EPA STAR Grant

Community Monitoring – Technical Workshop

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

(Conducted October 2017 – August 2018)

EPA STAR Grant

Engage, Educate, and Empower California Communities
on the Use and Applications
of “Low-cost” Air Monitoring Sensors

Main Objective

Provide communities across California with the knowledge necessary to appropriately select, use, and maintain “low-cost” sensors and to correctly interpret the collected data

EPA STAR Grant

HOW?

Specific Aims

Aim 1: Develop new methods (TOOLKIT) to engage, educate, and empower local communities on the use and applications of "low-cost" sensors

Aim 2: Conduct field and laboratory testing to characterize the performance of commercially available "low-cost" sensors and to identify candidates for field deployment

Aim 3: Deploy the selected sensors in multiple California communities, and perform a thorough validation and interpretation of the collected data

Aim 4: Communicate the lessons learned to the public and organize outreach activities

Develop a Toolkit

Aim 1

Engage local communities to inform toolkit materials through in- person meetings and phone interviews. Survey community on their knowledge and perception of sensors.

Draft guidebook, training videos, and data collection checklist.

Share draft toolkit with community members and survey them regarding sensor use to assess if their interaction and perception of sensors has changed.

Revise toolkit materials based on community feedback.

www.aqmd.gov/aq-spec

Field Testing

Aim 2

- Started in September, 2014
  - Over 30 sensors evaluated
- Process
  - Sensor tested in triplicates
  - Two month deployment
  - < ~ $2,000: purchase
  - > ~ $2,000: lease or borrow
- Location
  - Rubidoux station (main)
    - Inland site
    - Fully instrumented

www.aqmd.gov/aq-spec

Laboratory Testing

Aim 2

- Started in November, 2015
  - Over 10 sensors evaluated
- Process
  - Sensor tested in triplicates
- Location
  - SCAQMD Laboratory
    - Fully instrumented

www.aqmd.gov/aq-spec

Aim 2

Most PM sensors showed:

- Minimal down time
- Moderate intra-model variability
- Strong correlation (R^2) with EPA "approved" instruments (e.g., FEM)

However…

- Sensor "calibration" is needed in most cases
- Very small particles (e.g. < 0.5 µm) are not detected
- Bias in algorithms used to convert particle counts to particle mass

PM Sensors

Sensor Image	Manufacturer (Model)	Type	Pollutant(s)	Approx. Cost (USD)	*Field R^2	*Lab R^2	Summary Report
	**AethLabs** (microAeth)	Optical	BC (Black Carbon)	~$6,500	R^2 ~ 0.79 to 0.94		
	**Air Quality Egg** (Version 1)	Optical	PM	~$200	R^2 ~ 0.0		
	**Air Quality Egg** (Version 2)	Optical	PM	~$240	$PM_{2.5}$: R^2 ~ 0.79 to 0.85 PM_{10}: R^2 ~ 0.31 to 0.40		
	**Alphasense** (OPC-N2)	Optical	$PM_{1.0}$, $PM_{2.5}$ & PM_{10}	~$450	$PM_{1.0}$: R^2 ~ 0.63 to 0.82 $PM_{2.5}$: R^2 ~ 0.38 to 0.80 PM_{10}: R^2 ~ 0.41 to 0.60	R^2 ~ 0.99	PDF (1,291 KB)
	**Dylos** (DC1100)	Optical	$PM_{(0.5-2.5)}$	~$300	R^2 ~ 0.65 to 0.85	R^2 ~ 0.89	PDF (1,384 KB)
	**Foobot**	Optical	$PM_{2.5}$	~$200	R^2 ~ 0.55		
	**HabitatMap** (AirBeam)	Optical	$PM_{2.5}$	~$200	R^2 ~ 0.65 to 0.70	R^2 ~ 0.87	PDF (1,144 KB)
	**Hanvon** (Hanvon N1)	Optical	$PM_{2.5}$	~$200	R^2 ~ 0.52 to 0.79		
	**MetOne** (Neighborhood Monitor)	Optical	$PM_{2.5}$	~$1,900	R^2 ~ 0.53 to 0.67		
	**Moji China** (Airnut)	Optical	$PM_{2.5}$	~$150	R^2 ~ 0.81 to 0.88		
	**Naneos** (Partector)	Electrical	PM (LDSA: Lung-Deposited Surface Area)	~$7,000	$PM_{1.0}$: R^2 ~ 0.1 $PM_{2.5}$: R^2 ~ 0.2		
	**Origins** (Laser Egg)	Optical	$PM_{2.5}$ & PM_{10}	~$200	$PM_{2.5}$: R^2 ~ 0.58 PM_{10}: R^2 ~ 0.0		
	**Perkin Elmer** (ELM)	Optical	PM	~$5,200	R^2 ~ 0.0		
	**PurpleAir (PA-I)**	Optical	$PM_{1.0}$, $PM_{2.5}$ & PM_{10}	~$150	$PM_{1.0}$: R^2 ~ 0.93 to 0.95 $PM_{2.5}$: R^2 ~ 0.77 to 0.92 PM_{10}: R^2 ~ 0.32 to 0.44	$PM_{1.0}$: R^2 ~ 0.95 $PM_{2.5}$: R^2 ~ 0.99 PM_{10}: R^2 ~ 0.97	PDF (1,072 KB)
	**PurpleAir (PA-II)**	Optical	$PM_{1.0}$, $PM_{2.5}$ & PM_{10}	~$200	$PM_{1.0}$: R^2 ~ 0.96 to 0.98 $PM_{2.5}$: R^2 ~ 0.93 to 0.97 PM_{10}: R^2 ~ 0.66 to 0.70	$PM_{1.0}$: R^2 ~ 0.99 $PM_{2.5}$: R^2 ~ 0.99 PM_{10}: R^2 ~ 0.95	PDF (1,328 KB)
	**RTI** (MicroPEM)	Optical	$PM_{2.5}$	~$2,000	R^2 ~ 0.65 to 0.90	R^2 ~ 0.99	PDF (1,087 KB)
	**Shinyei** (PM Evaluation Kit)	Optical	$PM_{2.5}$	~$1,000	R^2 ~ 0.80 to 0.90	R^2 ~ 0.93	PDF (1,156 KB)
	**Speck**	Optical	$PM_{2.5}$	~$150	R^2 ~ 0.32		
	**TSI** (AirAssure)	Optical	$PM_{2.5}$	~$1,500	R^2 ~ 0.82		

Deploy the sensor

Aim 3

www.aqmd.gov/aq-spec

PurpleAir PM Sensor

AQ-SPEC

Air Quality Sensor Performance Evaluation Center

Sensor Description

Manufacturer/Model:
PurpleAir PA-II

Pollutants:
PM_1, $PM_{2.5}$, PM_{10}

Measurement Range:
0 - 500 µg/m³

Type: Optical

Additional Information

Field evaluation report:
http://www.aqmd.gov/aq-spec/evaluations/field

Lab evaluation report:
http://www.aqmd.gov/aq-spec/evaluations/laboratory

AQ-SPEC website:
http://www.aqmd.gov/aq-spec

Evaluation Summary

- Overall, the three PurpleAir PA-II sensors showed moderate to good accuracy, compared to the reference instrument for PM_1, $PM_{2.5}$, and PM_{10}, for a concentration range between 0 to 250 µg/m³.
- The three PA-II sensors exhibited high precision for most of the tested T/RH combinations.
- PA-II sensors showed low intra-model variability as well as good sensor a and b correlation in each node.
- PA-II sensors had good data recovery (95%).
- For PM_1 and $PM_{2.5}$, the PA-II sensors had high correlation with the reference instrument from both the field ($PM_{1.0}$ $R^2 > 0.96$, $PM_{2.5}$ $R^2 > 0.93$) and laboratory studies (linear correlation PM_1 $R^2 > 0.99$, $PM_{2.5}$ $R^2 > 0.99$). For PM_{10}, the PA-II sensors did not always follow the concentration change recorded by FEM instrument in the field (PM_{10} $R^2 > 0.66$), however in the laboratory, the PA-II sensors followed the concentration ramping (increasing) change, reporting (PM_{10} $R^2 > 0.95$).

