Global and custom calibration approaches for Clarity's Node-S air quality measurements

$PM_{2.5}$ and NO_2 Calibration

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ASAQ Annual Seminar 3rd December 2025; Online
Instrumentation and advances in air quality monitoring session.

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Proudly supporting

BREATHE ACCRA

Breathe Metro Manila

Breathe London
the community sensing project

www.clarity.io

A proven air quality measurement solution for African countries

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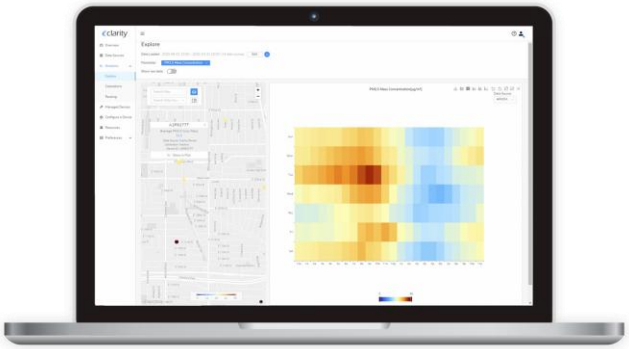


Deployed in **15+** African countries

Accra, Ghana
15+ sensors to support the Breathe Accra project

Freetown, Sierra Leone
15 sensors (monitoring starting from 2026)

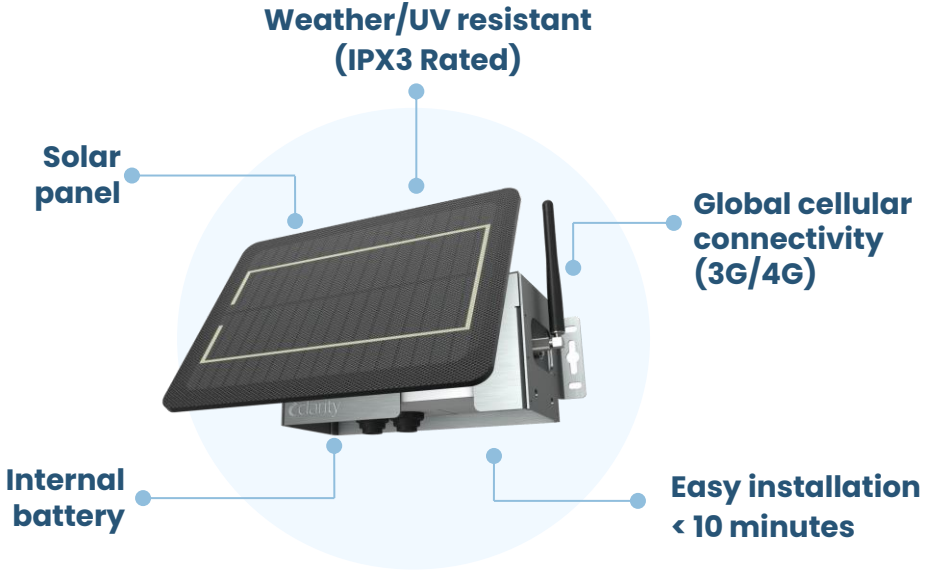
Kampala, Uganda
25+ sensors to establish KCCA official air monitoring

Tundavala, Angola
8+ sensors for urban & rural air quality monitoring

Kansanshi, Zambia
Compliance monitoring for Kansanshi mine

Clarity Node-S

A resilient, independently powered, and cellular-connected air monitor

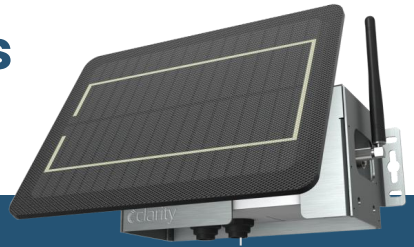


Measures **PM** and **NO2**.

FCC + CE, MCERTs certified and designed for **easy deployment** everywhere, and **reliable operation** in adverse weather conditions.

mCERTS
CSA MC230425/00

Clarity Add-On Modules



Node-S provides connectivity to Clarity Cloud

Wind Module

Determine where air pollution is coming from.

Ozone Module (FEM-Capable)

Confirm ozone attainment with this FEM-capable device.

Black Carbon Module (Lab -Grade)

Understand the composition and sources of particulates.

