

Feasibility of Using Low-Cost PM_{2.5} Sensors for Air Quality Monitoring by Citizen Scientists

10th BAQ Conference, Kuching, Malaysia

Nov 15, 2018

Prakash Doraiswamy¹, Pawan Gupta^{2,3}, Olga Pikelnaya⁴, Brandon Feenstra⁴, Andrea Polidori⁴, Robert Levy³ and Karmann Mills¹

¹RTI International, ²USRA, ³NASA, ⁴South Coast Air Quality Management District

<https://aqcitizenscience.rti.org>

***Acknowledgements to
NASA for funding this work***

About RTI International

4,905

Staff Members

3,236
North America

137
Latin America
and the Caribbean

98 Europe

55
Middle East
and North Africa

951 Africa

425 Asia

3 Australia

90 
Languages

250 
Degree Fields

100 
Nationalities

- Multidisciplinary non-profit research institute
- Headquarters in Research Triangle Park, NC, USA
- 12 U.S. offices and 12 international offices
- Environment area
 - Air Quality - measurements, modeling, policy support
 - Climate Change
 - Risk Assessment
 - Capacity Building
- www.rti.org

Nearly 6.5 Million Deaths Attributed to Air Pollution

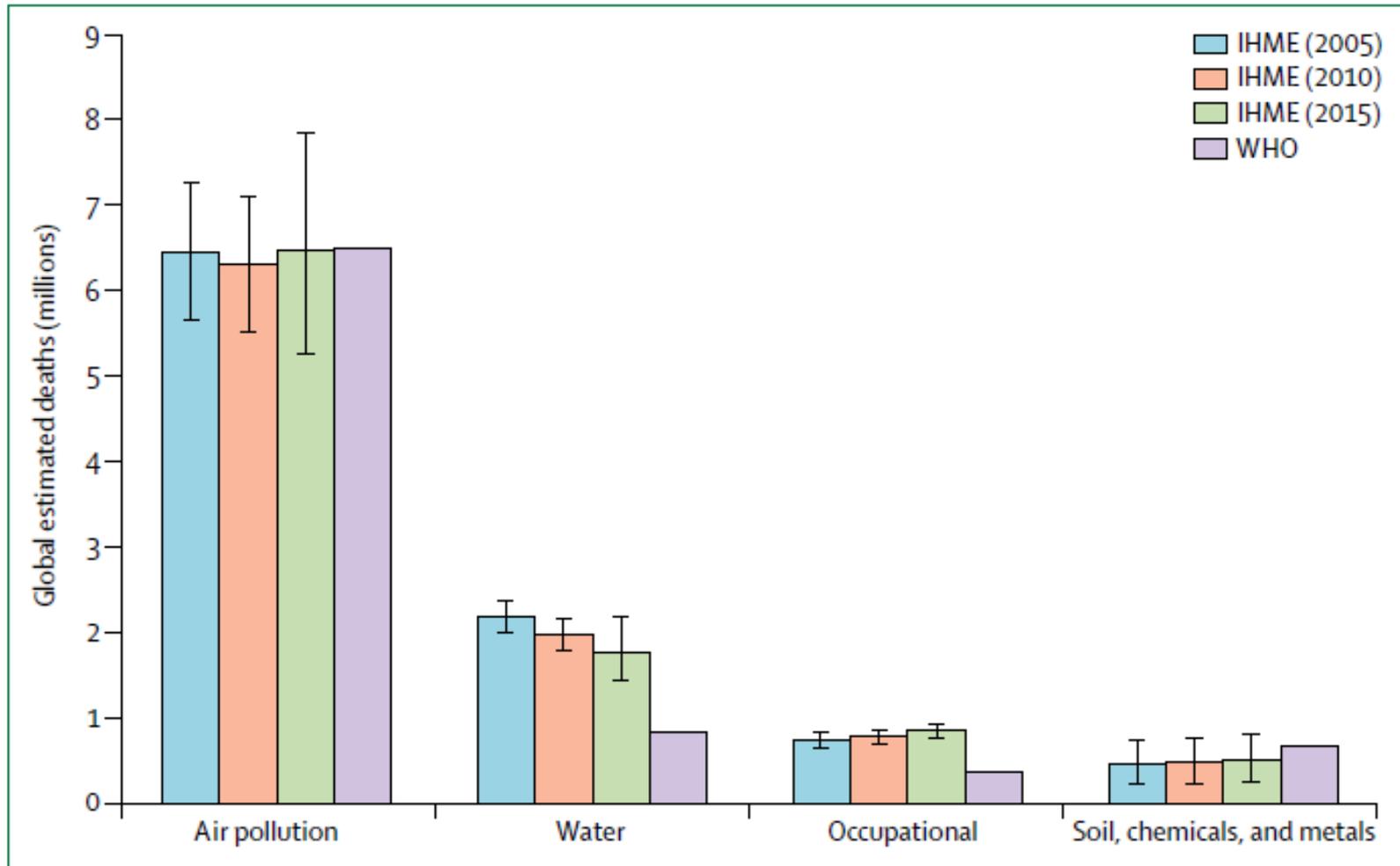


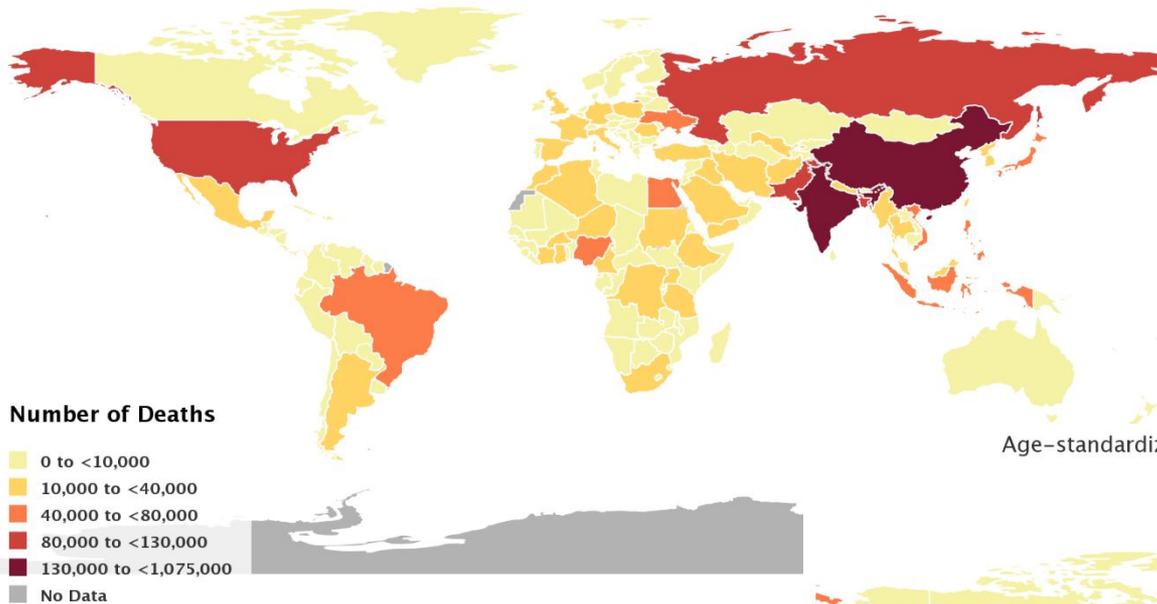
Figure 4: Global estimated deaths (millions) by pollution risk factor, 2005–15

Using data from the GBD study⁴² and WHO.⁹⁹ IHME=Institute for Health Metrics and Evaluation.

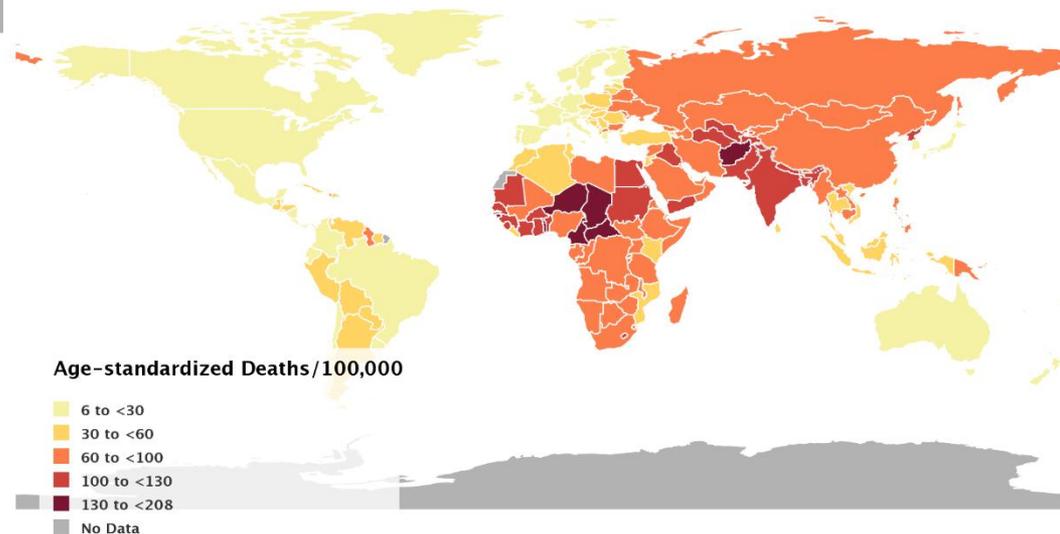
Landrigan, P.J., Fuller, R., Acosta, N.J.R., Adeyi, O., Arnold, R., Basu, N., et al., 2018. The Lancet Commission on pollution and health. *The Lancet* 391, 462-512.

