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Closing the coarse particle gap

An innovative approach to low-cost PM_{10} measurement

David Lu Co-founder & CEO • **Jack Kodros** Co-Author **Clarity Movement Co.**

Clean Air CONFERENCE 2026

MOTIVATION

Why did we develop the Dust Module?

Customer interest & use cases

Enhanced PM_{10} topped customer requests for new measurement capability.

Pollutant	Votes
Enhanced PM10	152
Ultrafine PM	138
Speciated VOC	109
CO	107
CO2	93

Limitations of low-cost sensors

Published field studies show low-cost PM sensors lose accuracy on coarse particles.

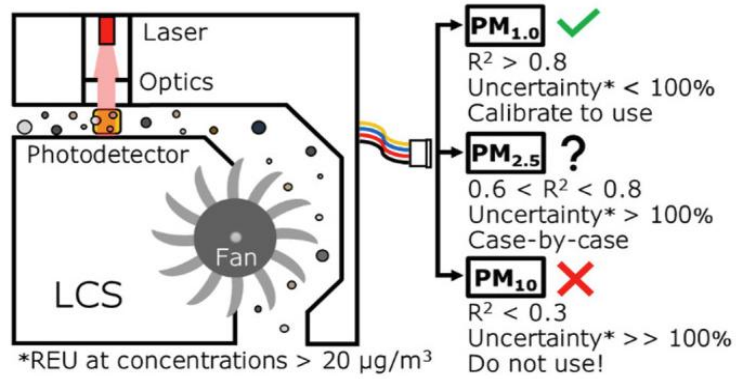
Size-Resolved Field Performance of Low-Cost Sensors for Particulate Matter Air Pollution

Emilio Molina Rueda †, Ellison Carter ‡, Christian L'Orange †, Casey Quinn †, John Volckens †,*

Author information · Article notes · Copyright and License information

PMCID: PMC10018765 PMID: 36938150

Abstract

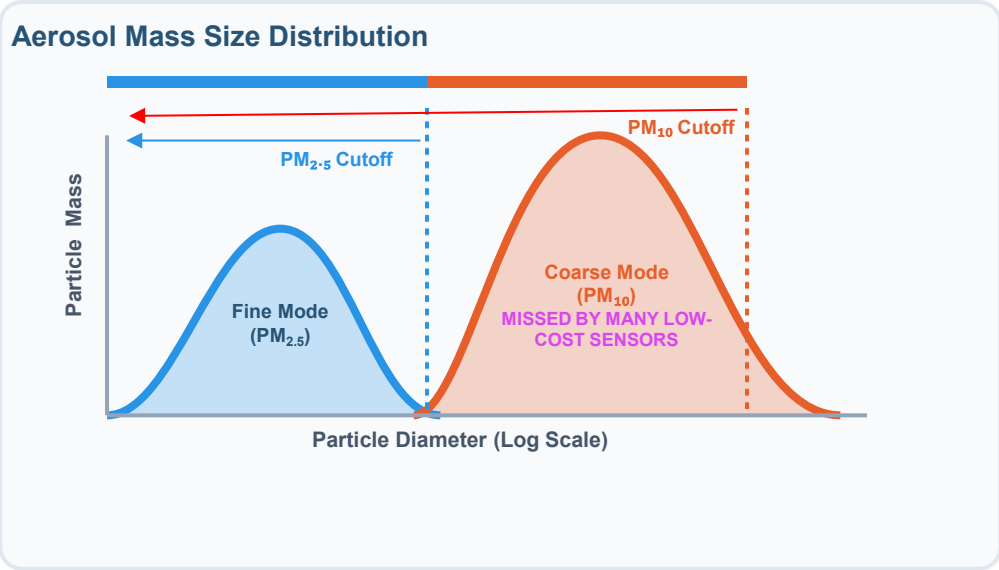


THE INCOMPLETE PICTURE

Measuring only $PM_{2.5}$ misses major pollution sources

The Limitation of Low-Cost Sensors

Standard low-cost optical monitors primarily detect particles with diameters less than 1-2.5 µm. By only tracking **$PM_{2.5}$**, these networks remain completely blind to the coarse particulate fraction.



What You Miss Without PM_{10}

Major mechanical, agricultural, and natural emission sources generate larger coarse fractions that bypass $PM_{2.5}$ sensors entirely:

Windblown Dust	Sea Spray	Mining & Const.
Soil erosion & storms	Coastal aerosols	Mechanical crustal dust

The Coarse Particle Measurement Gap

- Low-cost sensors fail to register heavy, coarse particles due to basic optical inlet limitations.
- Crucial environmental indicators are missed entirely, leaving communities vulnerable to unmonitored dust and industrial events.
- True regional air quality management requires simultaneous monitoring of both fine and coarse particles.

MARKET CONTEXT

The PM_{10} monitoring landscape

PM_{10} performance ↑

Reference
~$30,000
Certified FEM / FRM instrument

ThermoFisher SCIENTIFIC · Met One Instruments · TELEDYNE API Everywhereyoulook

Near reference
~$10,000
Optical Particle Counter

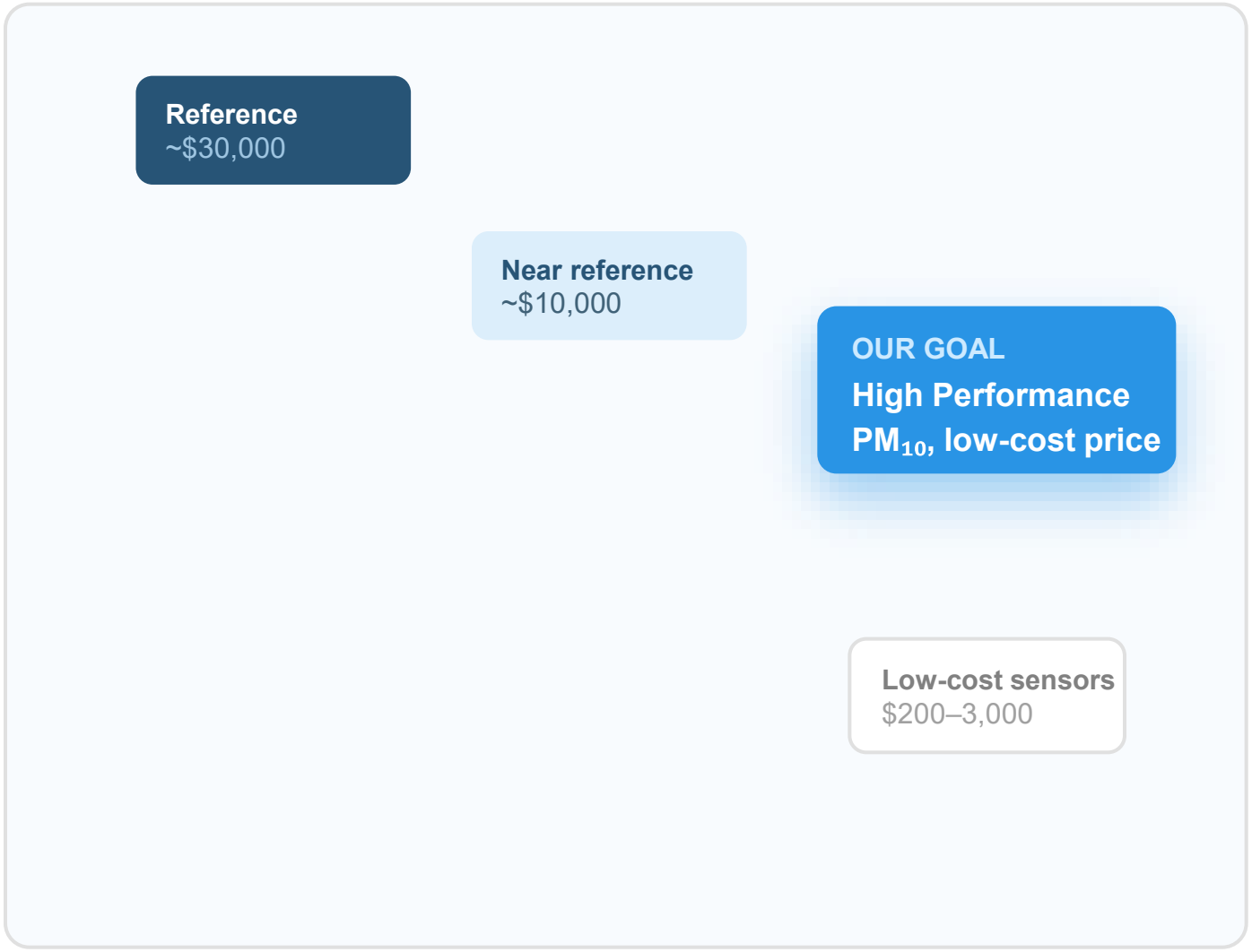
Met One Instruments E-BAM · aeroqual · PALAS · TSI