Multi-Gas Module (NOx, CO, O3)

Measure additional gaseous pollutants - CO, NOx (NO2 + NO) and O3

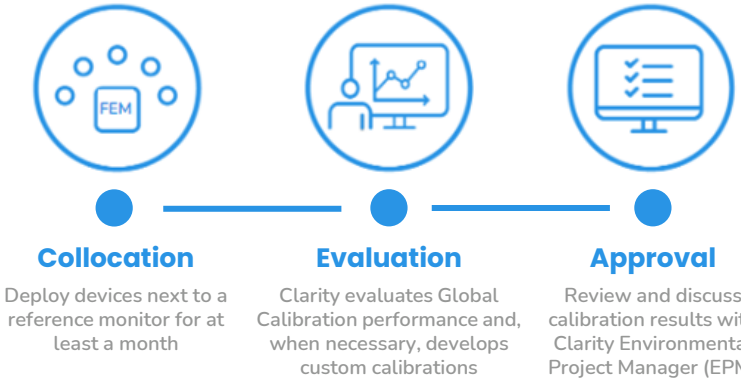
Dust Module (PM10)

Accurate coarse mode PM detection

Calibrating the Clarity Node-S

The Need for a Global Calibration

- While we encourage each customer to perform a collocation, often times this is not possible due to lack of access to a FEM, project timeline (i.e. emergency response), or other logistical challenges
- In these instances, it's critical to have an out-of-the-box solution that can enable rapid, seamless, and reliable roll-out of a network
- Further, a Global Calibration typically performs better than a Custom Calibration, because it is trained on a substantially more diverse dataset



Custom vs. Global Calibrations

Understanding the pros and cons of each approach

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Custom Calibration

Tailored to local conditions using collocation data collected at one or more local monitoring stations

Pros:

- Can improve performance in certain conditions
- Can be more easily explained to the general public
- Developed using project-specific data

Cons:

- Typically less-accurate long-term
- May be hindered by limited variability during collocation period requiring longer or permanent collocations to gather suitably varied data
- May need to be updated more frequently, making longitudinal comparisons more challenging

Global Calibration

Developed with a substantial dataset from collocations across the world to provide accuracy across a wide-range of conditions

Pros:

- Ready out-of-the-box
- Tested globally and typically outperforms custom calibrations
- Strong performance across a wide-range of concentrations and weather conditions

Cons:

- There may be some areas that are not well-represented by the calibration
- Less-traceable (though still developed using data from collocations with FEMs)

Clarity Air Quality Project Support

We will work with you to find the best calibration approach.

***Collocation is optional**, but recommended if access to reference equipment is available*

Onboarding

Align on air quality monitoring goals and define a calibration strategy

Global Calibration

Pre-applied proprietary Global Calibrations enhance $PM_{2.5}$ and NO_2 accuracy

Collocation

Deploy devices next to a reference monitor for at least a month

Evaluation

Clarity evaluates Global Calibration performance and, when necessary, develops custom calibrations

Approval

Review and discuss calibration results with Clarity Environmental Project Manager (EPM)

Field deployment

Devices are moved to the field — when possible, one device is left collocated to monitor accuracy over time