Much of the deaths are in low and middle-income countries (LMICs)

Number of Deaths Attributable to PM2.5 in 2016



Age-standardized Deaths/100,000 Attributable to PM2.5 in 2016



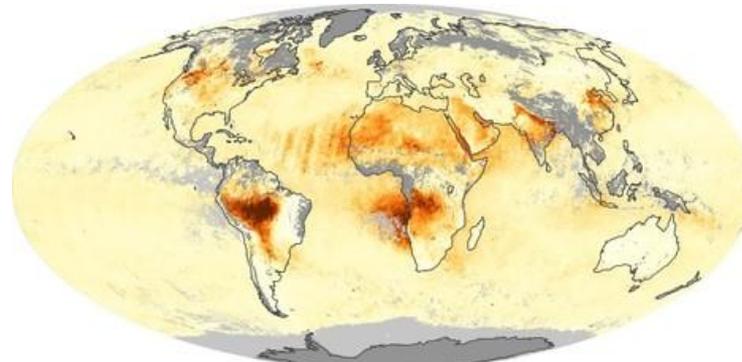
State of Global Air,
<https://www.stateofglobalair.org/data/#/health/map>

Project Motivation and Objectives

- Air quality monitoring is an important component of the air quality management framework



“Reference” methods -
Point measurements,
spatially sparse,
expensive, “gold
standard”



Source: NASA Earth Observatory

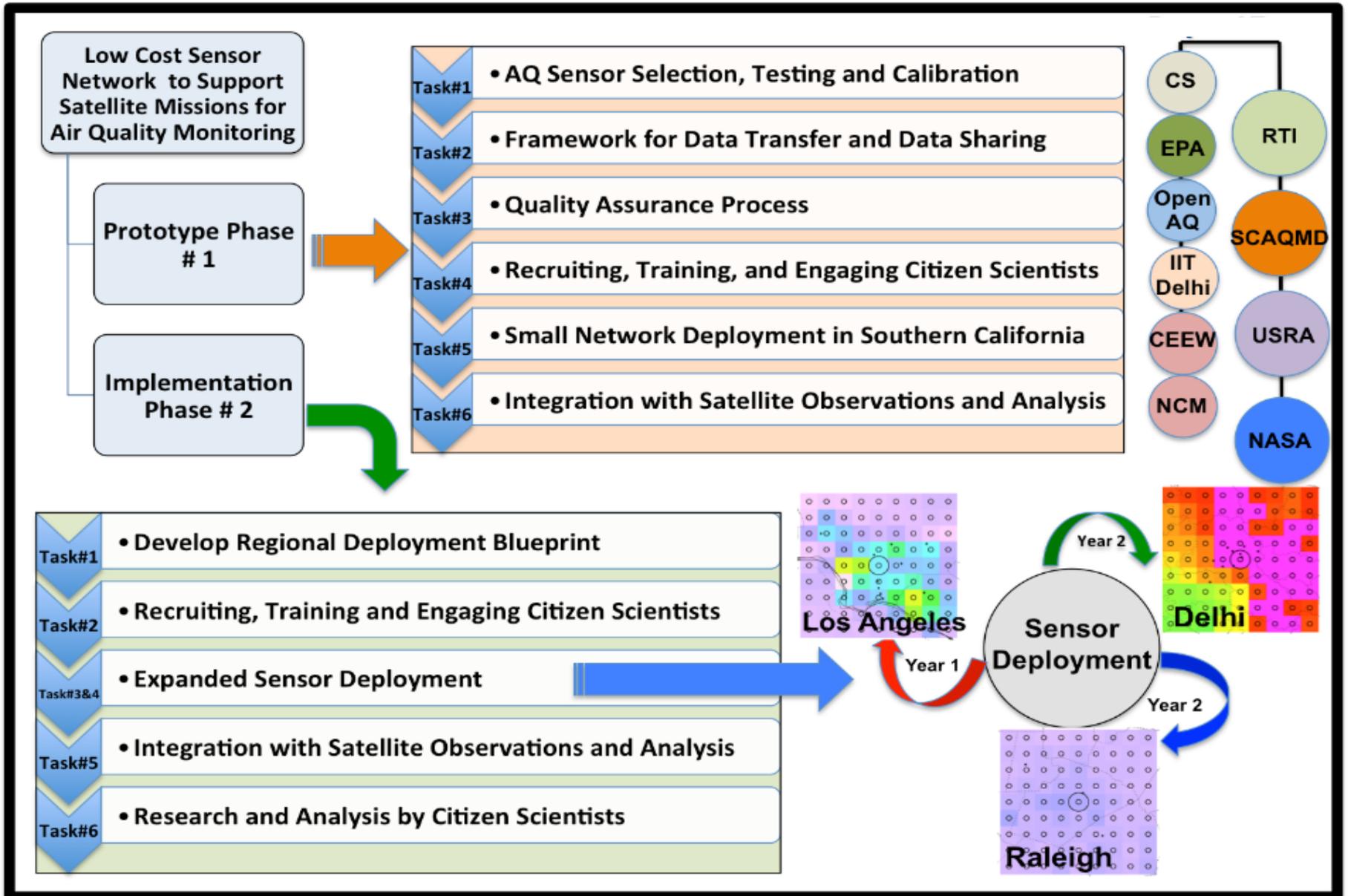
Satellite data - Global
spatial coverage,
freely available,
column metric