Low-cost sensors
$200–3,000
Nephelometer or Sensor Fusion

PurpleAir · QUANTAQ · airgradient · kunak SENSING ANYWHERE · airly

WHERE WE ARE HEADED

Our goal: High-Performance PM_{10} at low cost



- Direct coarse particle detection, not algorithm estimates
- Reliable performance in all environments
- Sensor-class affordability and deployment

THE PROBLEM SPACE

Three challenges for PM_{10} performance

01

True coarse particle detection

02

Hygroscopic growth in high humidity

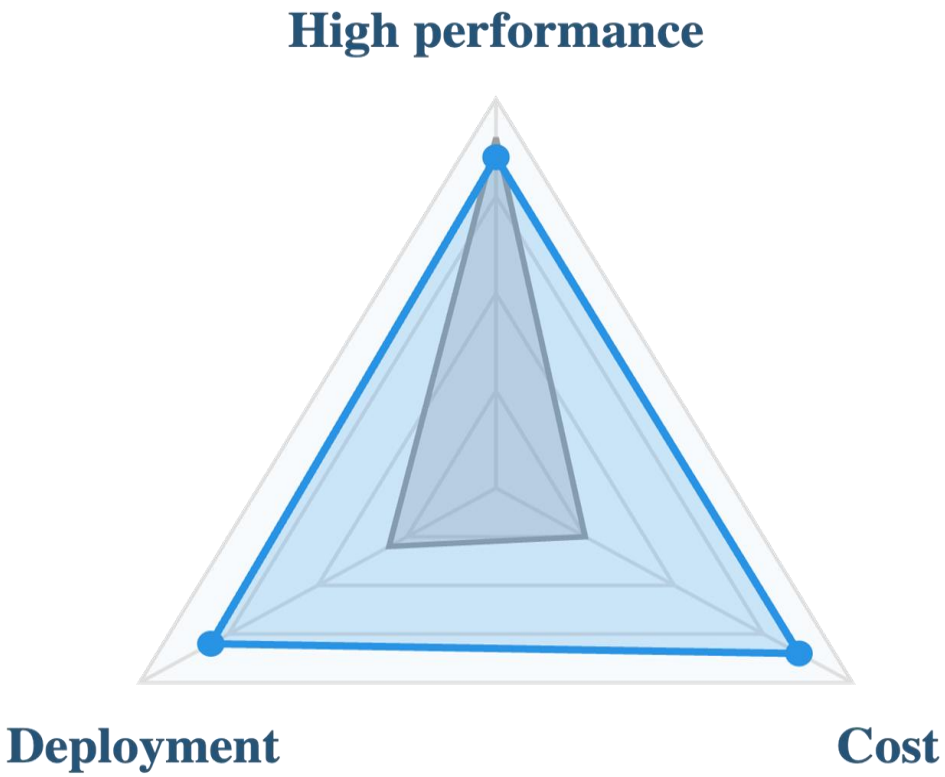
03

Accuracy in high wind conditions

THE DESIGN TENSION

The real challenge is balance

Most instruments optimize one corner. The Dust Module has to hold all three at once.



Hold all three corners at once

- Conventional instrument, strong on a single axis
- Dust Module target, balanced across all three

Performance reliable coarse detection in all environments

Cost remain in the low-cost-sensor price band

Deployment solar capable, small, plug-and-play


MMW4Q33P
TYPE: CLA-DUST01
clarity
WWW.CLARITY.IO
Dust Module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Dust Module
DEERE

THE PRODUCT

Clarity Dust Module

Our first low-cost, high-performance PM_{10} solution.

Dynamic heated inlet
Reduces humidity interference at low power

Advanced optical engine
Direct detection of coarse particles

Modular design
Small, lightweight, plug-and-play

STUDY DESIGN

Robust global collocation across seven sites

Evaluating low-cost sensor accuracy directly alongside regulatory-grade reference instrumentation.

SITE LOCATION	REFERENCE	ENVIRONMENT	MODS
Calexico, CA (USA)	BAM-1020	Border dust, Agricultural	3
King City, CA (USA)	BAM-1020	High humidity & Fog	3
El Paso, TX (USA)	T640X	High-intensity dust storms	3
Sefton (UK)	FIDAS 200E	Urban / Coastal	2
Sellicks Beach (AUS)	TEOM 1405	Coastal / Hygroscopic	1
Västerås (SWE)	FIDAS 200E	Urban / Northern climate	1
Queensland (Aus)	T640X	Urban / Arid	3

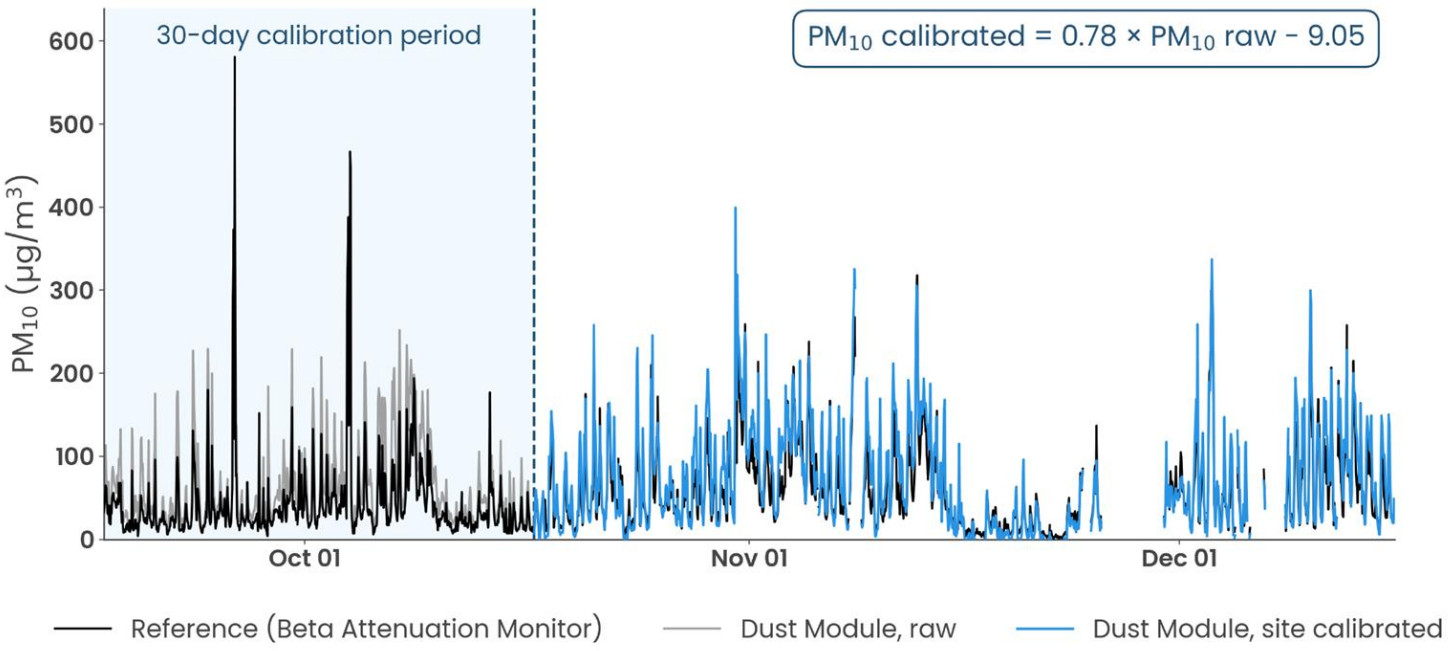
Each Dust Module is co-located and paired with a previous-generation Plantower PMS6003 optical sensor to establish a comparative baseline performance.

