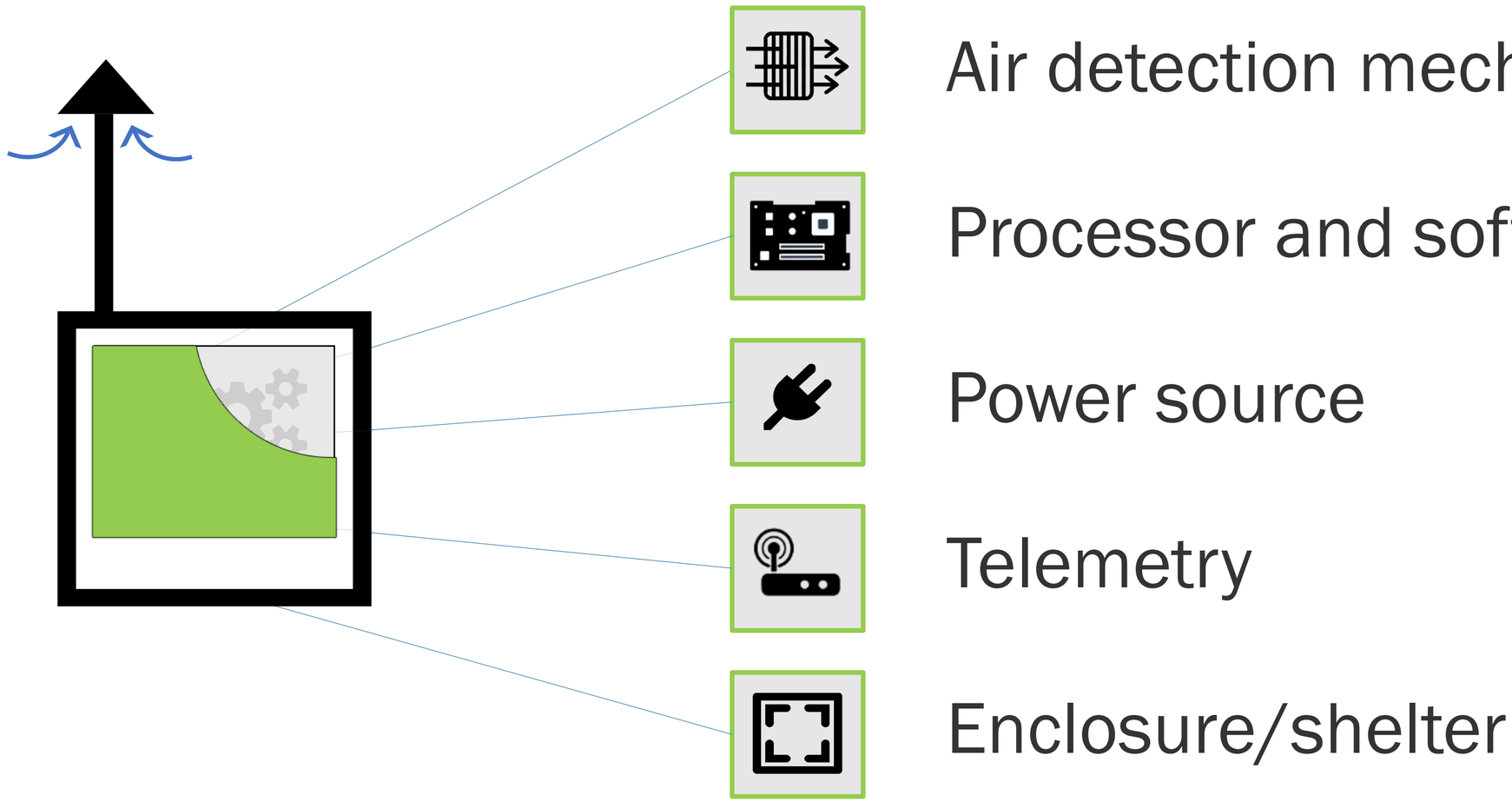
Mobile Platforms



Personal

Outdoor

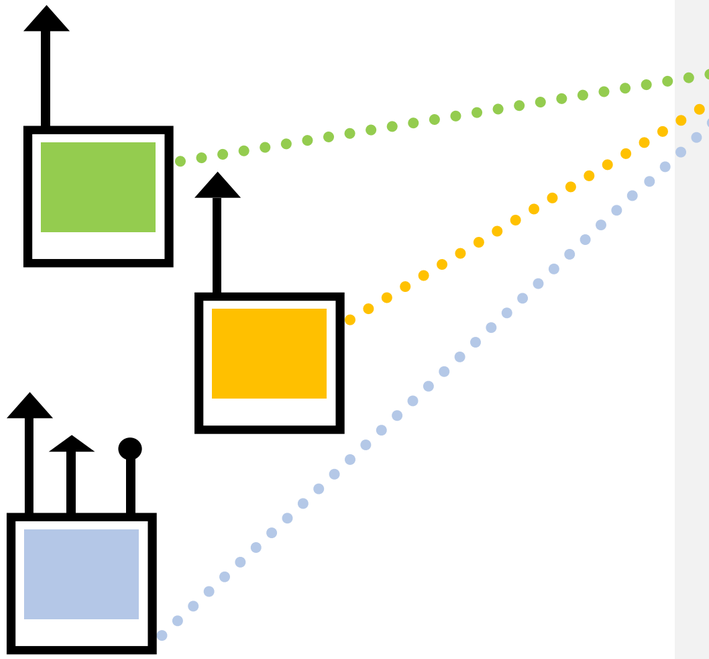
Air Monitor Components



- Air detection mechanism
- Processor and software
- Power source
- Telemetry
- Enclosure/shelter

Air Monitor System Components

Air Monitors



Central Location

Data management

Staff

Procedures

Data analytics

Distribution

Air Sensor Performance

	Accurate	Reliable
Particulate Matter	✓	✓
Ozone and Nitrogen Dioxide	✓	✓
Carbon Monoxide	✓	✓
Sulfur Dioxide	?	?
Hydrocarbons & VOCs	?	✗
Toxics	✗	✗

Applications

Organization	Application: Health	Application: Regulatory	Application: Economic
Research (Academia/NGOs)	✓	–	○
AQ Agencies (Gov't)	✓	○	○
Consumer	✓	–	○
Industry/manufacturing (Business)	○	○	○
Agricultural	○	○	○
Building management	○	○	○
City management	✓	○	○
Transportation	○	○	○
Health care	○	○	○
Real Estate / Insurance	○	–	○