“Low-cost Sensors” -
Point measurements,
relatively cheap,
potential for broader
spatial coverage, less
accurate

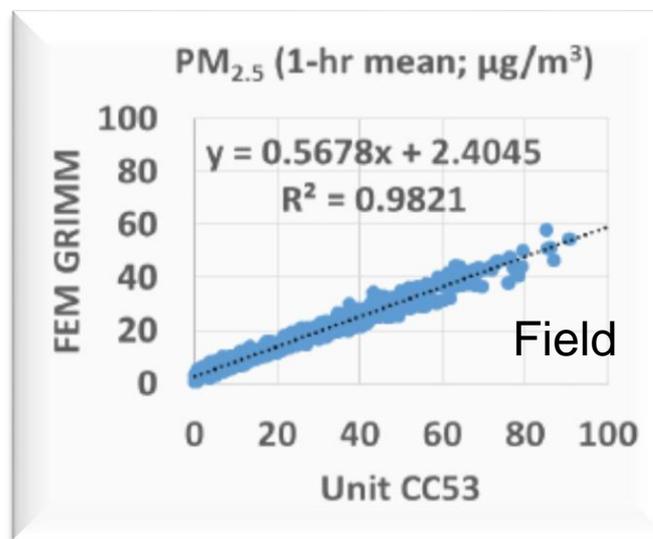
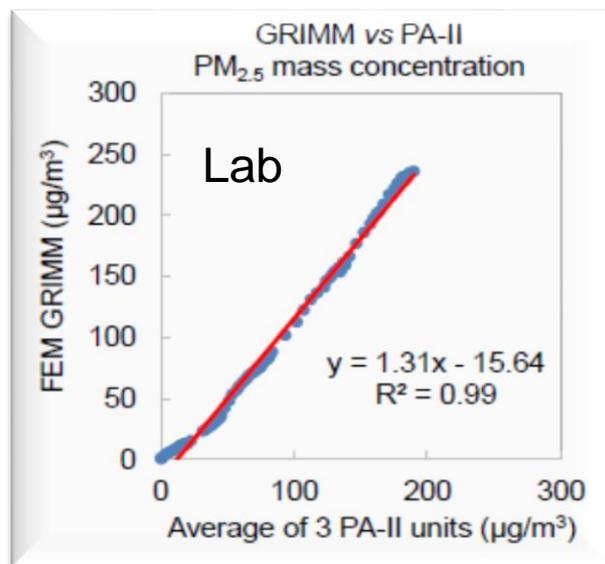
- Our **objective** is to examine the utility of a low-cost sensor network to generate spatially and temporally resolved, high caliber, air quality data that complement satellite observations in a sustainable manner using citizen scientists

Overall Project Concept



Sensor Evaluation for Citizen Use

- 20 commercial low-cost sensors evaluated in the AQ-SPEC lab and in the field at the Rubidoux air monitoring station by collocating with Federal Equivalent Method (FEM)
- PurpleAir sensor was chosen for deployment due to
 - High correlation (>0.90), excellent linearity, precision, high data completeness ($>90\%$), ease of operation and existing data infrastructure



Source:

www.aqmd.gov/aq-spec/evaluations/

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

- Prototype field deployment of ~90 sensors in Southern California using citizen scientists