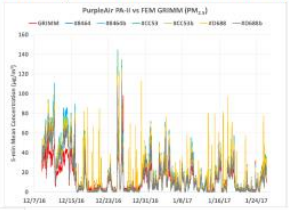
Field Evaluation Highlights

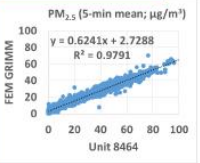
- Deployment period 12/18/2016- 01/26/2017: the three PA-II nodes correlated well the PM_1, $PM_{2.5}$ concentration change as monitored by GRIMM and BAM. PA-II nodes did not always follow the PM_{10} concentration change.
- The units showed 95-99% data recovery as well as low intra-model variability.

$PM_{1.0}$ R^2 ~ 0.96 to 0.98

$PM_{2.5}$ R^2 ~ 0.93 to 0.97

PM_{10} R^2 ~ 0.66 to 0.70





Correlation coefficient (R^2) quantifies how the three sensors followed the PM concentration change by GRIMM.

An R^2 approaching the value of 1 reflects a near perfect agreement, whereas a value of 0 indicates a complete lack of correlation.

Laboratory Evaluation Highlights

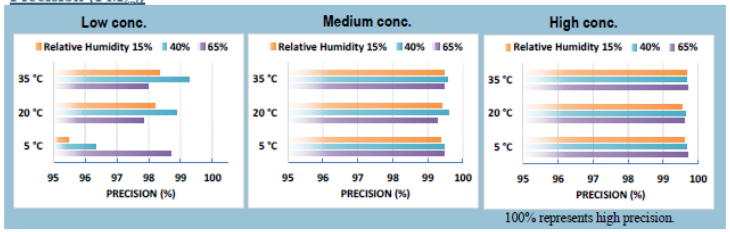
Accuracy

$$A\,(\%) = 100 - \frac{|\bar{X} - R|}{R} * 100$$

Steady State (#)	Sensor mean (µg/m³)	GRIMM (µg/m³)	Accuracy (%)
1	19.7	13.5	54.3
2	44.3	35.7	75.7
3	80.8	84.1	96.1
4	134.7	155.1	86.8
5	186.3	233.5	79.8

Accuracy was evaluated by a concentration ramping experiment at 20 °C and 40%. The sensor's readings at each ramping steady state are compared to the reference instrument.

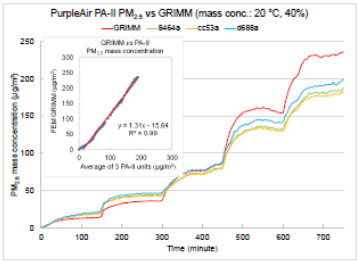
Precision ($PM_{2.5}$)



100% represents high precision.

Sensor's ability of generating precise measurements of PM concentration at low, medium, and high pollutant levels were evaluated under 9 combinations of T and RH, including extreme weather conditions like cold and dry (5

Linear Correlation Coefficient



The three PA-II sensors showed excellent correlation with the corresponding FEM $PM_{2.5}$ data (R^2 = 0.99) at 20 °C and 40% RH.

For conc. ramping experiments of PM_1 and PM_{10}, please see full length lab reports.

Climate Susceptibility

From the laboratory studies, temperature and relative humidity had minimal effect on the PA-II sensors' precision. At the set-points of RH changes, PA-II reported spiked changes in concentrations.

Observed Interferents

N/A

All documents, reports, data, and other information provided in this document are for informational use only. Mention of trade names or commercial products does not constitute endorsement or recommendation. The South Coast AQMD's AQ-SPEC program, as a government agency, recommends the interested parties to make purchase decisions based on their application.

www.aqmd.gov/aq-spec

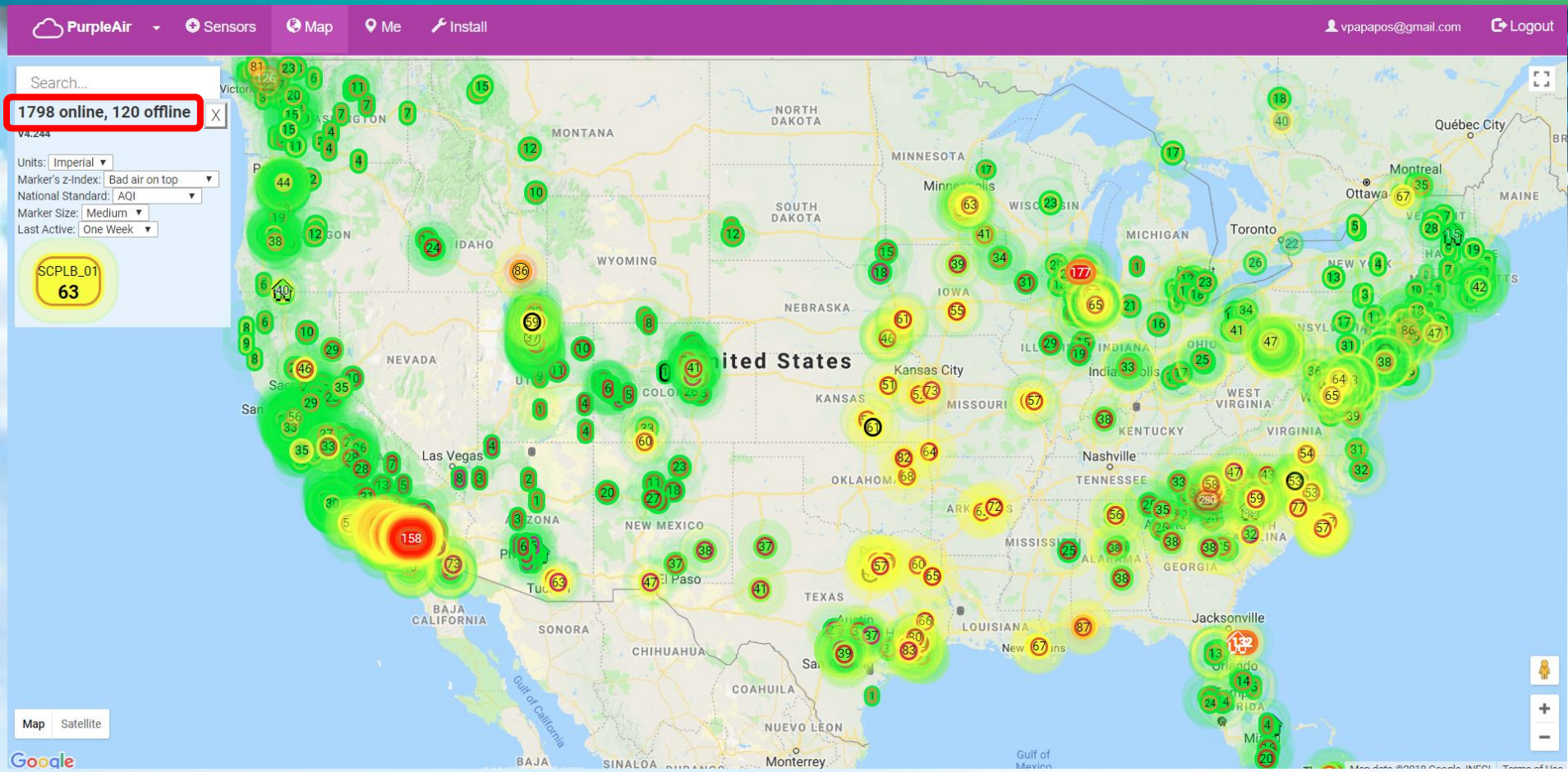
PurpleAir PM Sensor

Rationale for Selection

- Open-access data: this makes the data easily accessible to all community members (including those not hosting a sensor) and project leads
- Low-cost: the cost enables the distribution and installation of more sensors than initially proposed
- Performance: relatively well-performing sensor based on AQ-SPEC evaluation