Air sensor use

- ✓ Current
- ○ Near-term
- ○ Long-term

Major Events in 2020

TRUST

Quality of sensors improves

Major Events in 2020

TRUST

Quality of sensors improves

More focus on performance standards

Major Events in 2020

TRUST

Quality of sensors improves

More focus on performance standards

Lots of evaluation projects

Academia

Evaluation Centers

NGOs

Major Events in 2020

TRUST

- Quality of sensors improves
- More focus on performance standards
- Lots of evaluation projects
- Methods to “calibrate” sensors emerge

Major Events in 2020

Applications

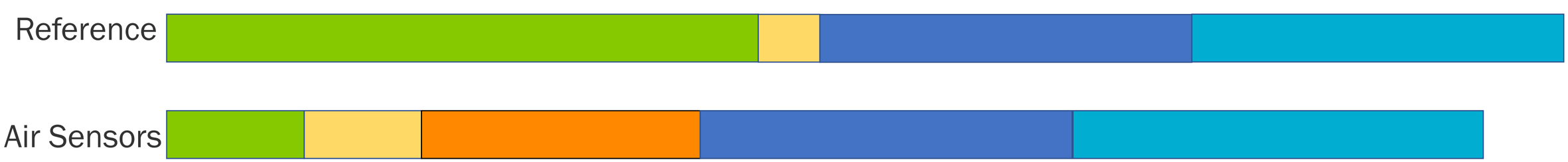
Applications expanding – hybrid networks

Major Events in 2020

Applications

Applications expanding – hybrid networks

Not so “low-cost” solutions



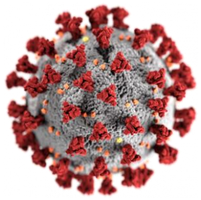
Hardware Software Quality Demo Operations Analysis & Interpret

Major Events in 2020

Applications

- Applications expanding – hybrid networks
- Not so “low-cost” solutions
- Open data and software emerging
- Events drive awareness

Major Events in 2020



Inequities exist & exposure to poor air quality increases the potency of COVID-19

Noticeable & convincing proof that air quality can improve

Widespread, low-cost, easy to administer monitoring is required for decision making

Real-time, precision public health data helps create tailored local or regional actions

People act when it’s clear their health will be negatively affected

2020 Market Challenges

- Experience and capacity building
- VOC/SO_2 sensor not accurate; yet needed
- Performance standards & high quality data
- Insufficient analysis tools/systems
- No data standards exist
- Mobile data still challenging to use
- Funding
- Linking data to policy

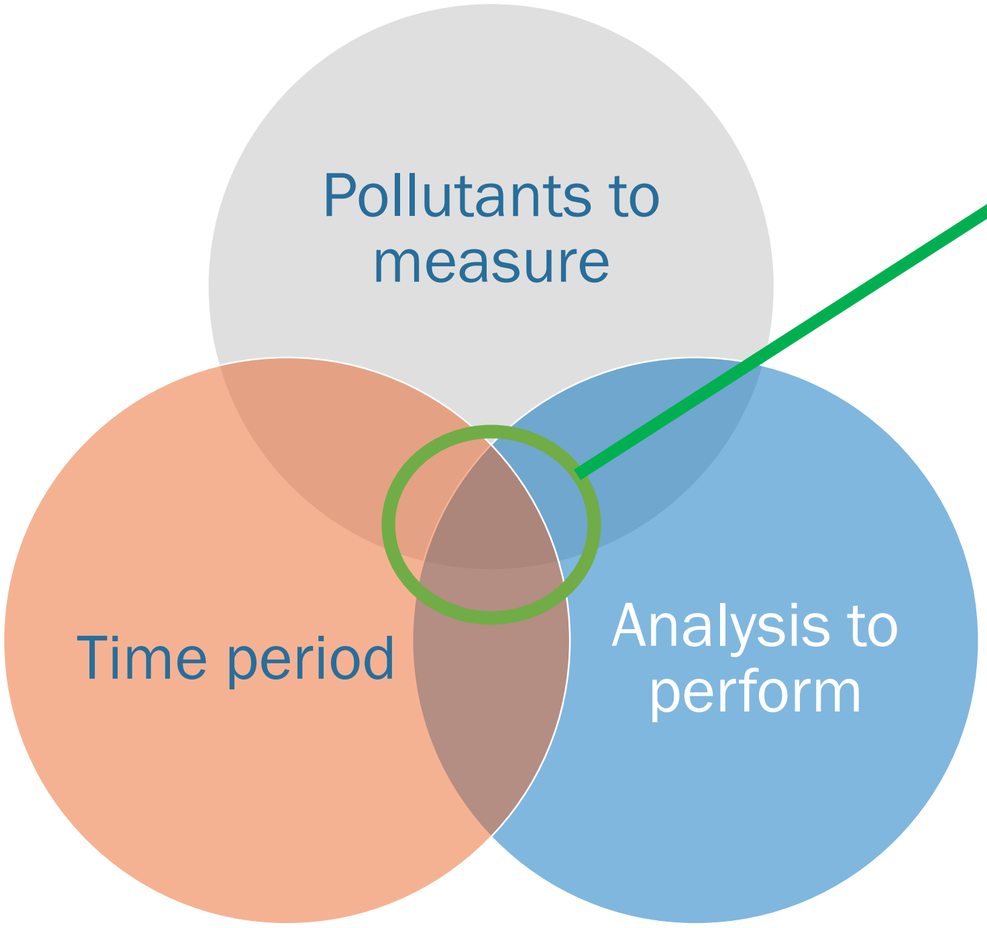
Initial Questions

My questions for you

1. What's the best, surprisingly good project that you've seen using air sensors?
2. What is the single most important need right now?
3. What is most frustrating about air sensors?

Enter your answers in the Chat Box. Include your name and organization.

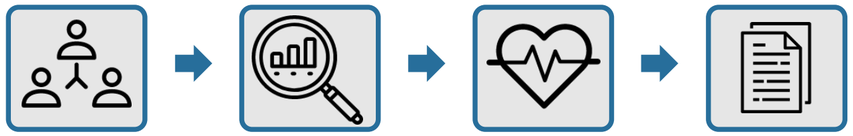
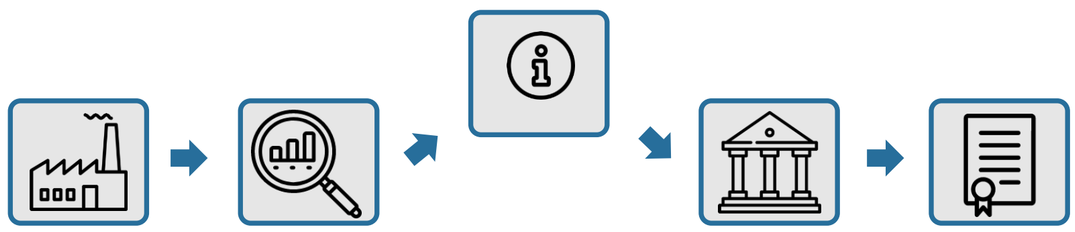
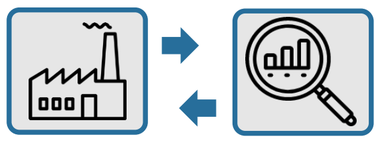
Applications – Sensor Selection



A sensor must:

- Measure the pollutant of concern with sufficient accuracy and precision.
- Measure at the desired temporal resolution and over a time period.
- Meet the needs of the analysis to be performed.