Study Region and Citizen Scientist Recruitment

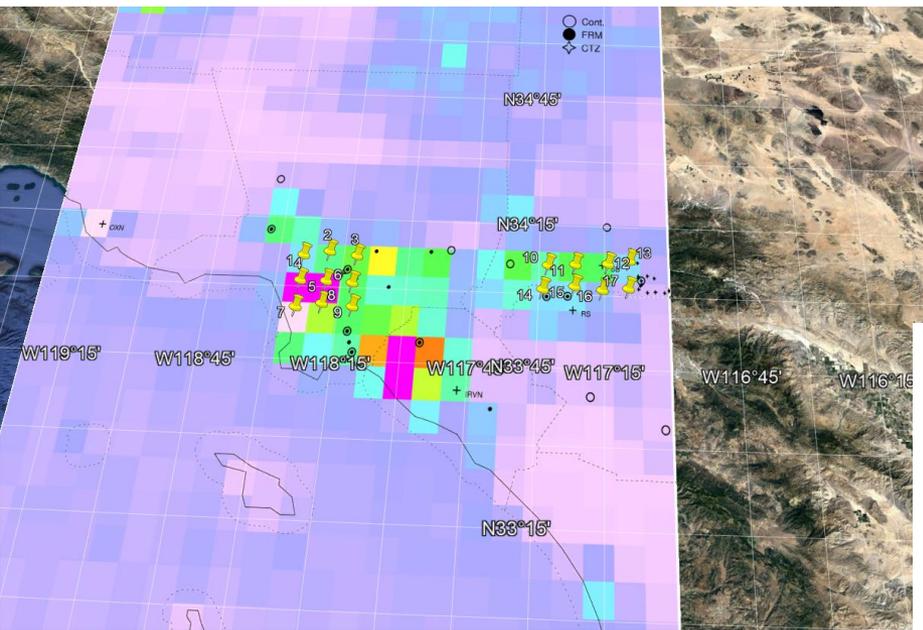
- Study area was identified by comparing satellite AOD gradients with surface PM_{2.5} gradients
- Satellite showed high AOD near the coast, while surface monitors showed high concentrations inland
- Two regions chosen - West Los Angeles, San Bernardino/Riverside area

2011 Maximum 24-hour Average PM_{2.5} Concentrations by Basin and County

BASIN/COUNTY	MAXIMUM 24-HR AVERAGE* (μG/M ³)	PERCENT OF FEDERAL STANDARD* (35 μG/M ³)	AREA
South Coast Air Basin			
Los Angeles**	49.5	139	East San Gabriel Valley
Orange	39.2	110	Central Orange County
Riverside	60.8	171	Metropolitan Riverside County
San Bernardino	65.0	183	Central San Bernardino Valley
Salton Sea Air Basin			
Riverside***	35.4	99.7	Coachella Valley

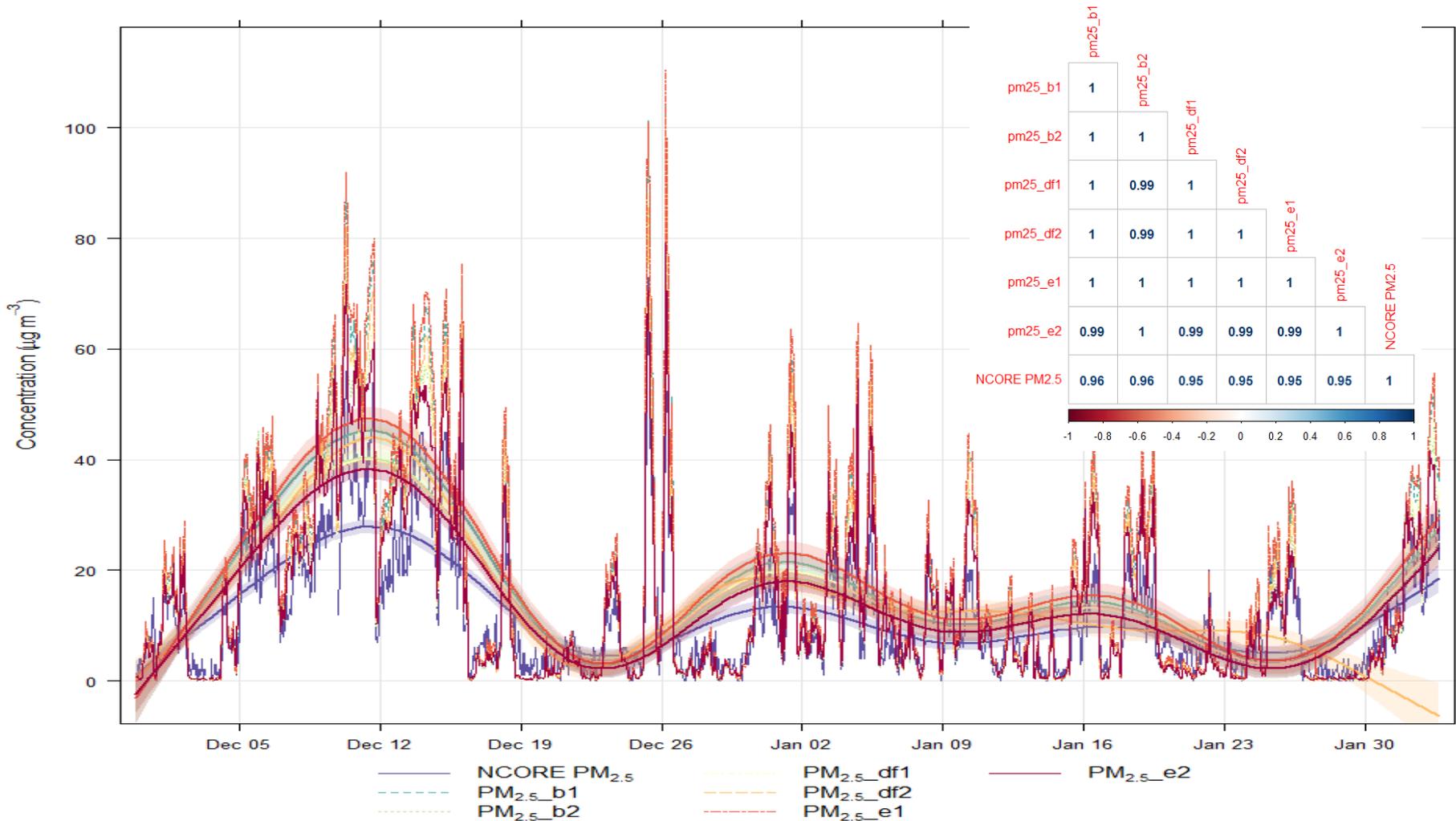
2011 Maximum Annual Average PM_{2.5} Concentrations by Basin and County