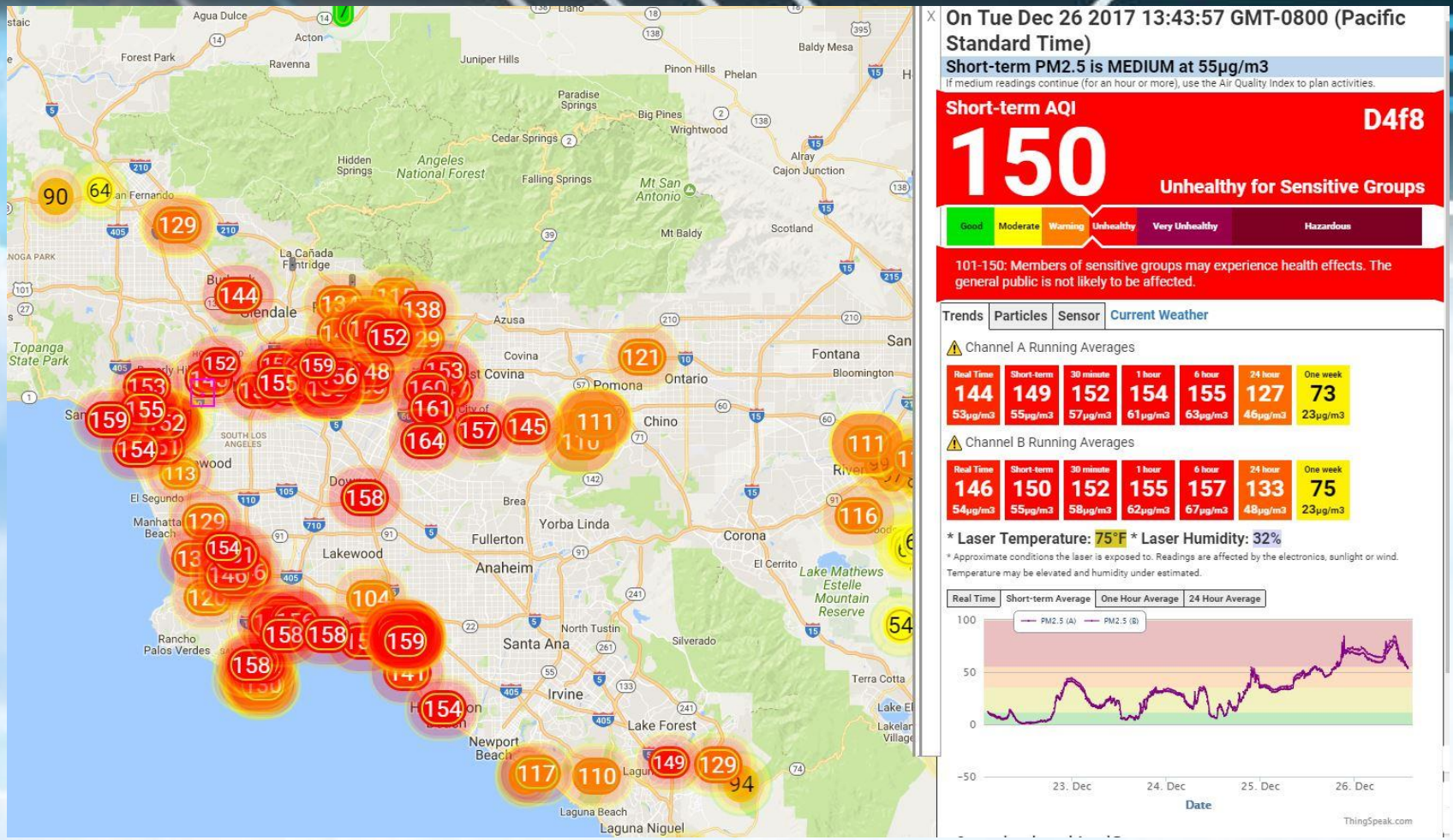
South Coast AQMD

www.purpleair.com/map



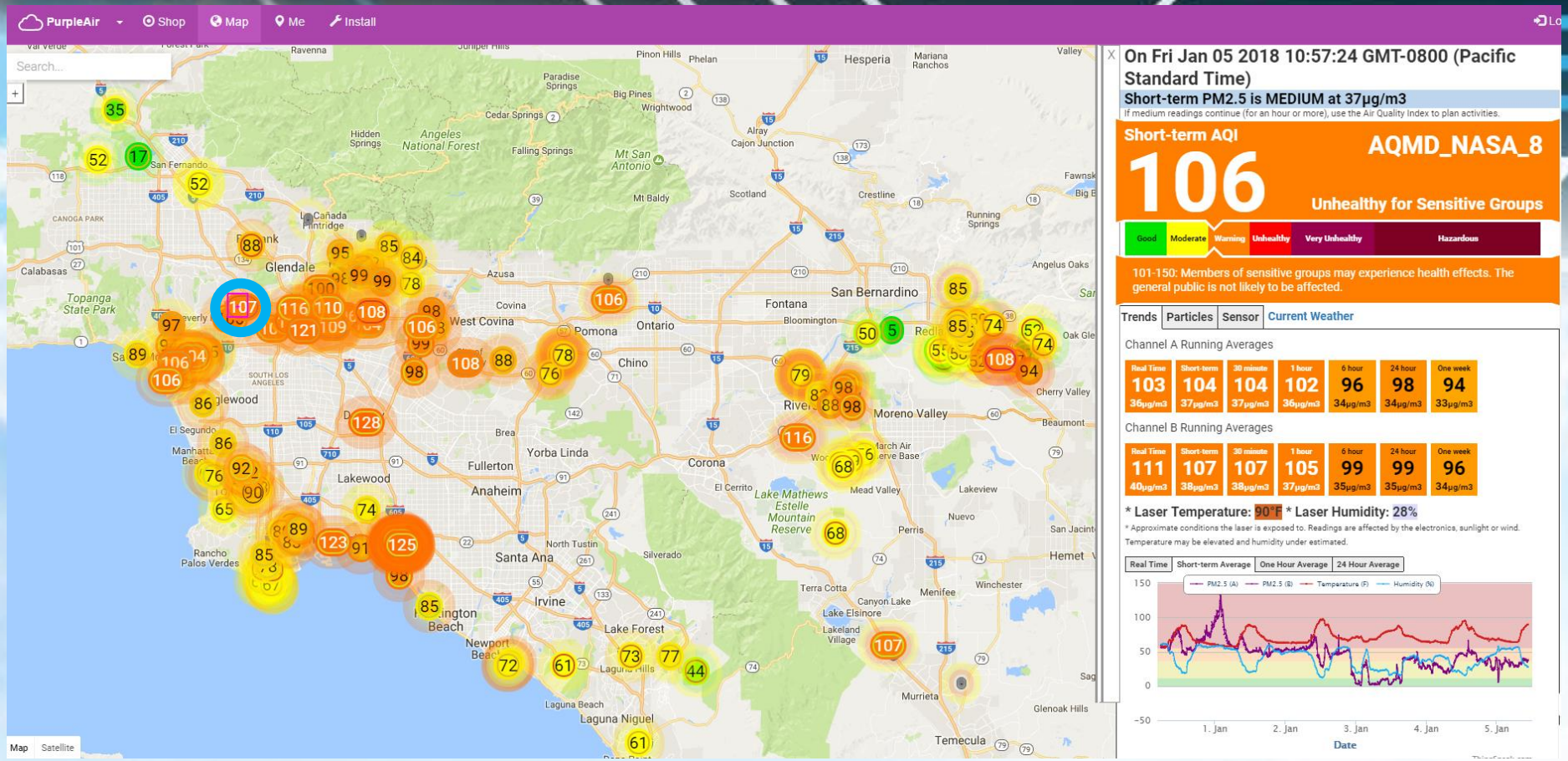
South Coast AQMD

www.purpleair.com/map



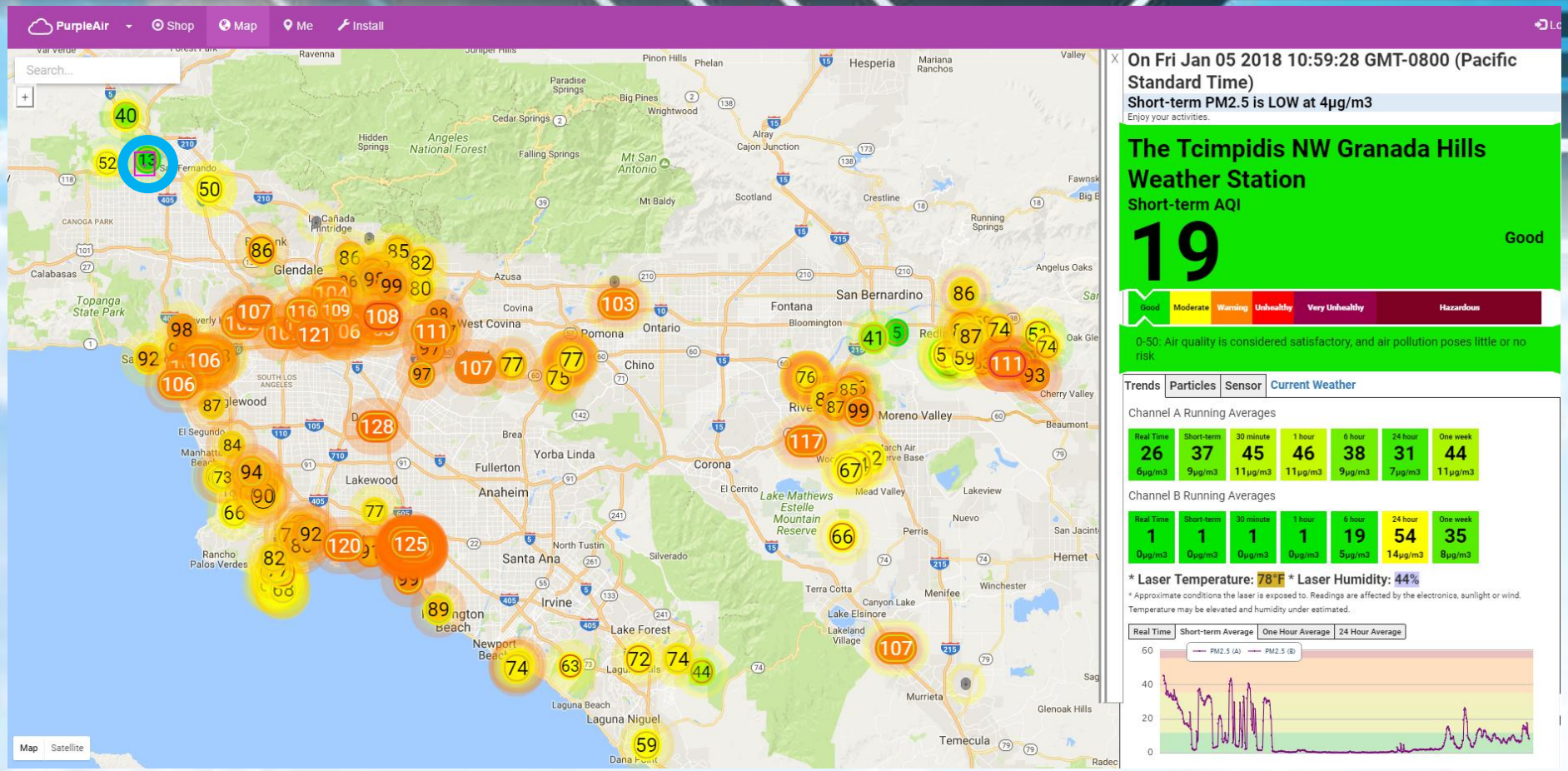
South Coast AQMD

www.purpleair.com/map



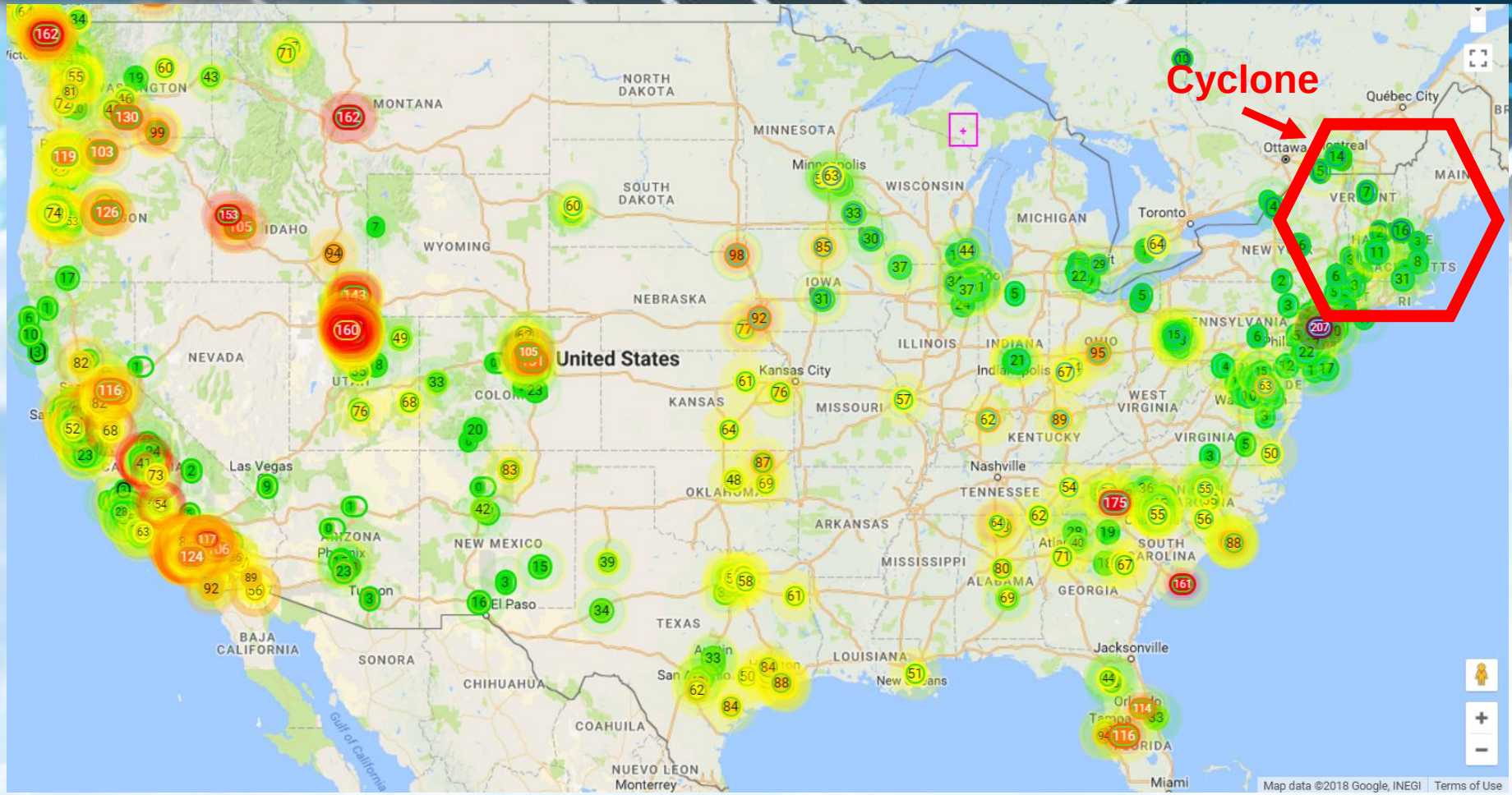
South Coast AQMD

www.purpleair.com/map



South Coast AQMD

www.purpleair.com/map



Air Sensor Questionnaire

Contact Information

1. Full Name:
2. Address:
3. Phone number:
4. e-mail:
5. Are you willing to participate in our low-cost sensor project that will involve installing a small air sensor in your apartment/house and allowing it to collect data for 12 to 15 months? ☐ Yes ☐ No
6. Will you be able to provide a wireless internet connection for the sensor? ☐ Yes ☐ No
7. Are you interested in learning how to set up and install an air sensor outdoors at your apartment/house? ☐ Yes ☐ No

Context and Awareness of Air Quality and Sensors

1. To what extent do you agree with the following statement: "Issues related to air quality affect me and/or my family"

Strongly disagree | Disagree | Neutral/ Undecided | Agree | Strongly agree

2. How concerned are you about air quality?

Not at all | Slightly | Moderately | Very | Extremely

3. In your opinion, how often does air quality affect you and/or your family (e.g., trigger asthma, affect visibility, cause coughing or other respiratory problems)?