Pathways to Action with Air Quality Data

		Duration	Role for Sensors
1 Health Study		5-20 Years	Emerging
2 Regulate		3-5 Years	Not yet
3 Find & Fix		Months to Years	Yes
4 Public Pressure		Months to Years	Yes

Applications for Air Sensors

2014 Applications

1. Public education
2. Process study research

Today's Applications

1. Air quality forecasting
2. Air quality index reporting
3. Community near-source monitoring
4. Control strategy effectiveness
5. Data fusion
6. Emergency response
7. Epidemiological studies
8. Exposure reduction (personal)
9. Hot-spot detection
10. Model input
11. Model verification
12. Process study research
13. Public education
14. Public outreach
15. Regulatory and policy support
16. Source identification
17. Supplemental monitoring

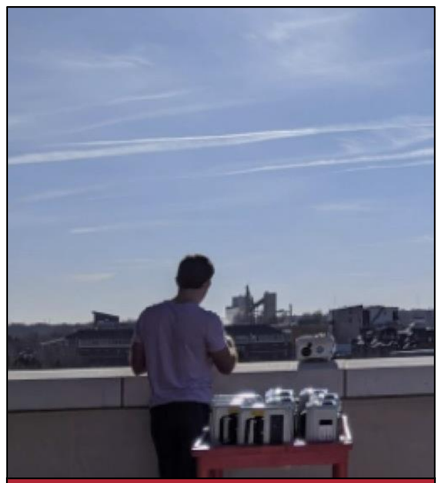
Projects

Juneau, AK

Many Co’s

London

U.S.



London

Case Study

Cruise Ship Emissions

Alaska, DEC
Juneau, Alaska

Challenges

- Juneau pristine location with visible emission source
- Public complaints regarding cruise ship emissions
- Needed a “saturation study” with lots of monitoring sites

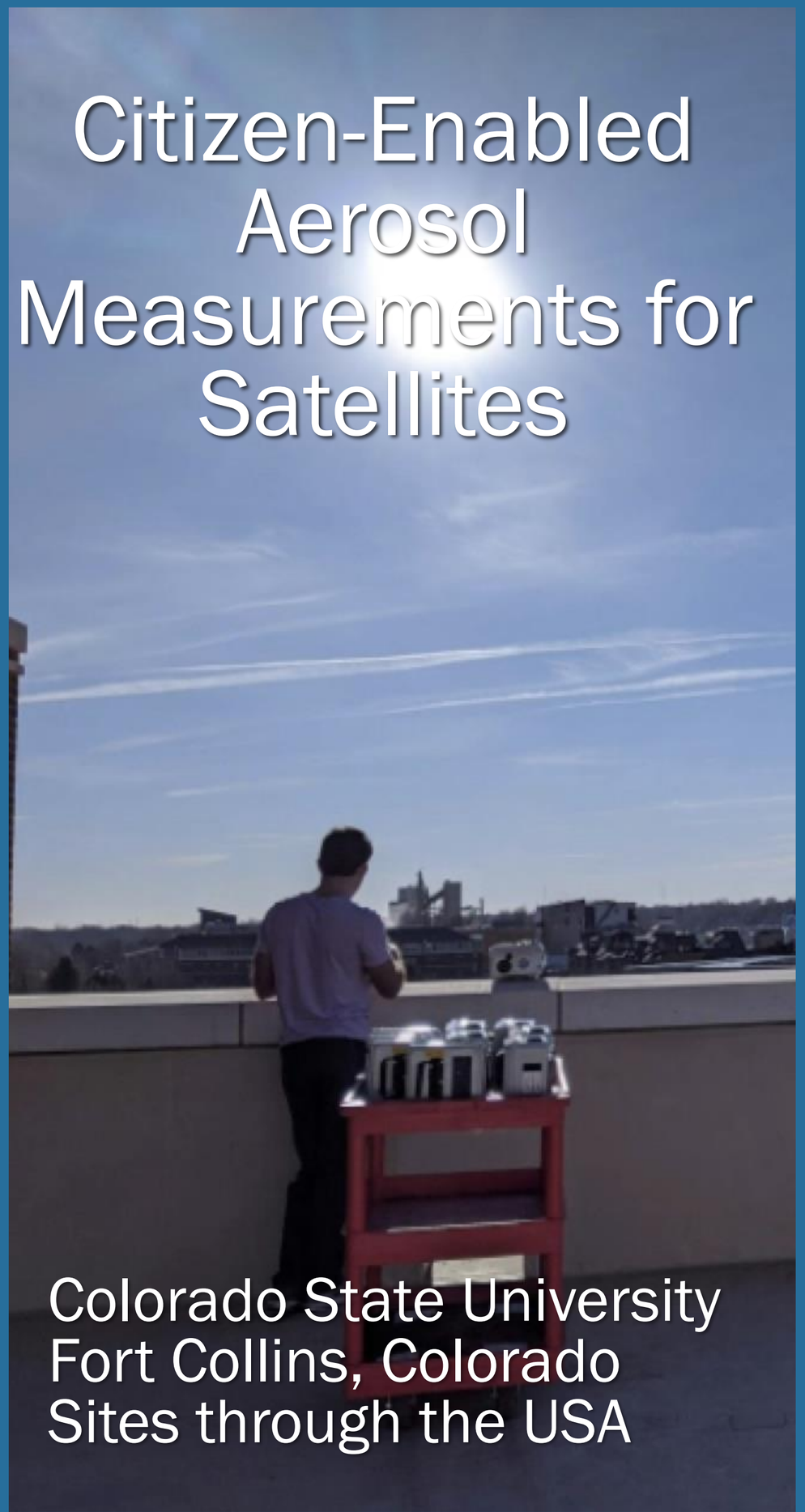
Cruise Ship Emissions

Solution

- Hybrid network of
  - $PM_{2.5}$ air sensors and passive SO_2 samplers
  - Meteorological stations
  - Web cameras
- Collocation with reference station
- Results
  - The air sensors were able to detect air quality impacts from ship emissions.
  - Strong evidence cruise ships had short term impacts on air quality in downtown Juneau, there is no evidence that the impacts would have led to 24-hour $PM_{2.5}$ violations of the NAAQS.