BASIN/COUNTY	ANNUAL AVERAGE* (μG/M ³)	PERCENT OF FEDERAL STANDARD (15 μG/M ³)	AREA
South Coast Air Basin			
Los Angeles	13.3	89	Central Los Angeles
Orange	11.0	73	Central Orange County
Riverside	15.3	101	Metropolitan Riverside County
San Bernardino	13.3	89	Southwest San Bernardino Valley
Salton Sea Air Basin			
Riverside	7.1	47	Coachella Valley



Source: SCAQMD 2012 AQMP

Longer Field Performance Evaluation (Dec 2016-Jan 2017)



- PurpleAir sensor data about 10 to 30% higher than FEM data, but highly correlated ($r \geq 0.95$)

Sensor + Satellite Data



AGU100 ADVANCING EARTH AND SPACE SCIENCE

GeoHealth

RESEARCH ARTICLE

10.1029/2018GH000136

Key Points:

- Low-cost air quality monitors and satellite observations respond to smoke from fires in California
- Low-cost air quality monitors demonstrate bias against federal equivalent monitors but can be very useful in places with no standard measurements
- Both low-cost air quality monitors and satellite provide unique and useful information on air quality

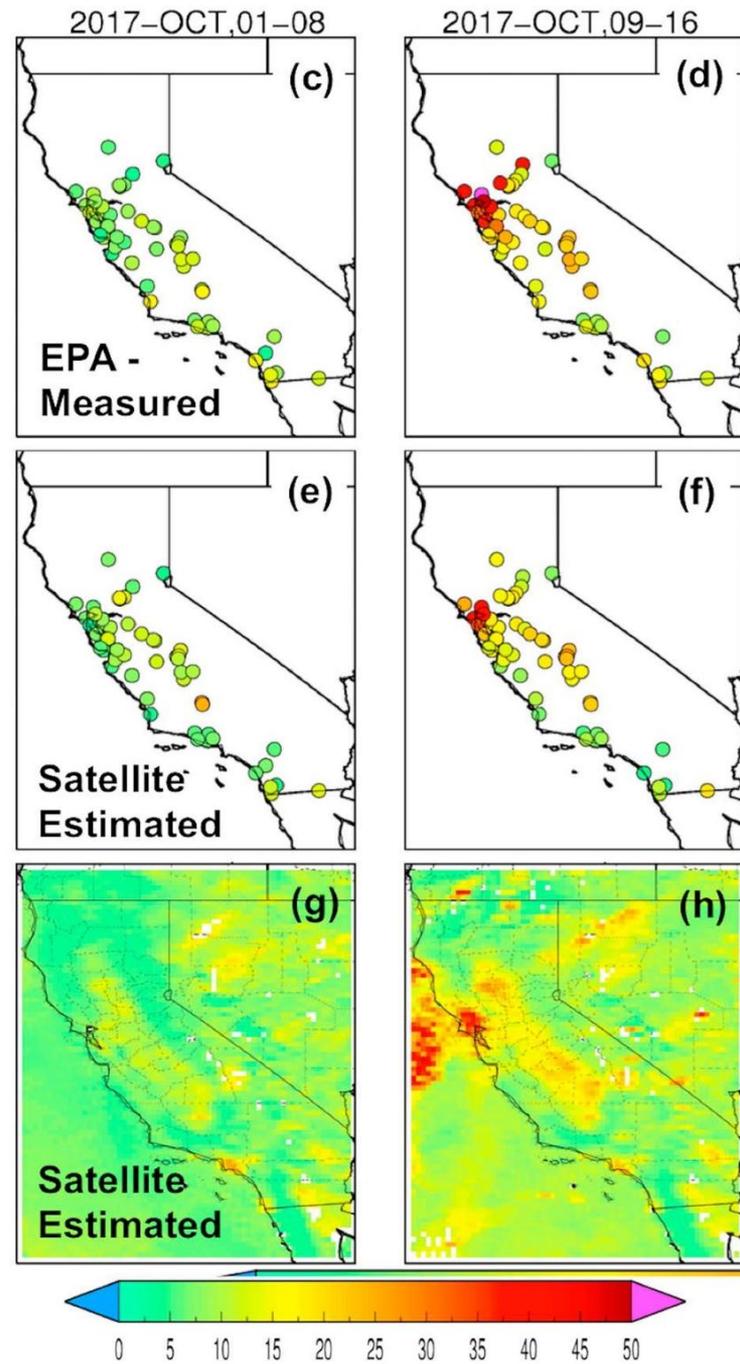
Impact of California Fires on Local and Regional Air Quality: The Role of a Low-Cost Sensor Network and Satellite Observations