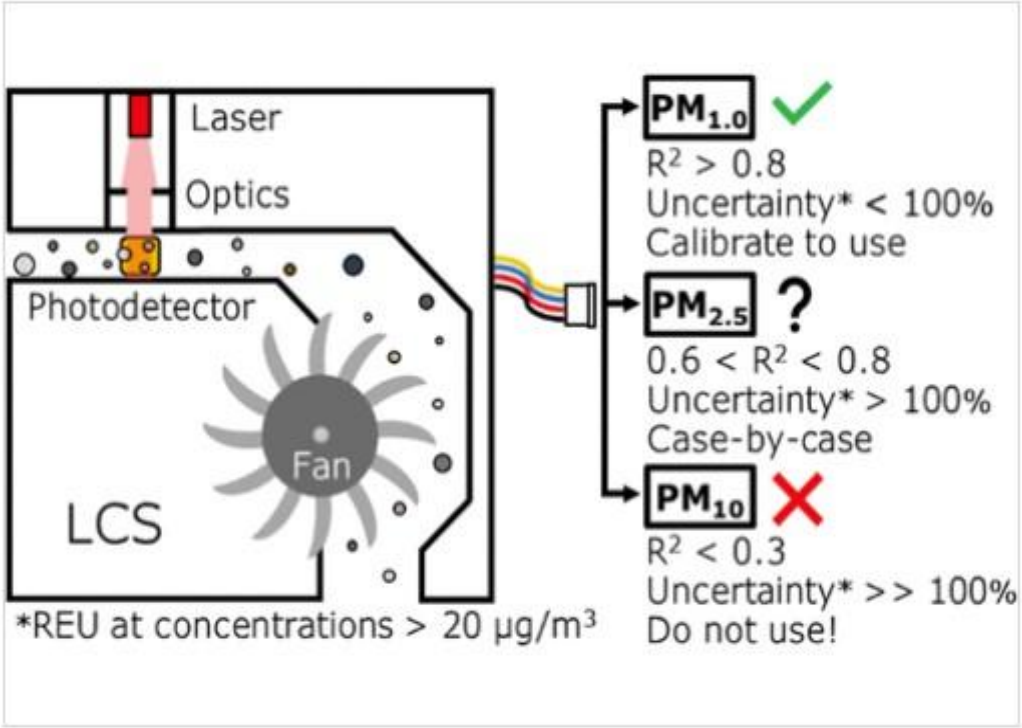
Ongoing support

Clarity EPMs work with customer to ensure continued data quality — faulty devices replaced free of charge under Sensing-as-a-Service

Importance of high quality Calibration

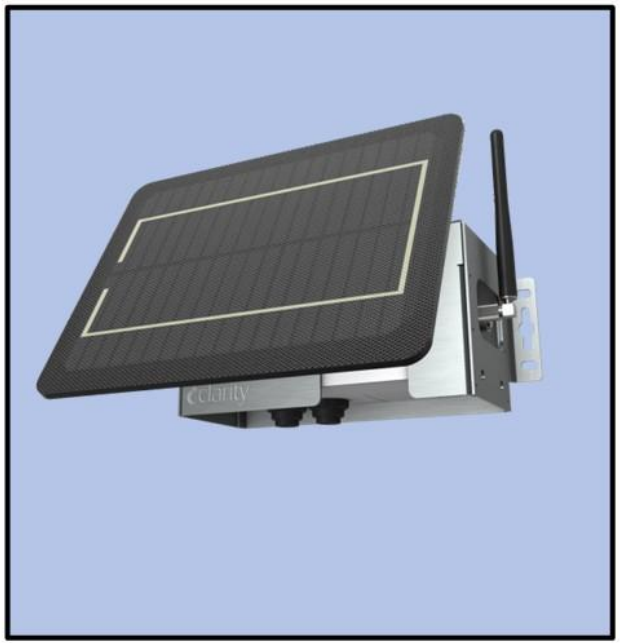
- Many organizations chose to use our global calibration year-round because of its good performance

What has been done for projects in Africa?



Size-Resolved Field Performance of Low-Cost Sensors for Particulate Matter Air Pollution, Emilio Molina Rueda, Ellison Carter, Christian L'Orange, Casey Quinn, and John Volckens, Environmental Science & Technology Letters 2023 10 (3), 247-253
DOI: 10.1021/acs.estlett.3c00030