Site-specific meteorological data for each collocation is systematically gathered utilizing either the local weather station or a co-deployed Clarity Wind Module.

Calibration Methodology

Calibration approach

Simple linear regression on the first 30 collocation days



Site-Specific Calibration

The first 30 days of collocated data were used to develop a site-specific calibration.

Simple Linear Regression

Calibration followed a simple linear regression using only the raw sensor PM_{10}.

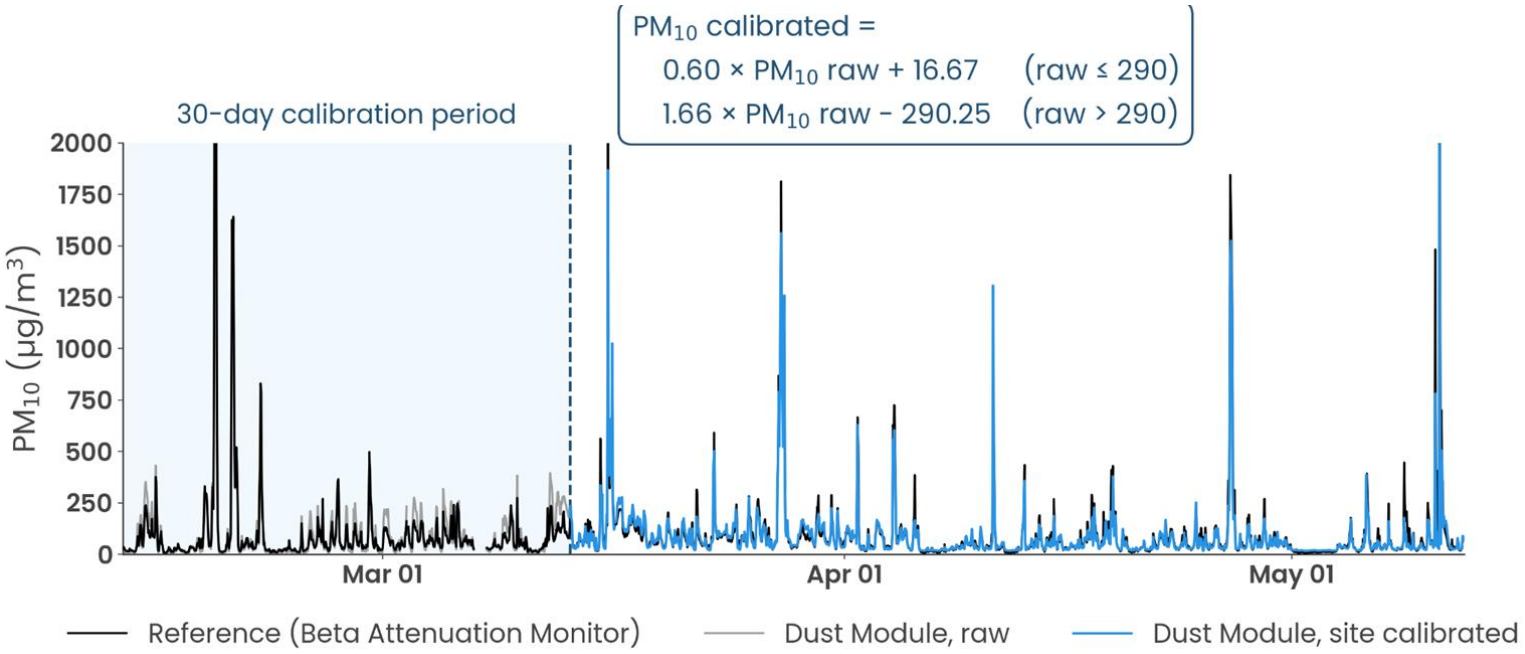
Rigorous Evaluation

Accuracy evaluation was conducted excluding the calibration development period.

Calibration Methodology

Calibration approach

High concentrations in El Paso, TX required a piecewise linear model



Piecewise Linear Regression

Due to extreme dust events in El Paso, peak concentrations exceeded 1,000 µg/m^3.

We observed a nonlinear effect at high concentrations. To account for this, we used a piecewise linear model with a breakpoint at 290 µg/m^3.

This approach follows the US EPA's Purple Air correction model used on the Fire and Smoke Map.

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01

VALIDATION 1

Accuracy across a range of conditions

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Preliminary Performance Data

Site-by-Site Evaluation (daily average PM_{10})

Site	R^2	RMSE	Slope	Intercept
Calexico, CA - Unit 1	0.86	17.7	1.2	2.4
Calexico, CA - Unit 2	0.90	13.6	1.1	-1.0
Calexico, CA - Unit 3	0.89	13.4	1.1	0.4
El Paso, TX - Unit 1	0.93	25.4	0.87	7.0
El Paso, TX - Unit 2	0.97	17.5	0.95	9.2
El Paso, TX - Unit 3	0.99	11.9	0.94	8.2
King City, CA - Unit 1	0.92	4.4	0.74	3.1
King City, CA - Unit 2	0.91	4.1	0.80	2.1
King City, CA - Unit 3	0.88	4.3	0.80	2.2
Sefton, UK - Unit 1	0.92	3.4	0.90	2.3
Sefton, UK - Unit 2	0.80	5.7	0.69	6.9
South Australia - Unit 1	0.75	6.9	0.67	11.0
Stora Gatan, SE - Unit 1	0.74	30.1	0.65	3.5
Queensland - Unit 1	0.80	2.9	0.57	4.5
Queensland - Unit 2	0.87	2.4	0.68	3.3
Study Median	0.89	6.9	0.8	3.3