P. Gupta^{1,2}, P. Doraiswamy³, R. Levy², O. Pikelnaya⁴, J. Maibach¹, B. Feenstra⁴, Andrea Polidori⁴, F. Kiros³, and K. C. Mills³

¹GSTAR-Universities Space Research Associations, Columbia, MD, USA, ²NASA Goddard Space Flight Center, Greenbelt, MD, USA, ³RTI International, Research Triangle Park, NC, USA, ⁴South Coast Air Quality Management District, Diamond Bar, CA, USA

Abstract PM_{2.5}, or fine particulate matter, is a category of air pollutant consisting of particles with effective aerodynamic diameter equal to or less than 2.5 μm. These particles have been linked to human health

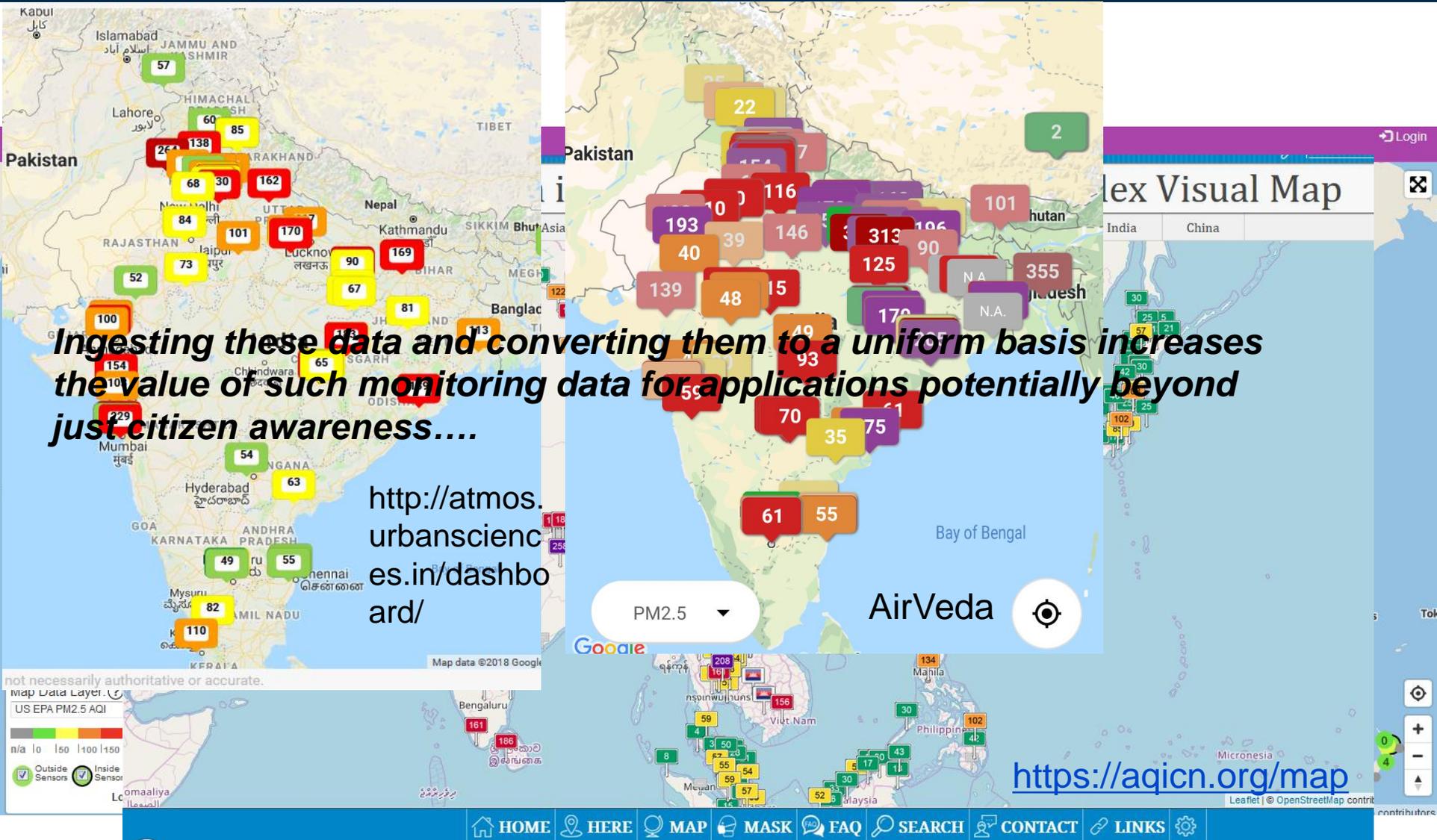
- Satellite-based PM_{2.5} estimated by relating satellite AOD to 180 sensor-PM_{2.5} data using geographically weighted regression
- Satellite-derived estimates then compared against EPA FEM data
- Good agreement demonstrating the value of low-cost sensors as a viable option to improve AOD-PM_{2.5} relationship for locations with limited or no surface monitoring