Source: https://dec.alaska.gov/air/air-monitoring/juneau-cruise-ship-monitoring-project/

Citizen-Enabled Aerosol Measurements for Satellites



Colorado State University
Fort Collins, Colorado
Sites through the USA

Case Study

Challenges & Goal

- Need more space-ground validation for NASA Aerosol Optical Depth (AOD) measurements
- Transitional photometers are expensive
- Collect measurements in different locations and improve our understanding of local air quality.
- NASA-funded project is led by John Volckens at Colorado State University

Source: csu-ceams.com & www.atmos-meas-tech.net/12/6385/2019/

Citizen-Enabled Aerosol Measurements for Satellites

Solution

- CSU Aerosol Mass and Optical Depth (AMOD) Monitor
- Includes:
  - Four wavelength sun photometry measurements
  - Dual axis solar tracking using stepper motors
  - Integrated gravimetric filter measurement with $PM_{2.5}$ inlet and mass flow sensor/control
  - Time-resolved PM monitor (Plantower PMS5003)
  - Custom cartridges for filter handling
- Specifications
  - Weather-proof enclosure
  - Wi-Fi connectivity for remote data transfer
  - 120Ah internal battery (also runs via solar power or 100-220V 50-60Hz AC input)
  - Compact design (10in x 10in x 8in, 8lbs)

Source: csu-ceams.com & www.atmos-meas-tech.net/12/6385/2019/

Citizen-Enabled Aerosol Measurements for Satellites

Lessons Learned

- AOD can sometimes be high even when $PM_{2.5}$ is low due to elevated smoke not at ground
- Demonstrated that cold nights in Colorado have higher PM which is not seen during the day (and missed by satellites).
- PM sensor often off by 25-50%
- Engagement - very popular with citizen scientists. Some gave their unit a pet name and expressed serious concern about leaving their unit out in the snow and rain!

Source: csu-ceams.com & www.atmos-meas-tech.net/12/6385/2019/

Case Study

Challenges

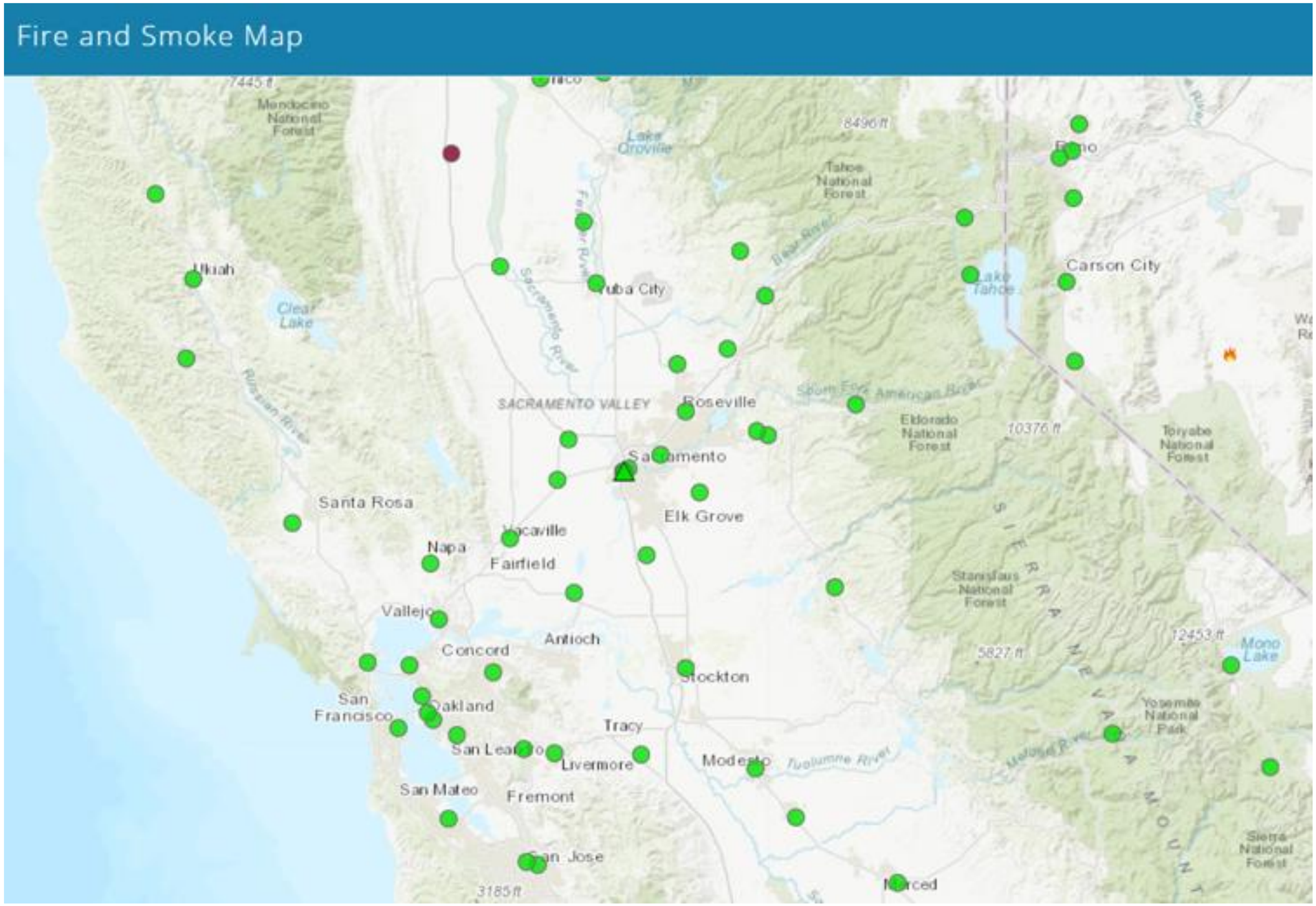
- Wildfire smoke increasing in frequency
- People want information on their air quality, especially during fires
- Lots of data sources/websites (conflicting information and public confusion)
- Private sector AQIs differ from the US AQI

Goal

- Goal is to 1) provide the public with additional air quality information and 2) use air sensor data to improve coverage