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VALIDATION 2

True detection of coarse-mode particles

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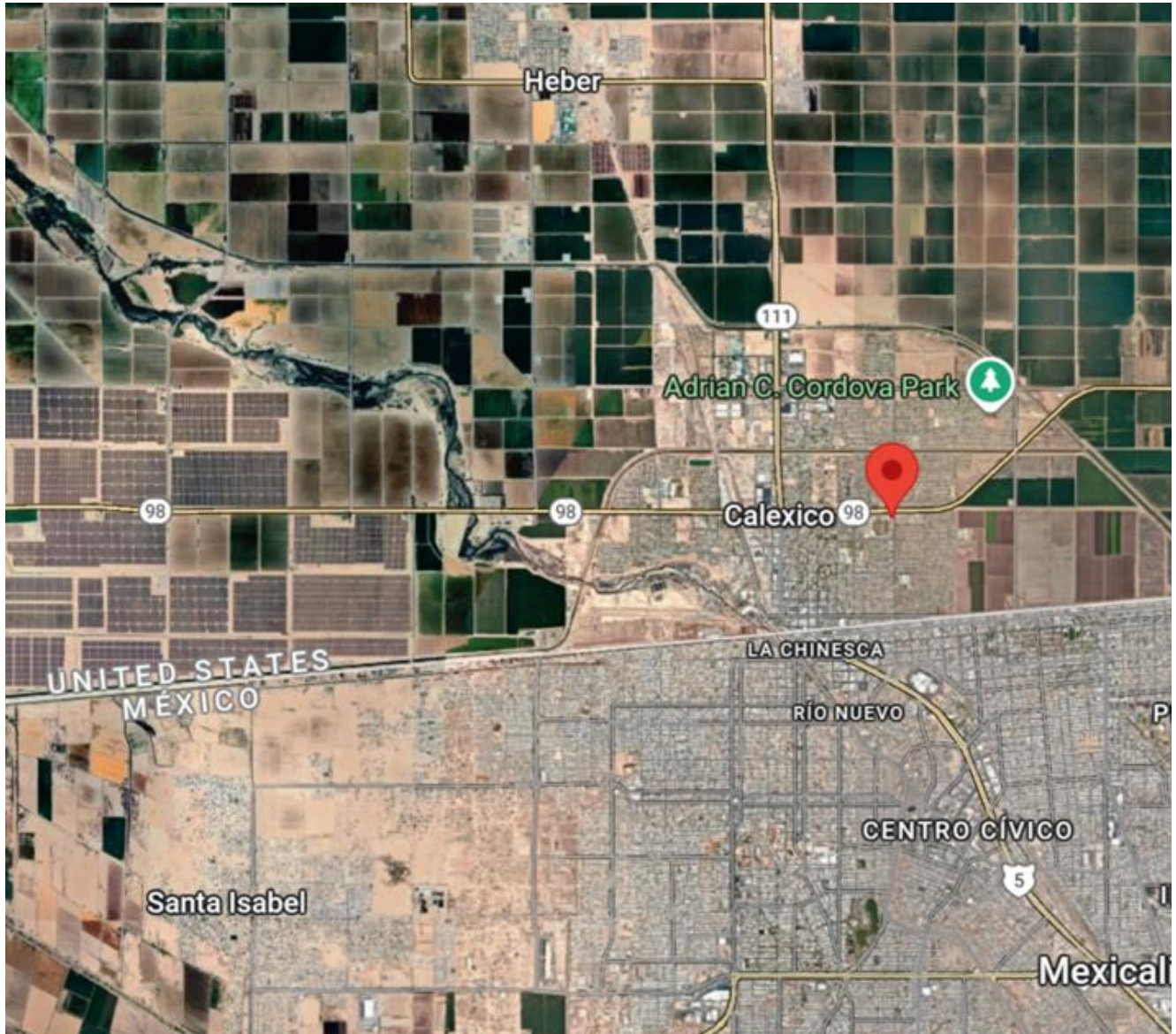
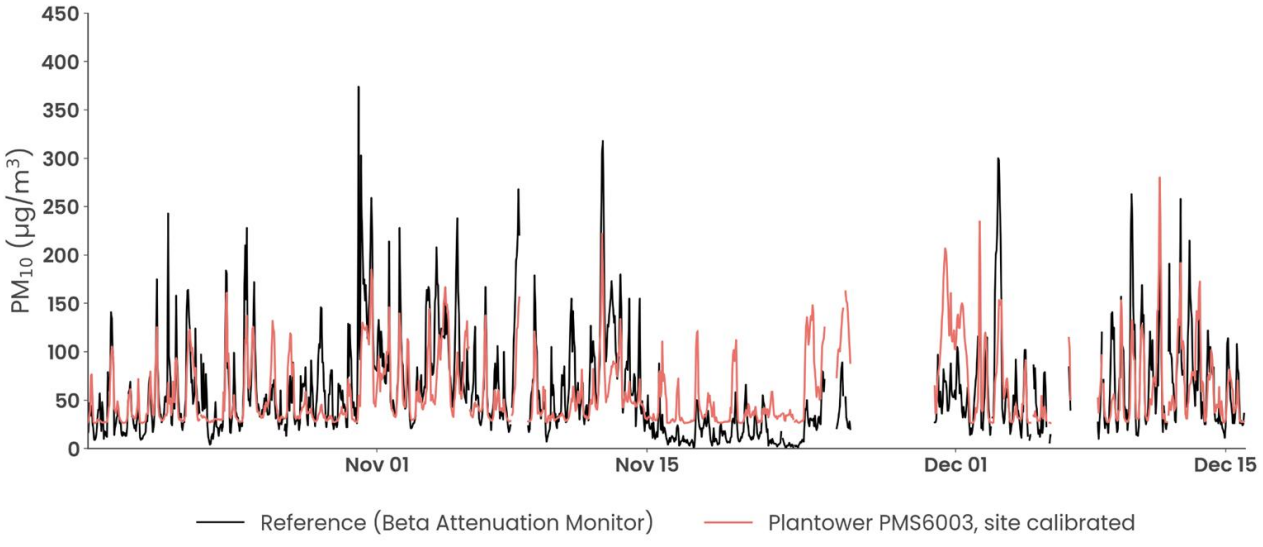
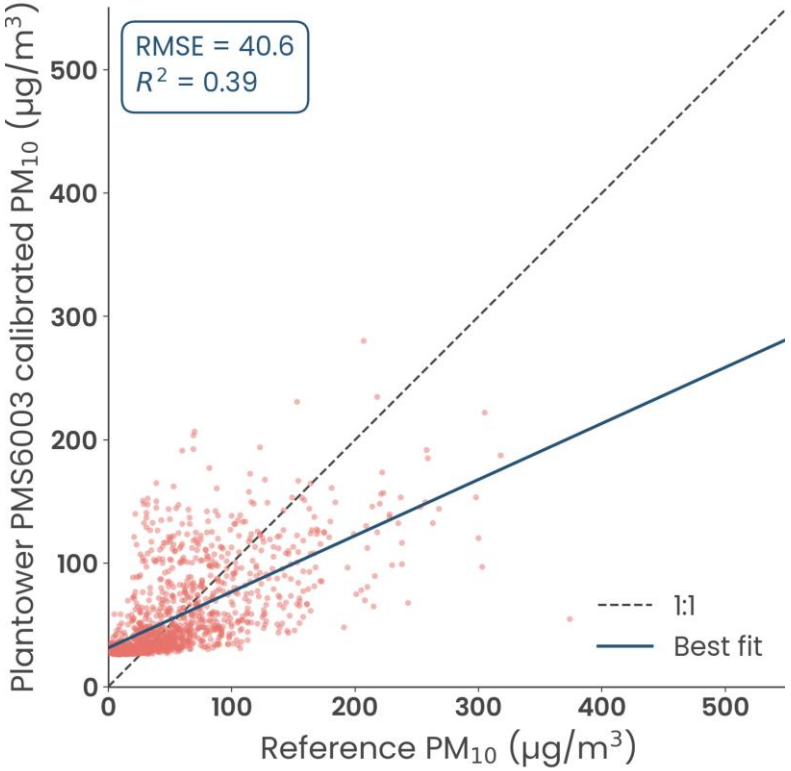
PRELIMINARY PERFORMANCE DATA