Never | Seldom | Sometimes | Often | Almost Always

4. What air pollutants are you concerned about in your area?

☐ Particle pollution ☐ Ozone ☐ Diesel exhaust ☐ Volatile Organic Compounds (VOCs)
☐ Nitrogen oxides (NOx) ☐ Traffic emissions ☐ Smog ☐ I am not concerned about air pollution
☐ Concerned, but unsure about specific pollutants ☐ Other (please specify: _____)

5. What are the biggest causes of air quality problems where you live, so far as you know?

☐ Cars ☐ Industry ☐ Residential wood burning
☐ Refineries ☐ Auto repair shops ☐ Ports
☐ Other (please specify: _____) ☐ I don't know

6. How do you typically get information about air quality in your community?

☐ News outlet ☐ Federal government website ☐ Local government website
☐ Phone app ☐ Social media ☐ Other (please specify: _____)

7. How often do you check local air quality information before planning your outdoor activities or other behaviors (e.g., opening windows, exercising outdoors, etc)?

Never | Seldom | Sometimes | Often | Almost always

8. How familiar are you with low-cost air quality sensors?

Not at all | Slightly | Moderately | Very | Extremely

9. In your opinion, how credible are data from low-cost air quality sensors?

Very Poor | Poor | Acceptable | Good | Very good

10. For what types of applications do you think low-cost air quality sensors could be useful to you and your community?

☐ Understanding local pollution sources ☐ Personal air quality information ☐ Planning for outdoor activities
☐ Other (please specify: _____)

11. What issues do you think are important to consider before selecting an air pollution sensor to monitor air quality?

☐ Sensor sensitivity ☐ Sensor selectivity ☐ Interferences ☐ Ease of use ☐ Price
☐ Battery life ☐ Reliability ☐ Precision ☐ Weight ☐ Portability
☐ Durability ☐ Accuracy ☐ I don't know
☐ Other (please specify: _____)

12. Do you think you would change your behavior (e.g., choose to exercise indoors or during a different time of day) based on air quality sensor data?

☐ Yes ☐ No ☐ I don't know

13. Do you have any questions or comments about air sensors?

Demographic Information

For statistical purposes, we must ask:

1. What is your age?

☐ 12-17 ☐ 18-24 ☐ 25-34 ☐ 35-44 ☐ 45-54 ☐ 55-64 ☐ 65+

2. Which categories best describe you (check all that apply):

☐ White ☐ Black or African American ☐ American Indian/Alaska Native
☐ Hawaiian Native or Pacific Islander ☐ Middle Eastern or North African ☐ Asian
☐ Hispanic, Latino, or Spanish origin ☐ Other

3. Highest level of education attained (if currently enrolled, the highest degree received):

☐ Some high school, no diploma ☐ High school graduate, diploma or the equivalent
☐ Some college credit, no degree ☐ Trade/technical/vocational training
☐ Associate degree ☐ Bachelor's degree
☐ Master's degree ☐ Professional Degree (e.g. M.D. or J.D.)
☐ Doctorate degree (Ph.D.)

4. How many people live in your home (Including yourself)? _____

5. Do you have any children under the age of 18 living in your household? ☐ Yes ☐ No
If yes, please provide their ages: _____

Specific Aims

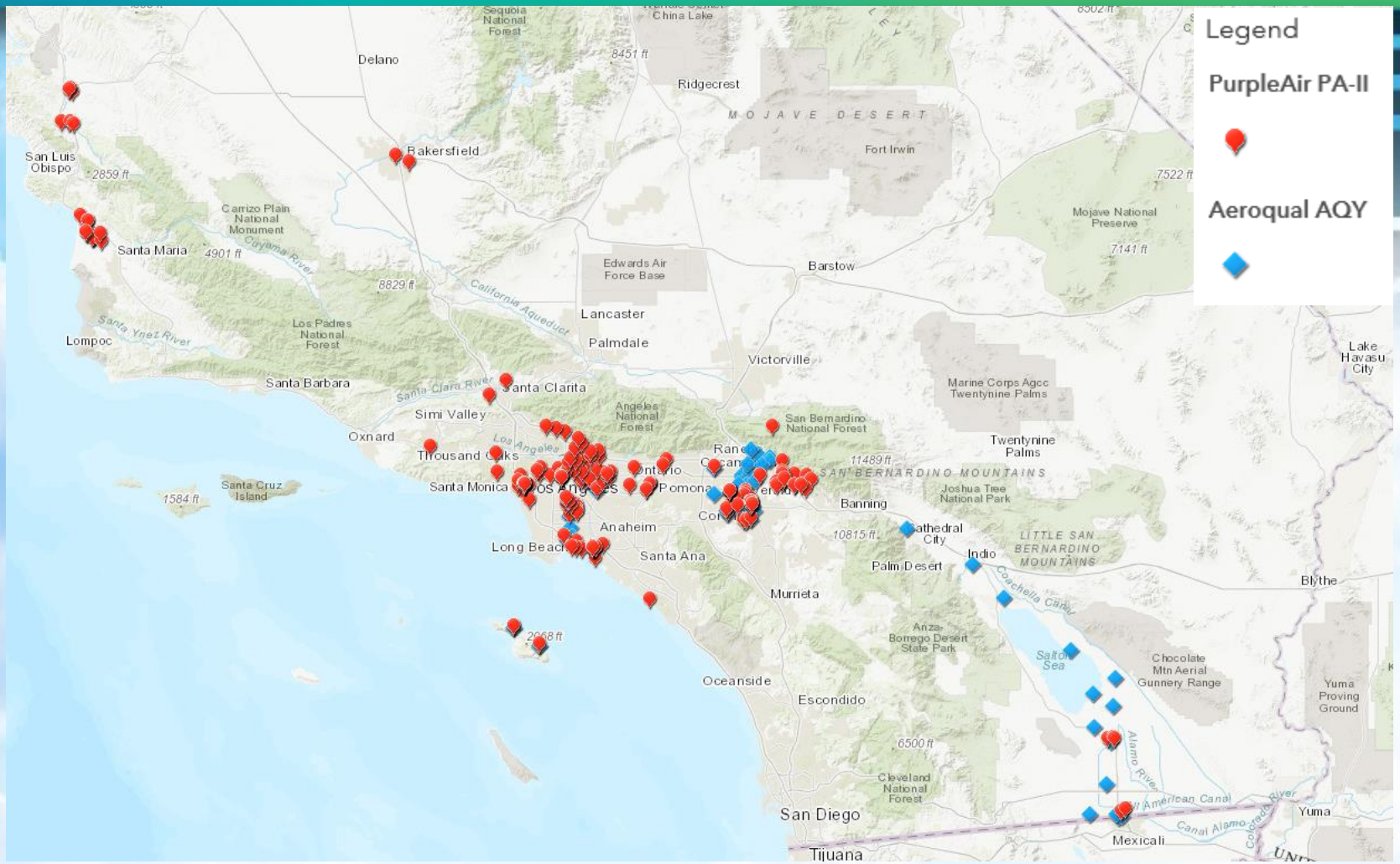
Aim 1: Develop new methods (TOOLKIT) to engage, educate, and empower local communities on the use and applications of "low-cost" sensors

Aim 2: Conduct field and laboratory testing to characterize the performance of commercially available "low-cost" sensors and to identify candidates for field deployment