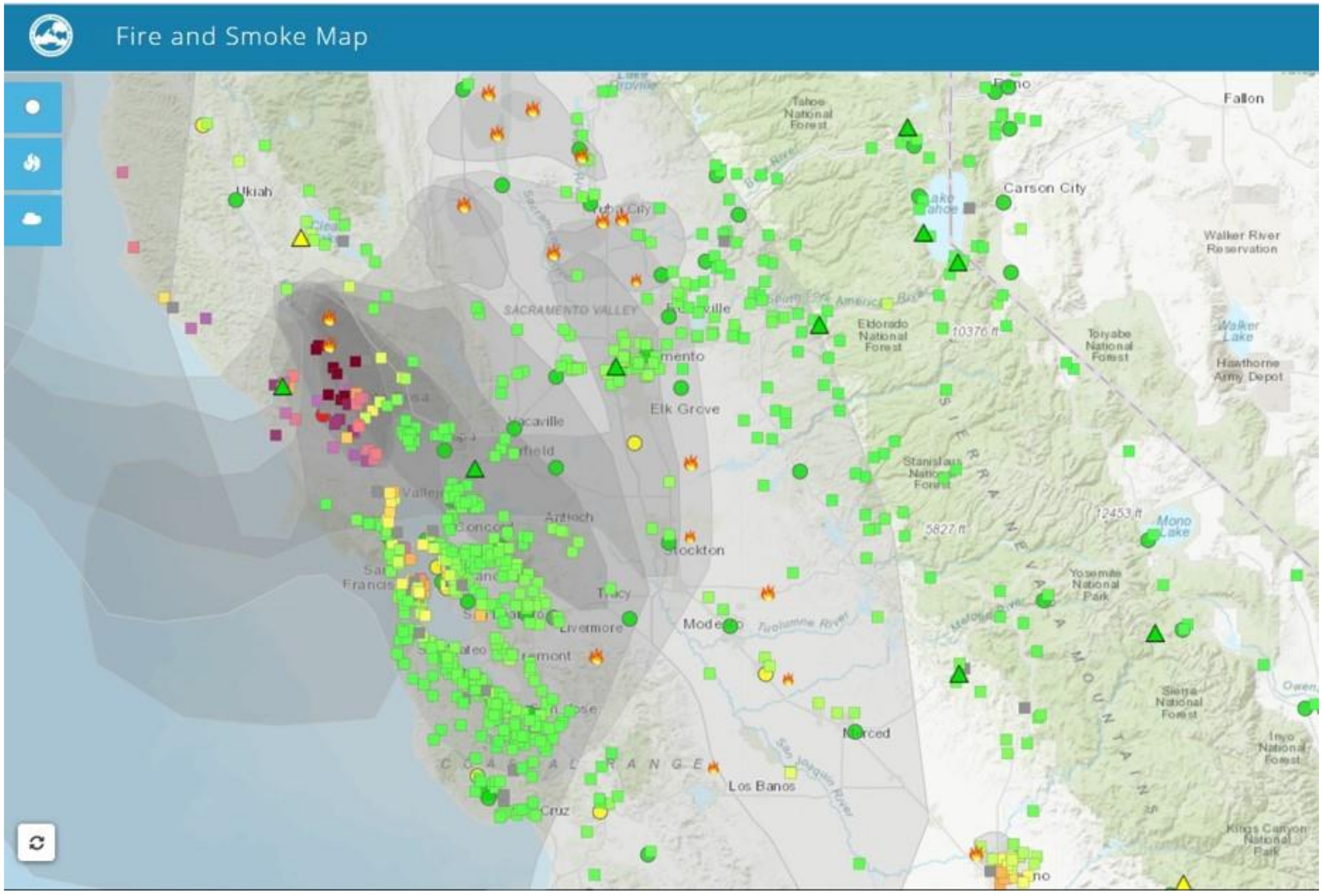
Source: U.S. EPA's AirNow program

AirNow Data Fusion



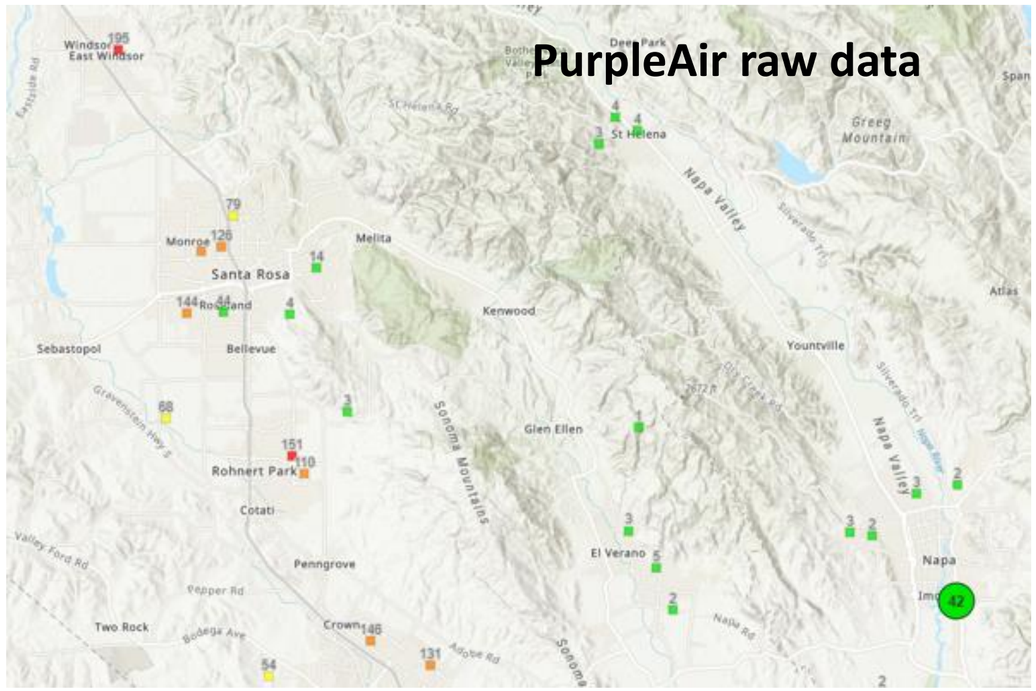
Source: U.S. EPA's AirNow program

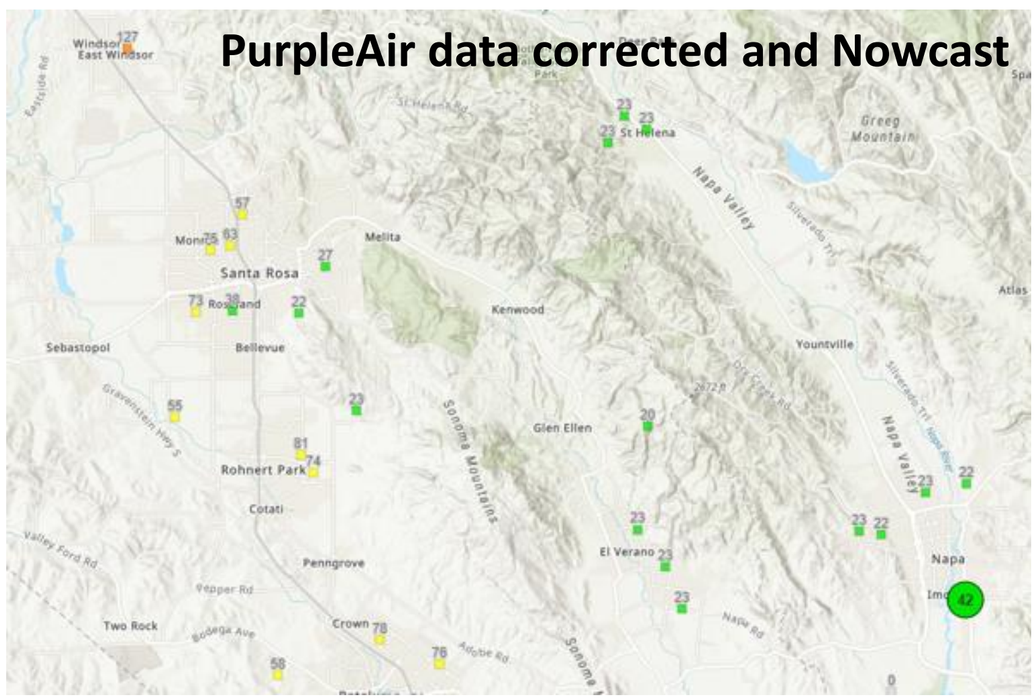
AirNow Data Fusion



Source: U.S. EPA's AirNow program

AirNow Data Fusion





October 30, 2019

Solution

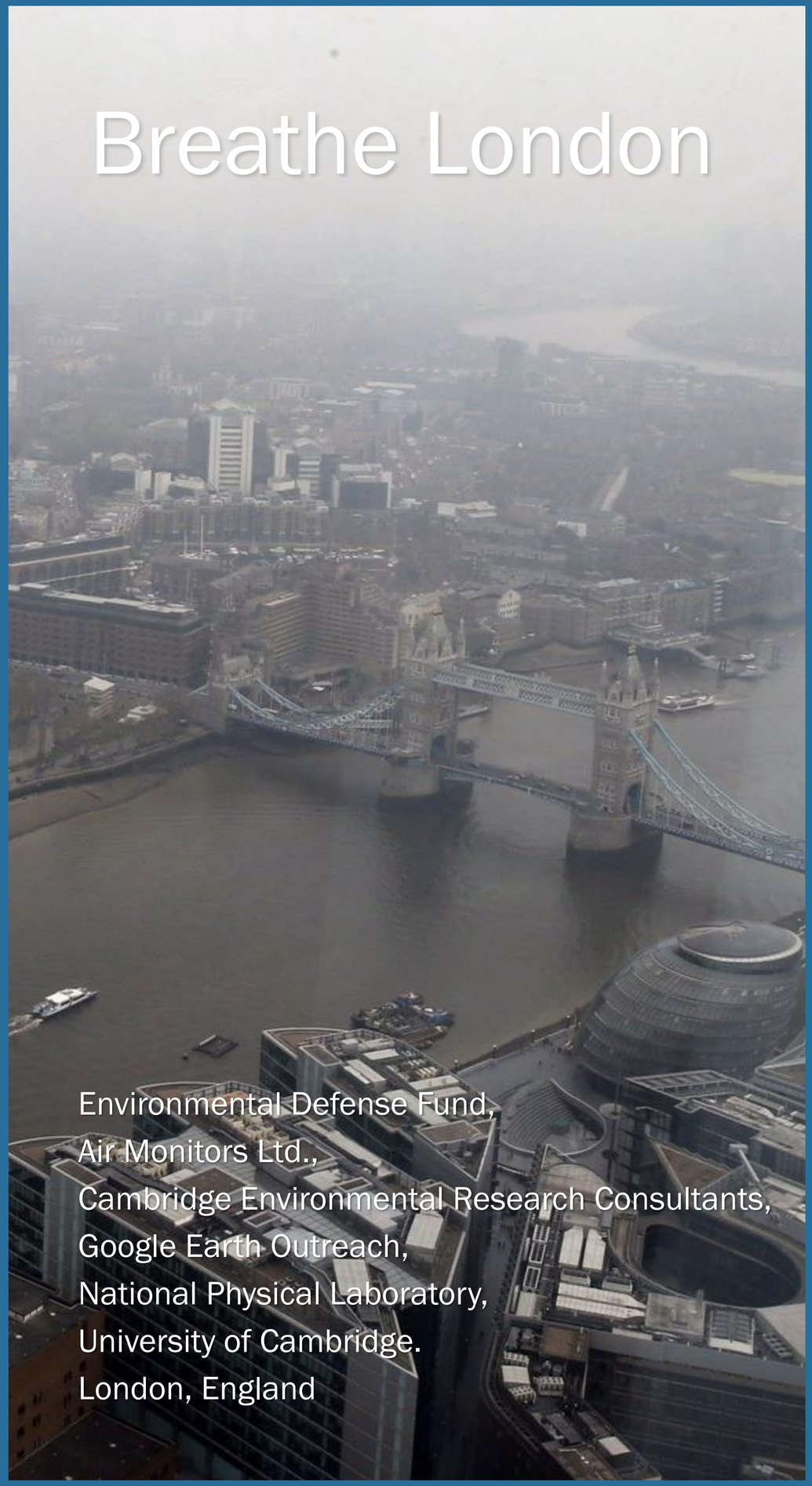
1. Access PurpleAir data
2. Average 2-min sensor data to 1-hr
3. Apply EPA national correction

   $PM_{2.5}$ corrected = 0.534*[PA_cf1(avgAB)] - 0.0844*RH +5.604 (Note: final algorithm will be updated)
4. Apply EPA $PM_{2.5}$ Nowcast algorithm (relates hourly readings to the AQI)
5. Add air sensor data (corrected) to the Fire and Smoke map on AirNow