Calexico, California



The limitation of traditional low-cost sensors

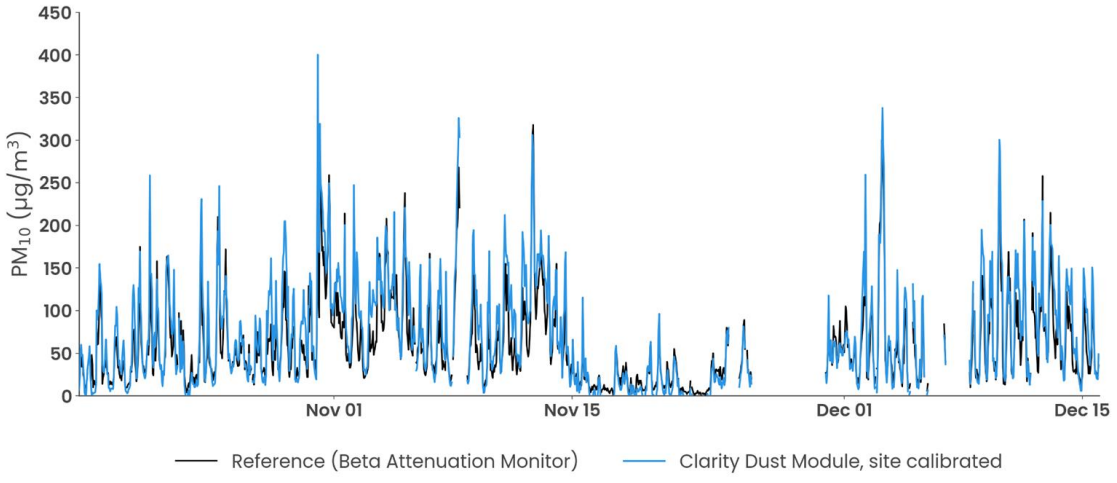


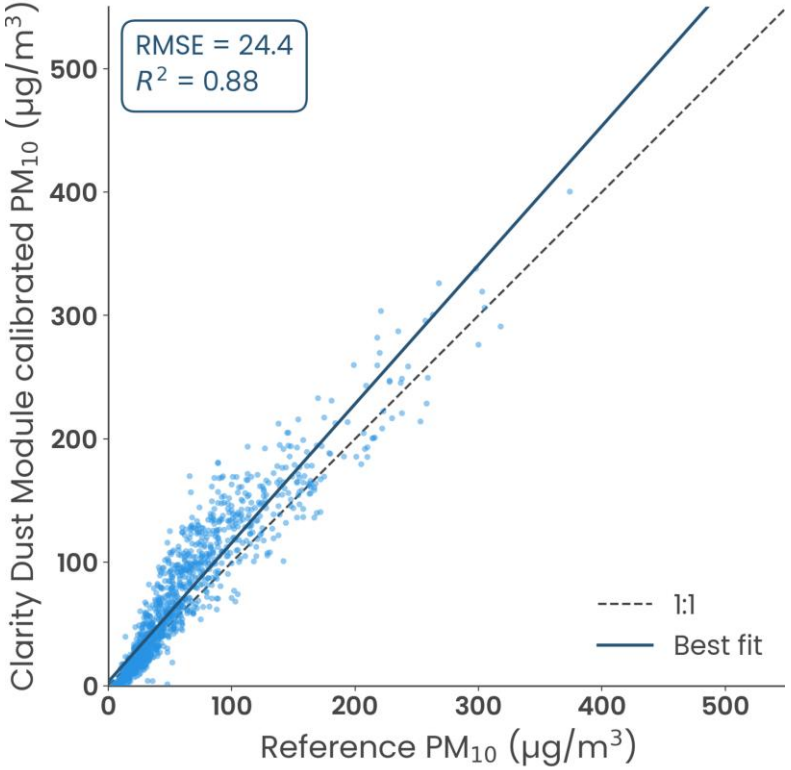


A Plantower PMS6003 tracks fine PM but undercounts the coarse peaks that define PM_{10}, with weak correlation to the reference.

CALEXICO · DUST MODULE

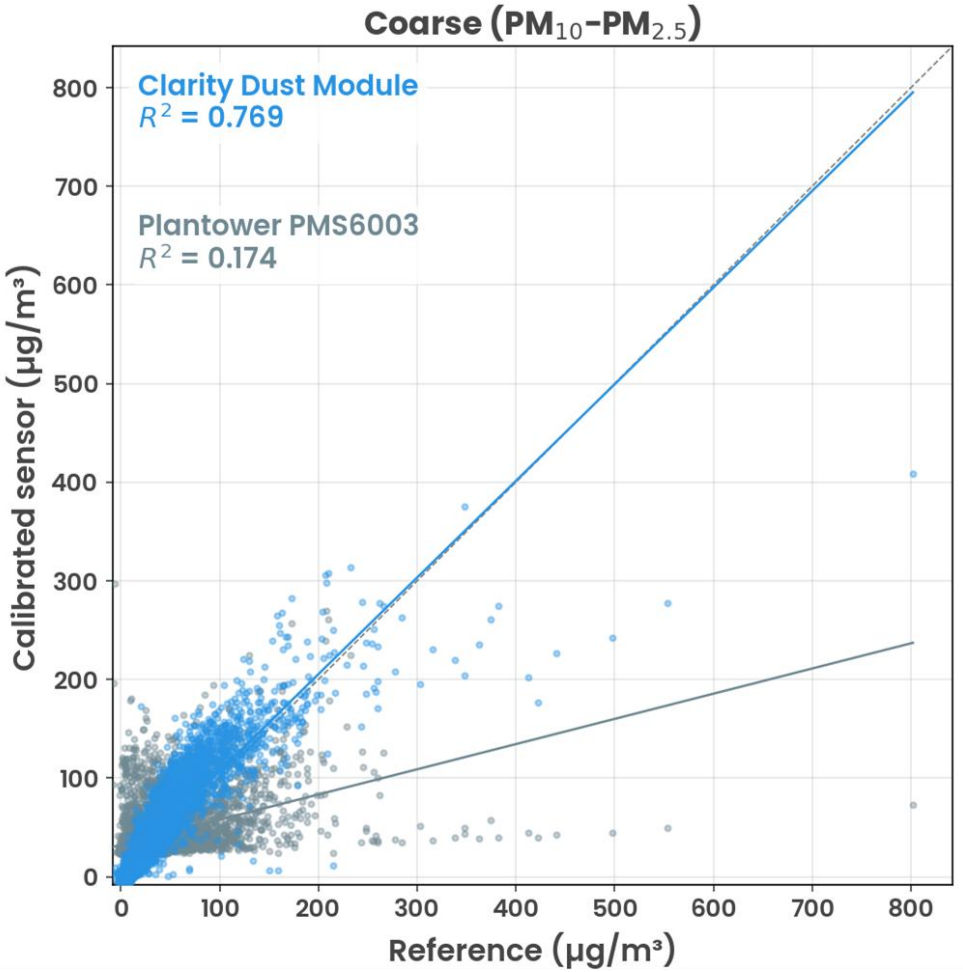
The Dust Module tracks the coarse peaks





CALEXICO, CALIFORNIA · PERFORMANCE

The Dust Module detects the coarse-mode that traditional sensors miss



- Correlation (R^2) is 0.77 with the Dust Module compared to only 0.17 with the Plantower PMS6003.
- The Dust Module is able to measure large (greater than 2.5 micron diameter) particles, closing a gap left from many traditional low cost sensors.
- This finding is consistent with results from a growing body of research (e.g., Molina Rueda et al., 2023)

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VALIDATION 3

Reducing hygroscopic growth in high humidity

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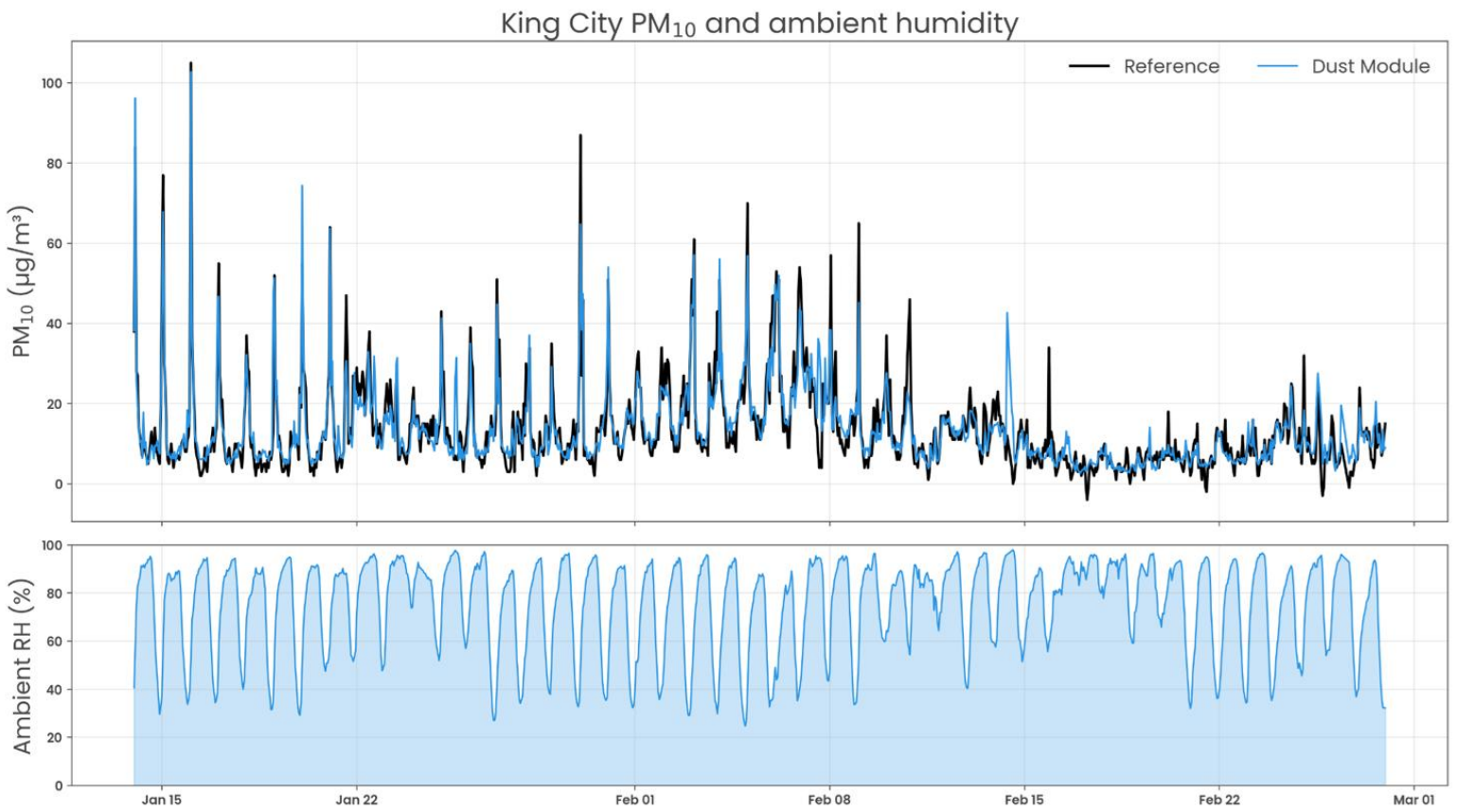
PRELIMINARY PERFORMANCE DATA