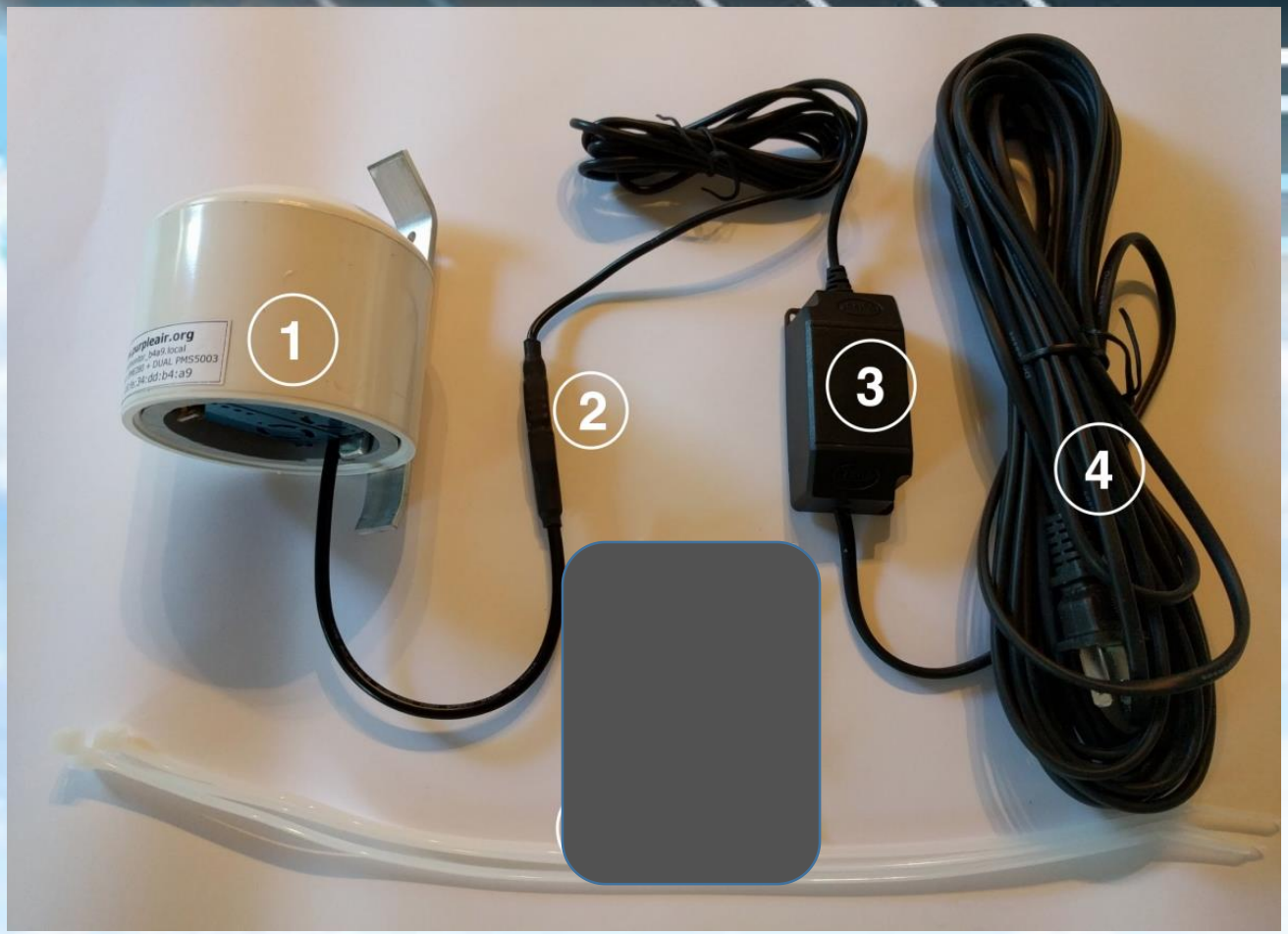
Aim 3: Deploy the selected sensors in multiple California communities, and perform a thorough validation and interpretation of the collected data

Aim 4: Communicate the lessons learned to the public and organize outreach activities

Participating Communities



PurpleAir PM Sensor



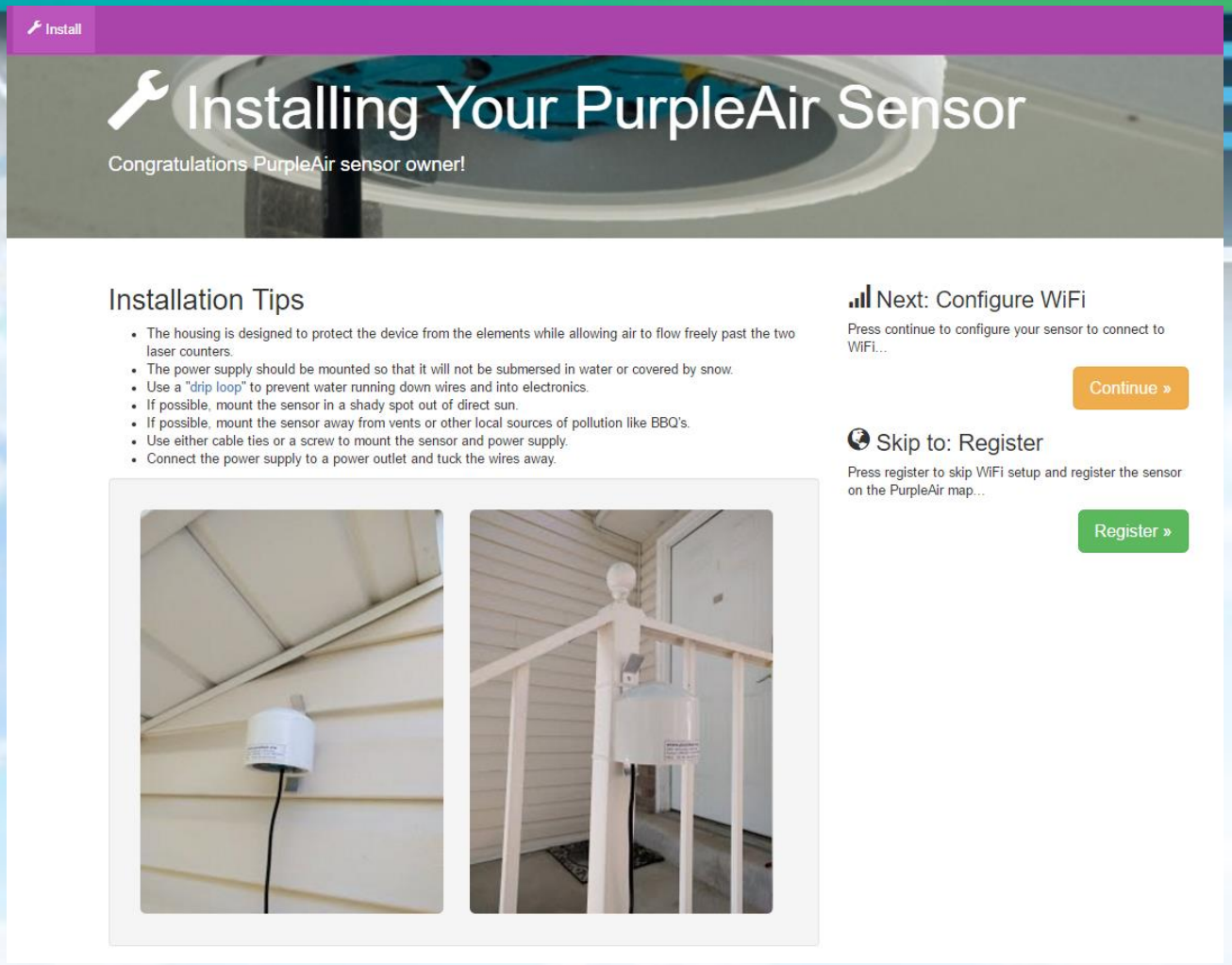
1) PA-II Dual Laser Sensor.
2) Micro USB connector.
3) 5V 2A USB Outdoor Power Supply.
4) 17 foot power cable.

3 STEPS

1. INSTALLATION
2. WiFi CONFIGURATION
3. REGISTRATION

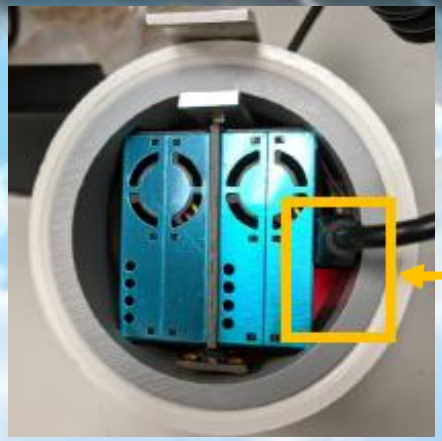
INSTALLATION

www.purpleair.com/install



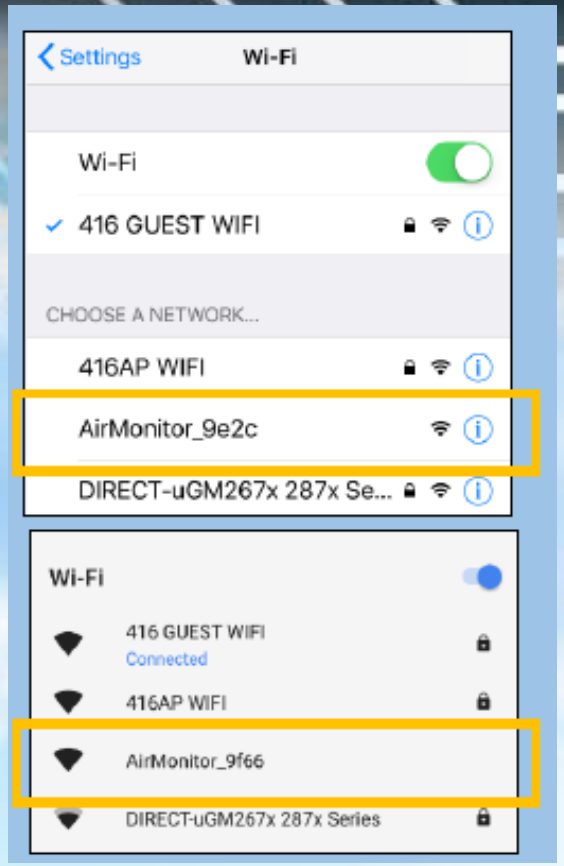
Siting

WiFi CONFIGURATION



Plug in the power chord and ensure that the power is turned on.