Source: U.S. EPA's AirNow program

Case Study

Breathe London



Challenges

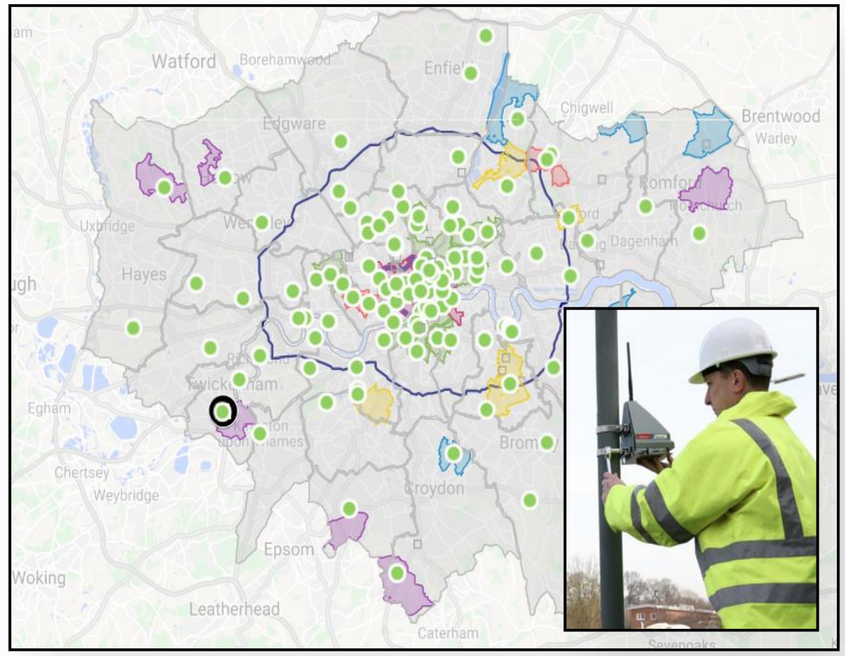
- Pollution contributes to over 3,500 deaths ($PM_{2.5}$) and 5,800 (NO_2)
- Results in £3.7 billion in health care costs
- How to measure and link to policy

Source: https://www.breathelondon.org

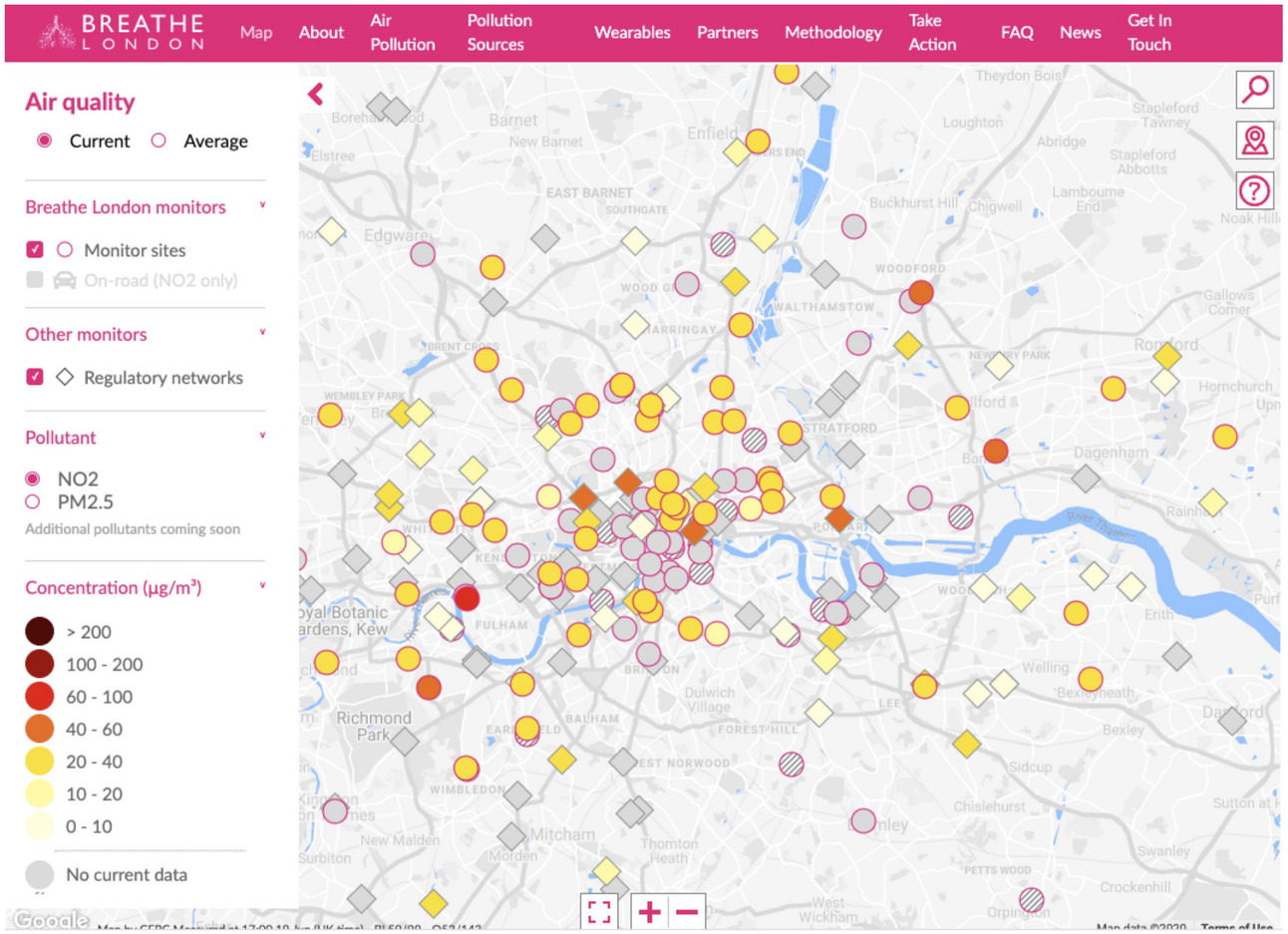
Hyperlocal London AQ Pilot

Solution

1. Fixed air sensors
   - 100 lamp-post mounted continuous monitors (AQ-Mesh Pods)
   - NO, NO_2, CO_2, PM_{10}, $PM_{2.5}$, PM_1, O_3
2. Mobile air monitoring
   - Two Google Street-view vehicles instrumented with reference-grade monitors
   - Measurements of BC, UFPs, $PM_{2.5}$, NO, NO_2, CO_2, O_3
3. Personal air sensing