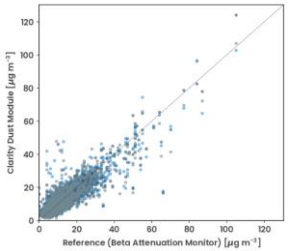
King City, California

Persistent fog and high relative humidity make King City the hardest test for hygroscopic interference.

KING CITY, CALIFORNIA · RESULTS

The heated inlet holds up in fog



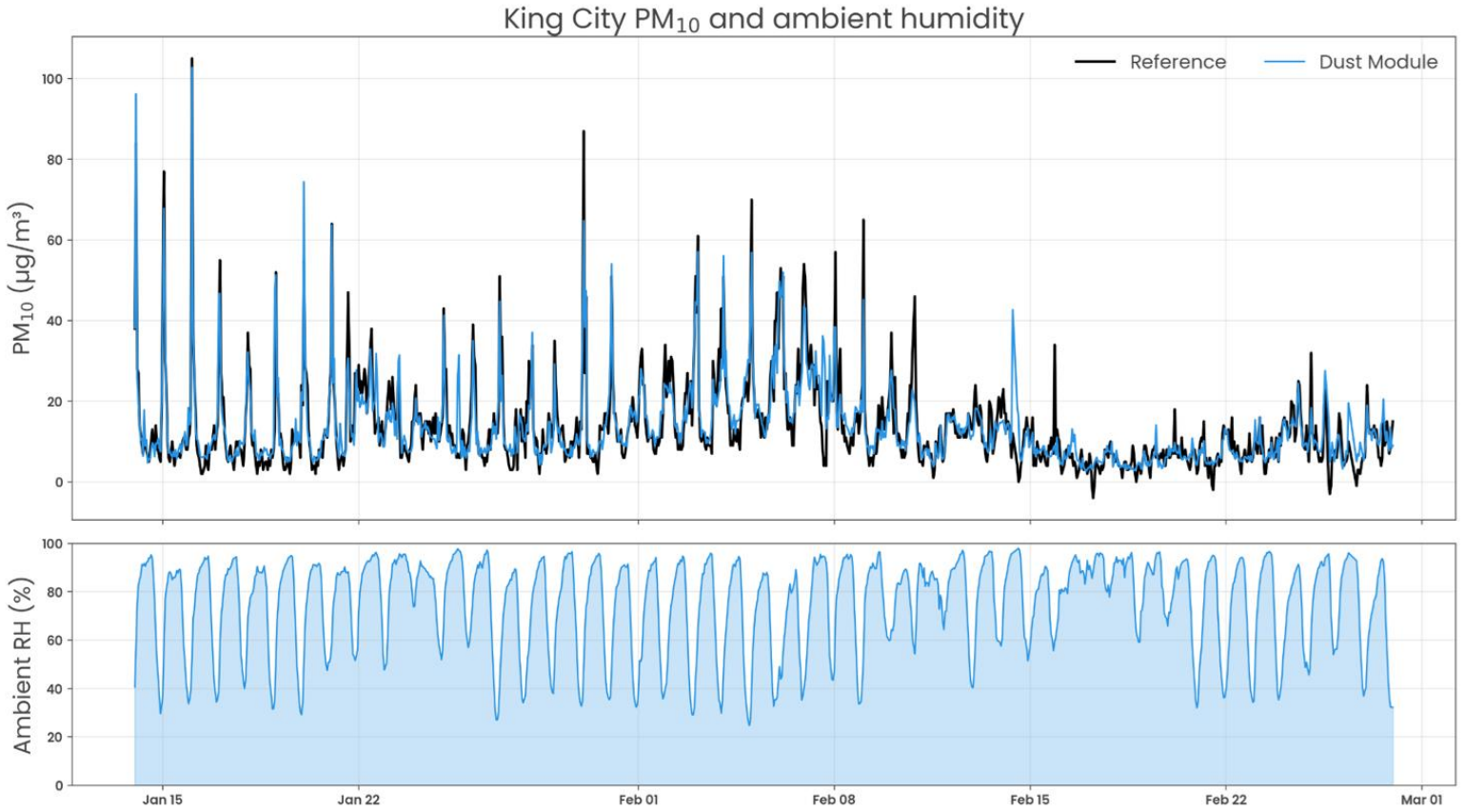


HEATED INLET

R^2 > 0.80

KING CITY, CALIFORNIA · RESULTS

The heated inlet holds up in fog



- We tested the impact of the inlet heater in King City by deploying three additional Modules *without* an inlet heater.
- Below 80% relative humidity (RH), heater-on and heater-off modules performed similarly.
- At 80-90% RH, heated modules maintained an R^2 of 0.69-0.74 while unheated modules declined to 0.53-0.59 and showed a positive bias of 3-6 µg/m³.
- Above 90% RH, fog artifacts affect PM10 measurements, but heated modules recorded 2-5x fewer discrete fog events.