Next Steps (Phase 2 – ongoing)

- Expand sensor deployment in CA, RTP, and India
- Timeframe for Citizen recruitment and sensor deployment
 - Nov 2018 – Feb 2019: California deployment
 - Fall 2019 – Spring 2020: RTP & India deployment
- Improve AOD-PM_{2.5} models using expanded data and using additional data sources such as regional air quality model data
- **Create an open-source data framework that can ingest any sensor data and provide such spatially resolved PM_{2.5} estimates**

The Power of Citizen Science Enabled Monitoring



Summary

- Sensors show promise for surface air quality monitoring, but require some form of correction
- Sensors and satellite data respond well for episodic events
- Sensor $PM_{2.5}$ and satellite AOD data relationship will need to be improved by incorporating meteorological variables and 3D air quality model data using advanced statistical methods
- **Once developed and expanded globally, this will serve as a valuable resource for surface $PM_{2.5}$ data in countries where there are minimal or no ground measurements**
- Such data will have significant applications in improved exposure data for humans which in turn will enable better evaluation of the health effects.

For more information

- <https://aqcitizenscience.rti.org>
- E-mail: pdoraiswamy@rti.org

The screenshot shows the website's navigation bar with links: Air Quality Citizen Science, Background, Citizen Science, Data Sources, View Air Quality Data, Collaborate, Resources, and News. Below the navigation is a dark blue header with the text 'Citizen Science'. The main content area features a 'Join Our Team' section. On the left is a recruitment poster with the text 'HELP NASA STUDY AIR QUALITY' and 'Sign up NOW to be a Citizen Scientist for NASA and help us improve the air we all breathe!'. On the right is a paragraph of text: 'Are you interested in becoming a citizen scientist? Do you have the interest in understanding more about the air quality in your neighborhood? Would you like to measure air quality using sensors that we provide? Are you interested in working on cool projects along with other citizens using the data that you and other citizen scientists collect? Have you been amazed by the type of data that we get from satellites and how to use that data? Then this is the perfect opportunity for you to get involved!'. Below this is another paragraph: 'Our recruiting process is very simple. We are looking for excited individuals of all ages to help with deploying and maintaining low-cost air quality sensors (provided by the project team), transmit data to a database and network and collaborate with others as per your interest.'. At the bottom of the section is a paragraph: 'We are currently looking for citizen scientists in the Southern California region and will be expanding to other regions in 2018. If you are interested in becoming a citizen scientist, please fill out the survey/questionnaire by clicking the button below. One of the members from the project team will get in touch with you. Don't be worried about the number of questions in the form. It is for us to get a general understanding of your background and level of interest.'. Below the text is a button labeled 'Become a Citizen Scientist Now' and a small upward-pointing arrow icon.