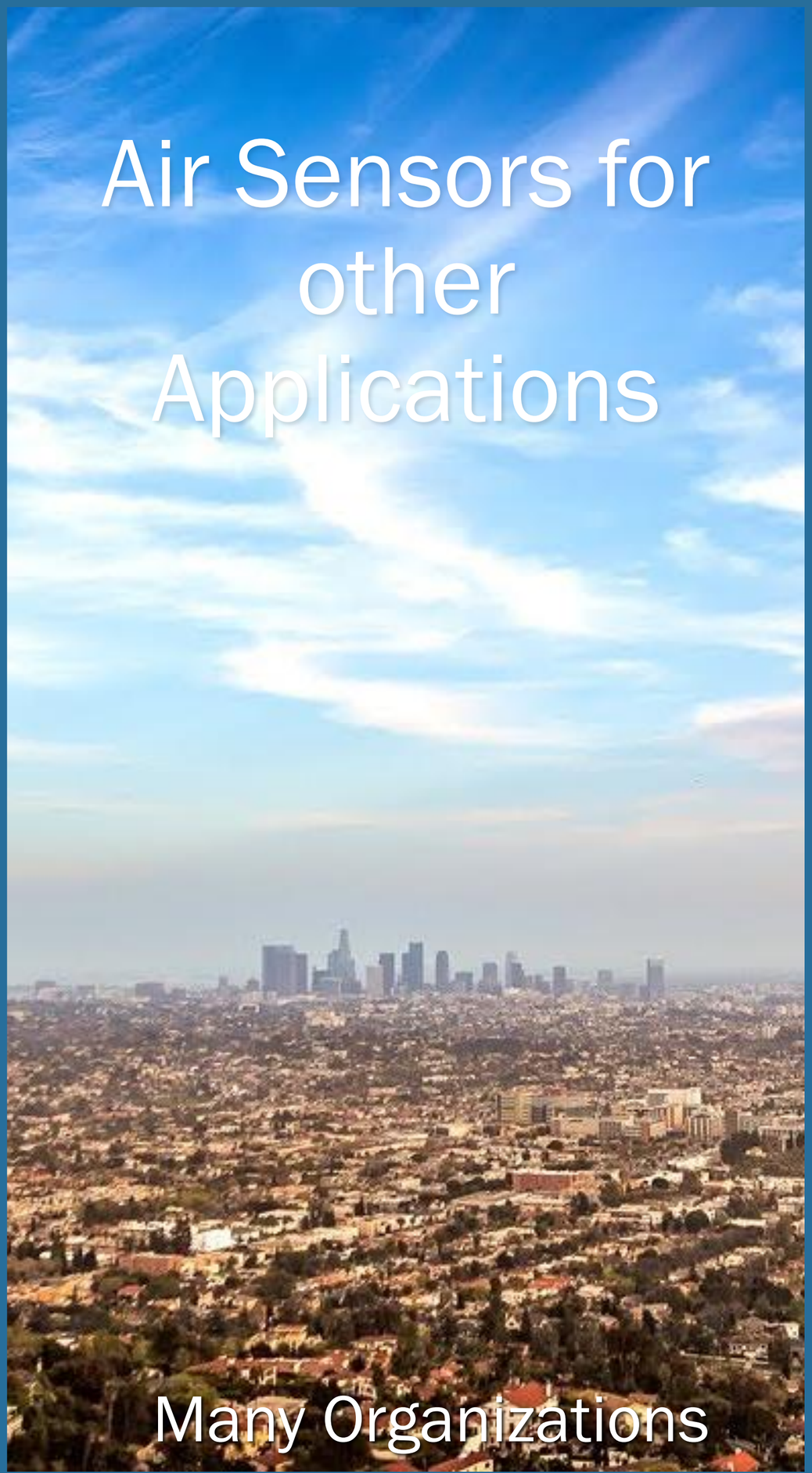
Hyperlocal London AQ Pilot



Outcomes

- Open data
- General guidance and ‘lessons learned’ from a hybrid network
- Source attribution techniques using lower cost monitors
- Calibration algorithms for air sensor networks for geographies with limited reference networks
- Machine learning techniques to quantify measurement uncertainty
- Mobile monitoring techniques

Research



Purpose

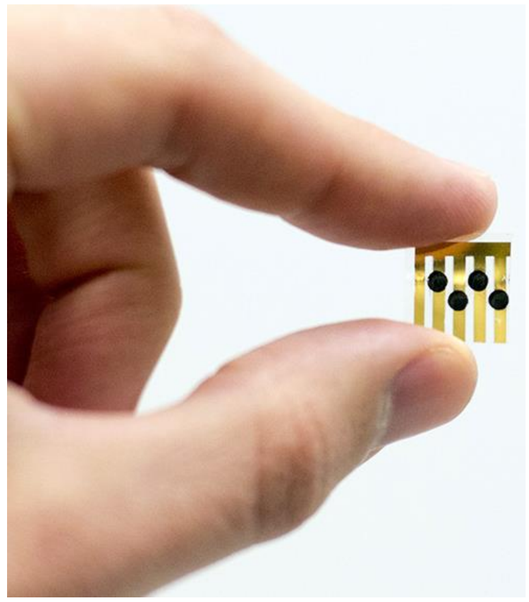
- Companies developing low-cost sensors for a range of applications
- Larger markets create larger R&D budgets to develop products
- Air quality community benefits from this derivative development

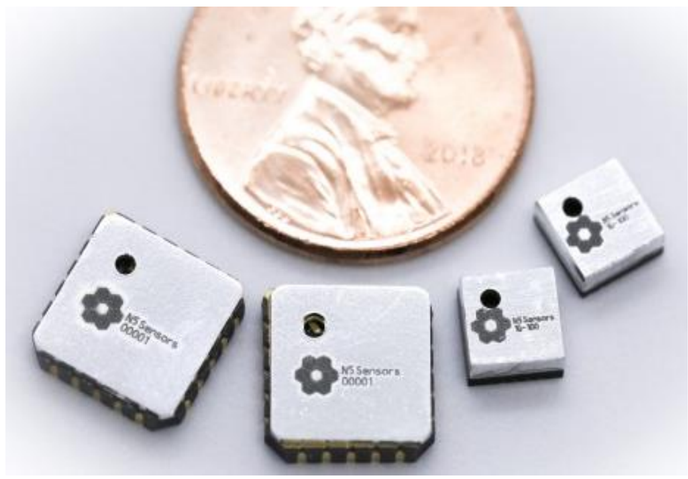
Air Sensors for other Applications

Some activities

Sensors for

- air purifiers
- food safety
- industry/processes





Azzarelli, J. M.; Mirica, K. A.; Ravnsbæk, J. B.; Swager, T. M. Wireless Gas Detection with a Smartphone via RF Communication. Proc. Natl. Acad. Sci. U. S. A. 2014, 111, 18162−18166.

Predictions

- Sensors improve
  - PM sensors continue to perform better
  - VOC sensors emerge
- More focus on data
  - Sensor data used for litigation
  - Ownership issues
- Open data and analysis software emerges
- Applications (hybrid) continue to flourish
- More focus on data interpretation
- Indoor market for air sensors grows rapidly

Contact Information

Air Quality Experience and Knowledge you can count on

We look forward to connecting with you.

Contact

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