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VALIDATION 4 · IN PROGRESS

Maintaining accuracy in high wind

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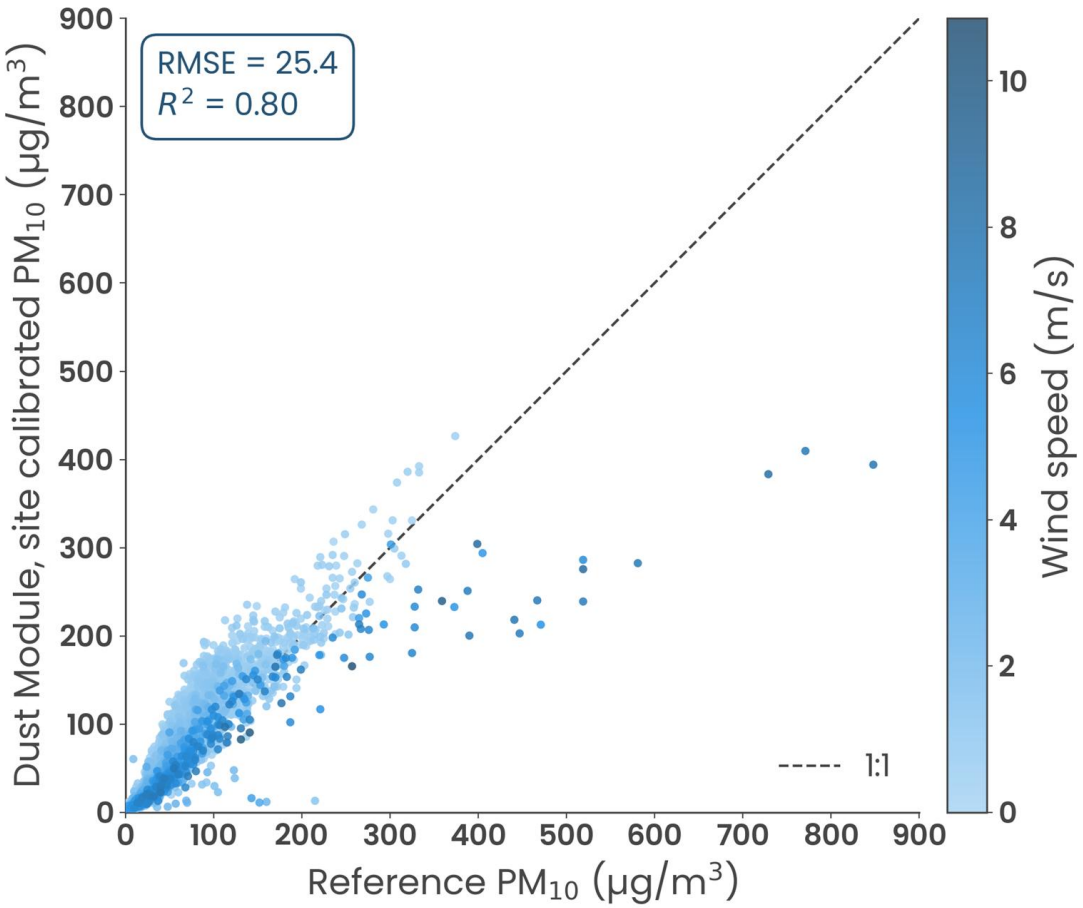
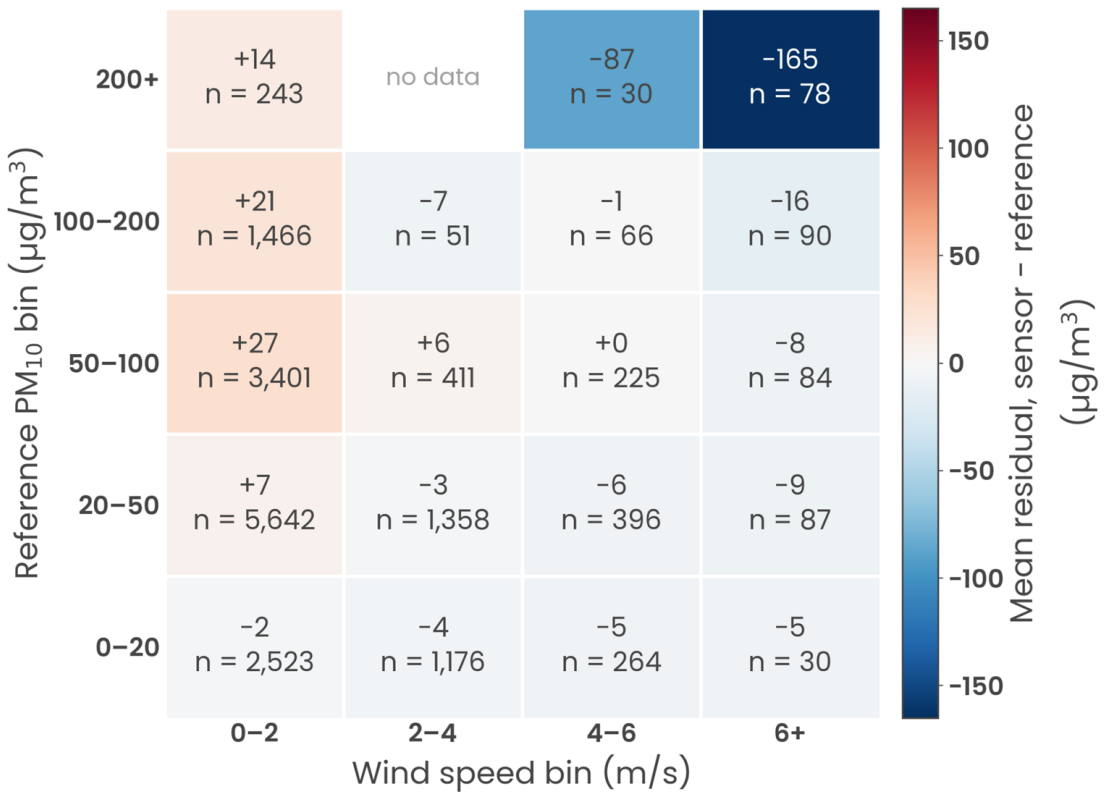
THE REMAINING CHALLENGE

High wind degrades accuracy

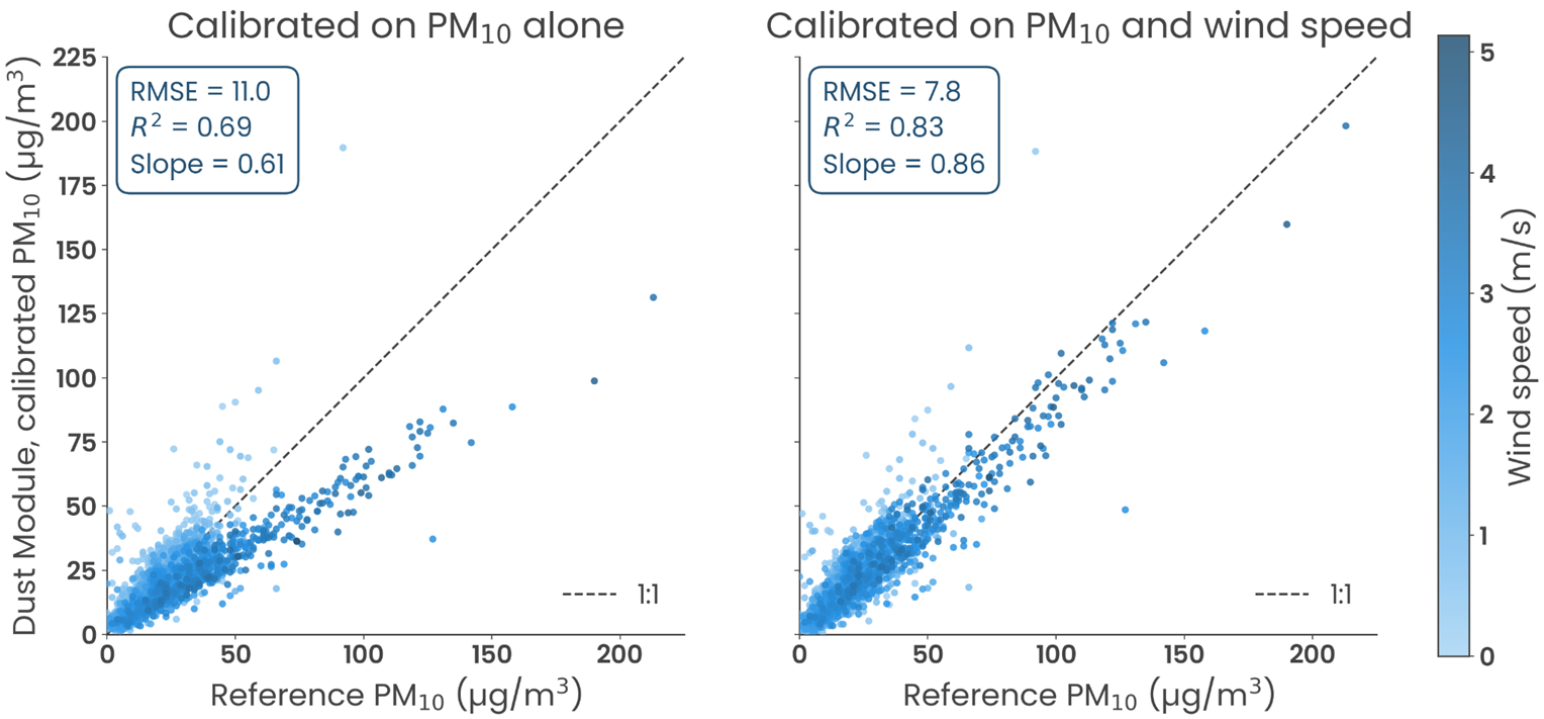




Residual error grows with both concentration and wind speed, pointing to a wind-driven inlet effect.