You will see a red light if powered.



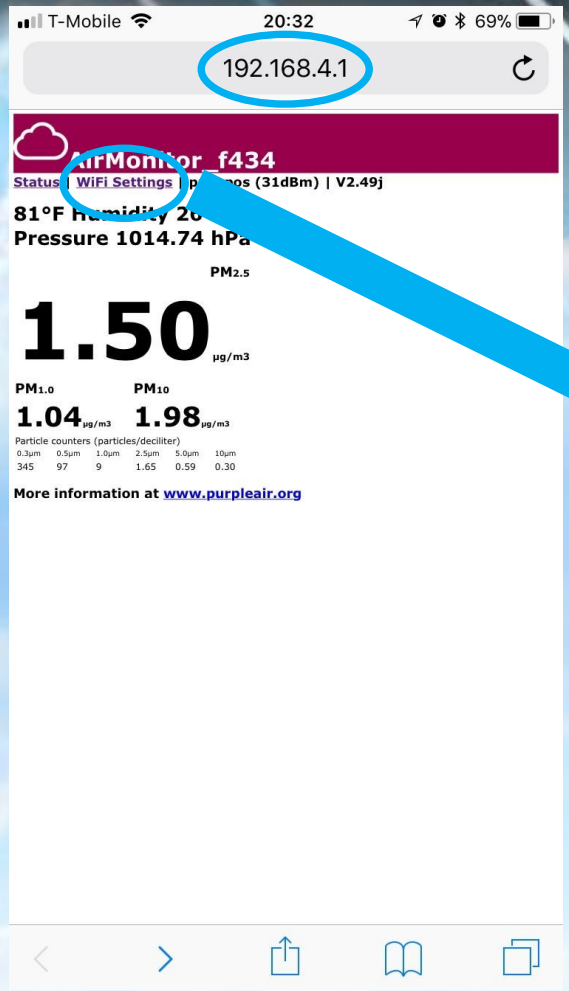
On a device:

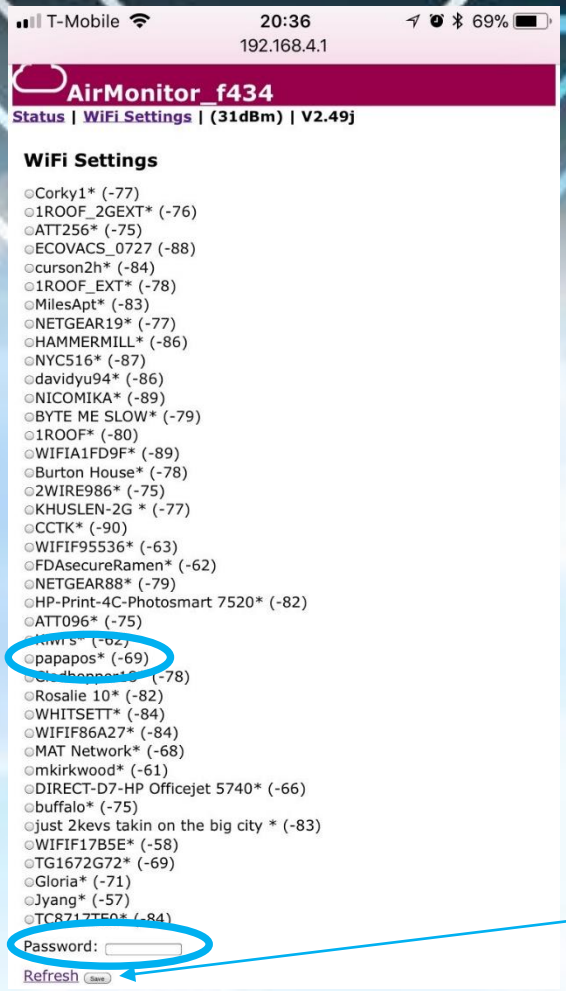
1. Go to “Settings” and Click on “Wi-Fi” settings.