OUR APPROACH · STILL VALIDATING

Calibrating with wind integration



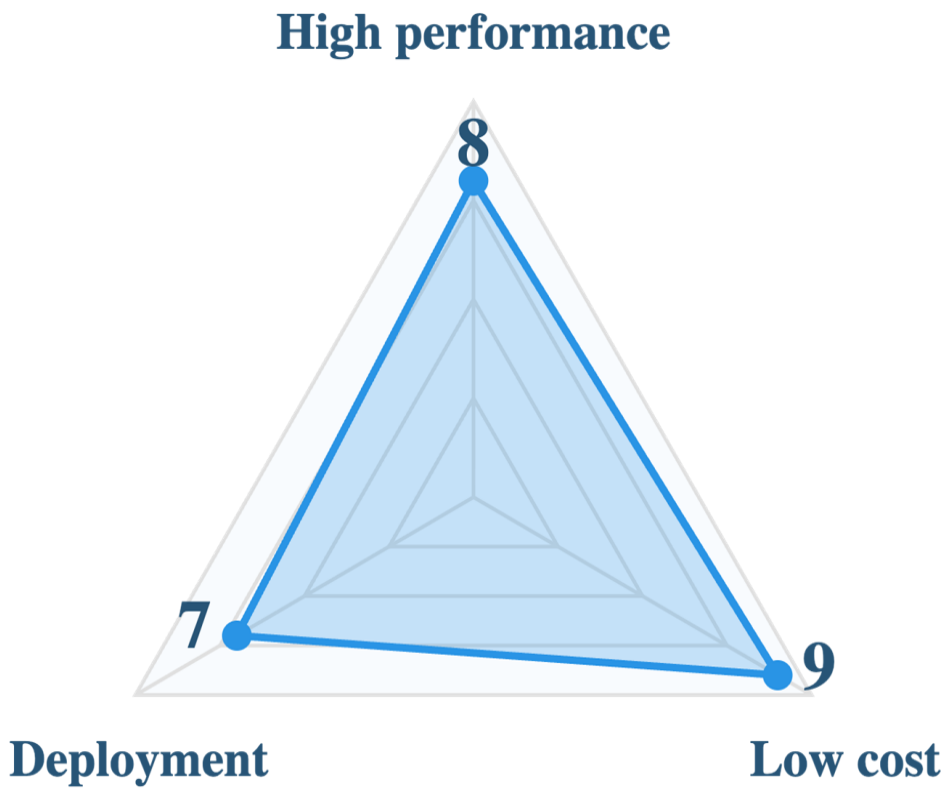
Folding wind into the model recovers the 1:1 fit

Wind-integrated calibration pulls the high-wind points back toward the reference line. Validation is ongoing across sites.

- **Validation in progress**

WHERE WE LANDED

Near-reference dust monitoring at low cost



High performance 8/10

Reliable coarse detection · Reduced high-RH growth · High-wind pending

Low cost 9/10

Priced in the low thousands · Affordable to scale

Easy deployment 7/10

Solar capable (25–50 W) · Small and modular · 12-hour battery

HONEST ASSESSMENT

Known limitations

01 **Saturated high-RH events**

The heated inlet is not yet efficient enough for fully saturated fog; these periods are currently QC-screened.

02 **Power efficiency**

The device relies on external solar to operate; power efficiency can be improved further.

03 **Inlet and flow control**

Air inlet and flow control can be improved to avoid relying on wind data for high-wind calibration.

AVAILABLE NOW

Two PM_{10} measurement options

- Available now

Dust Module

Standalone PM_{10} sensor module

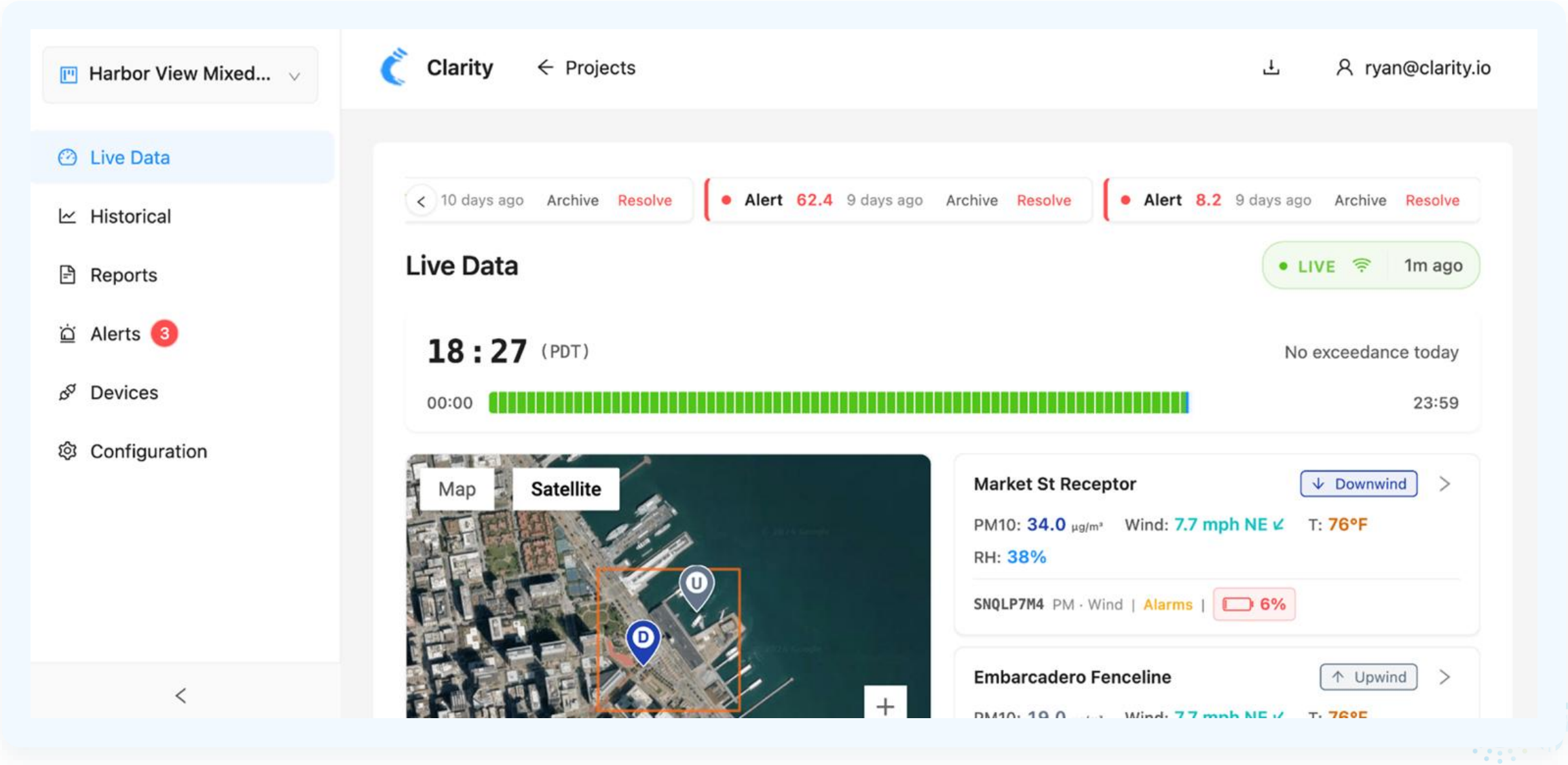
- Available now

Dust Measurement Suite

Complete solar station with met sensors

CLARITY CLOUD

Construction-focused dashboard



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DUST MODULE

High performance dust detection at low cost

- Reliable Ture PM_{10},
- Heated inlet reduces high-RH impact
- Low cost, built to scale
- 12-hour battery, solar optional

David Lu & Jack Kodros · Clarity Movement Co. · www.clarity.io