2. On the list of WiFi network names, find “AirMonitor_xxxx” (xxxx will be actual letters and numbers like “9f66”)

WiFi CONFIGURATION

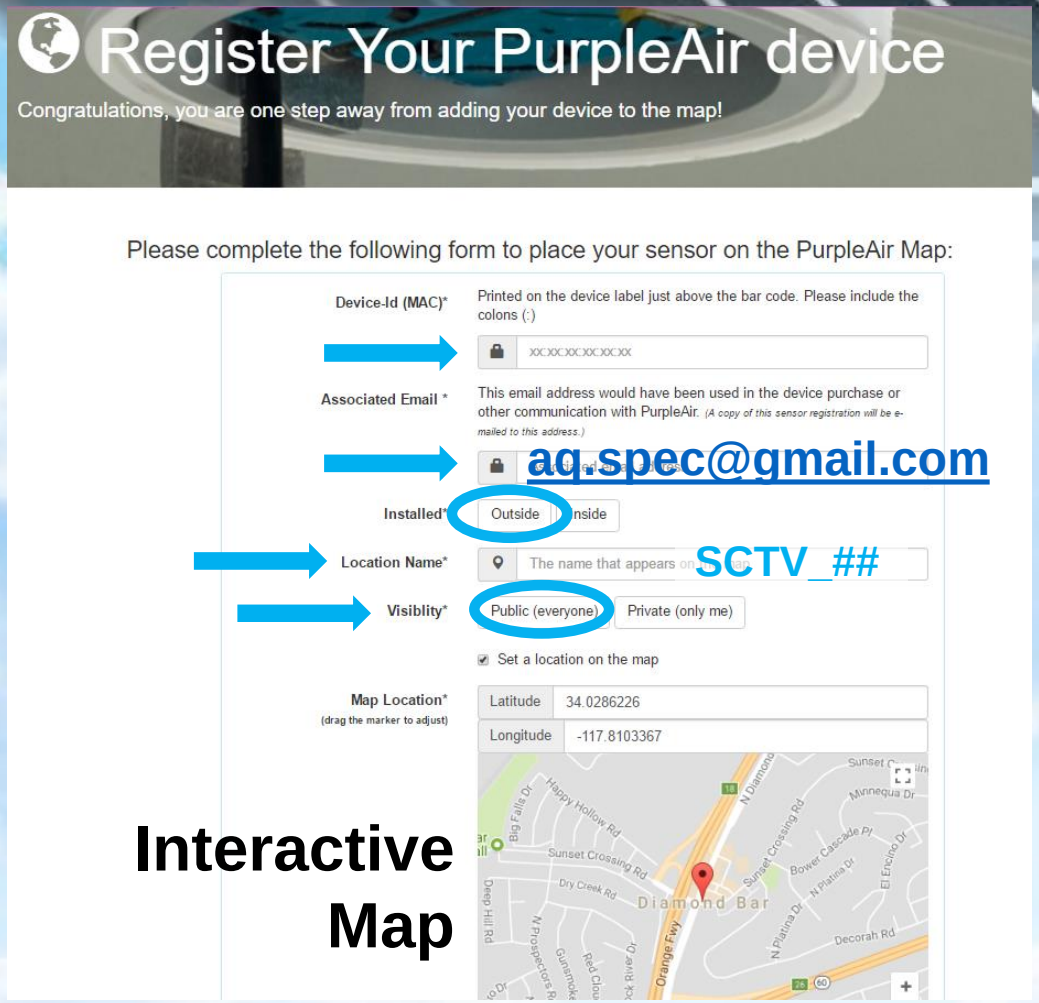
Go To → 192.168.4.1

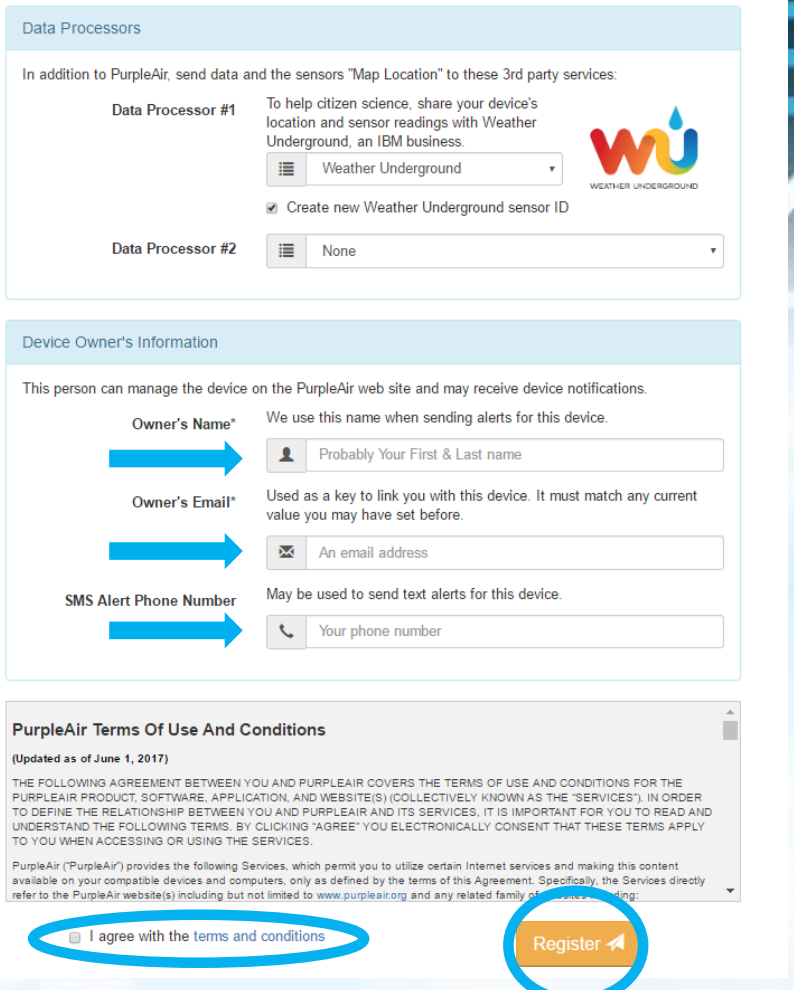




REGISTRATION

www.purpleair.com/register





Logbook/e-journal/e-diary thoughts

Where is the sensor:

- Where is your low-cost air sensing device located?

Air quality awareness:

- Did you look at the data today?
- Were air quality values higher or lower than yesterday?
- If the values were higher, what do you think caused them?
- If the values were lower, what do you think happened?
- What types of activities around your home could be contributing to particle levels at your sensor?
- Have you looked at air quality information from another source (e.g., www.airnow.gov , www.aqmd.gov)?
- If so, how do the PM values differ?

Weather:

- Is it windy today?
- Is it rainy today?

www.purpleair.com/map

U.S. EPA Science To Achieve Results Grant:
Engage, Educate and Empower California Communities
on the Use and Applications of Low-Cost Air Monitoring Sensors

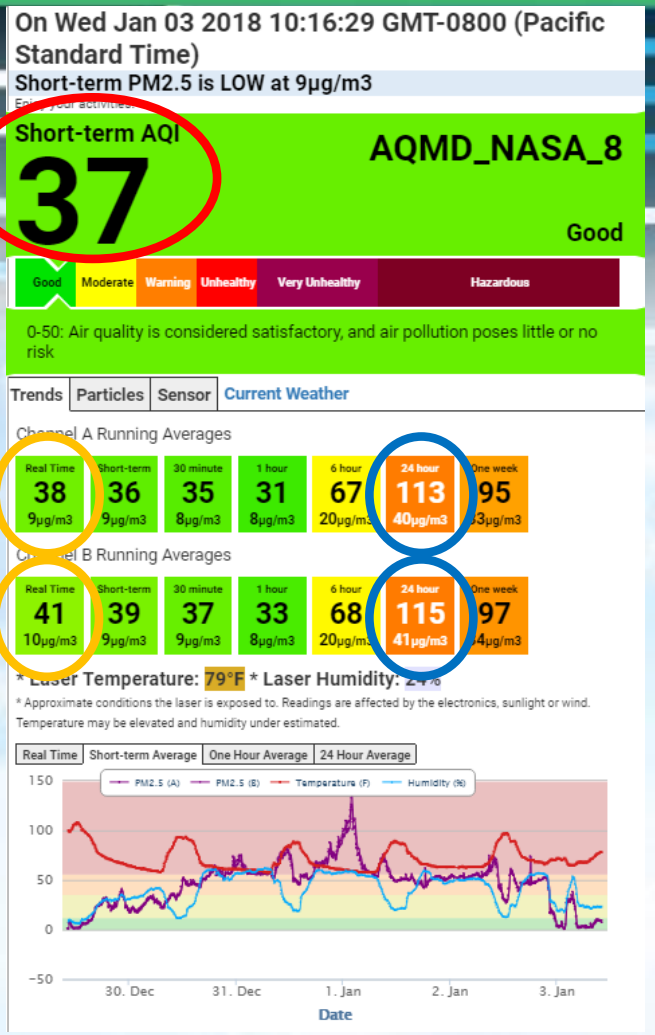
Log-Notes

User Name:

Sensor ID:

Address/Location:

Date (mm/dd/yy)	Time	Sensor Reading: Short-term AQI	Channel A Real-time $PM_{2.5}$ ($\mu g/m^3$)	Channel A 24-hour $PM_{2.5}$ ($\mu g/m^3$)	Channel B Real-time $PM_{2.5}$ ($\mu g/m^3$)	Channel B 24-hour $PM_{2.5}$ ($\mu g/m^3$)	Activity/Observation/Event
		37	9	40	10	41	



Particle Pollution (PM)	$PM_{2.5}$	primary	1 year	12.0 µg/m³	annual mean, averaged over 3 years
		secondary	1 year	15.0 µg/m³	annual mean, averaged over 3 years
		primary and secondary	24 hours	35 µg/m³	98th percentile, averaged over 3 years

Community Surveys/Workshops

Surveys/Workshops before/during/after the sensor deployment to assess the Community:

- Knowledge of air pollution, monitoring, and exposure
- Perception of sensor operation and data usefulness

GOAL -> Inform the Sensor Educational Toolkit:

- Informational material about “low-cost” sensors
- Best practices for data collection and interpretation
- Analysis reports
- Identification of pollution sources

Key Qs…and As

Q: How many sensors will be deployed during this study?
A: We have already purchased over 400 PM sensors to be deployed throughout California communities. We are also working with University of Auckland and Aeroqual (New Zealand) to deploy 100 of their multi-pollutant sensor devices.

Q: Where will the sensors be deployed?
A: Outdoors, at a location suitable to collect representative air quality data.

Q: What is going to happen with the sensors after the project ends?
A: The PM sensor is yours to keep and the sensor data will be posted online even after the end of the study.

Q: How are residents/project participants going to access the data?
A: Via dedicated website.

Key Qs…and As

Q: Is the data going to be presented in a way that is easy to interpret?
A: Yes. One of the main goals of this study is to communicate air quality data in a way that is easy to interpret by the general public.

Q: Other than providing access to WiFi and access to a power outlet, what other commitments are required from project participants?
A: Commitment to participate in meetings/workshops before, during and after the sensors have been deployed.

Q: Can schools participate in the project? If so, can they use the sensors as an educational tool?
A: Yes. We will work with a few schools in different parts of California, deploy sensors at students' and teachers' homes, and educate them in the use and operation of air quality sensors.

Thank you!