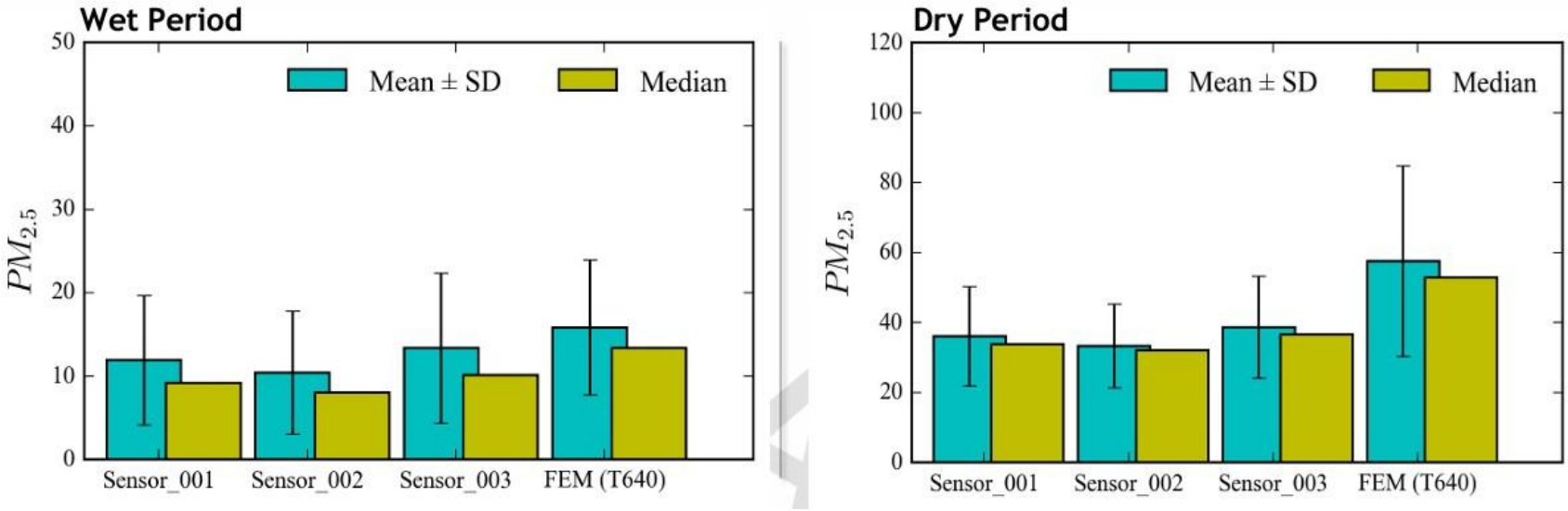
Field Evaluation $PM_{2.5}$ Afri-SET Calibration



Afri-SET Field Evaluation Report for Clarity Node-S Air Quality Sensor (Calibrated $PM_{2.5}$)

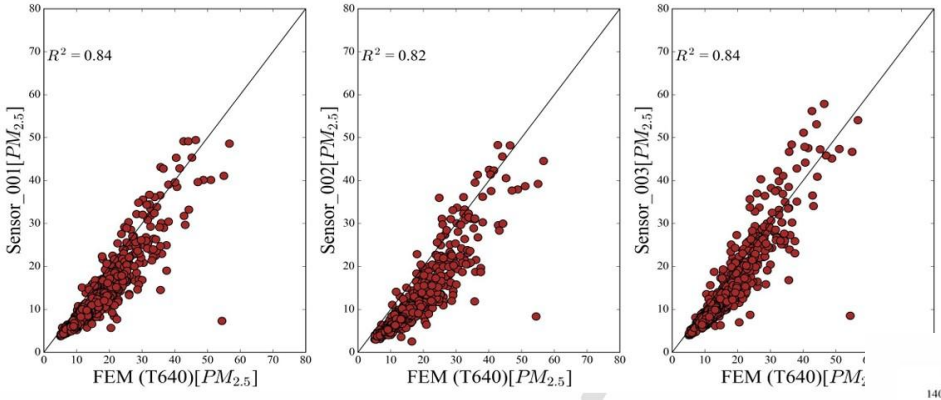
Field Evaluation $PM_{2.5}$ Afri-SET Calibration

Intra–unit variability of PM2.5 (30-minute mean; µg/m3)

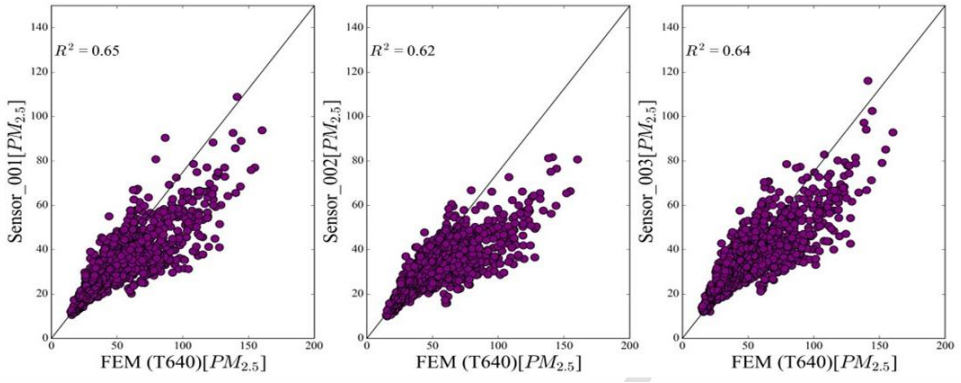


Field Evaluation $PM_{2.5}$ Afri-SET Calibration Clarity-NS vs FEM T640 PM2.5

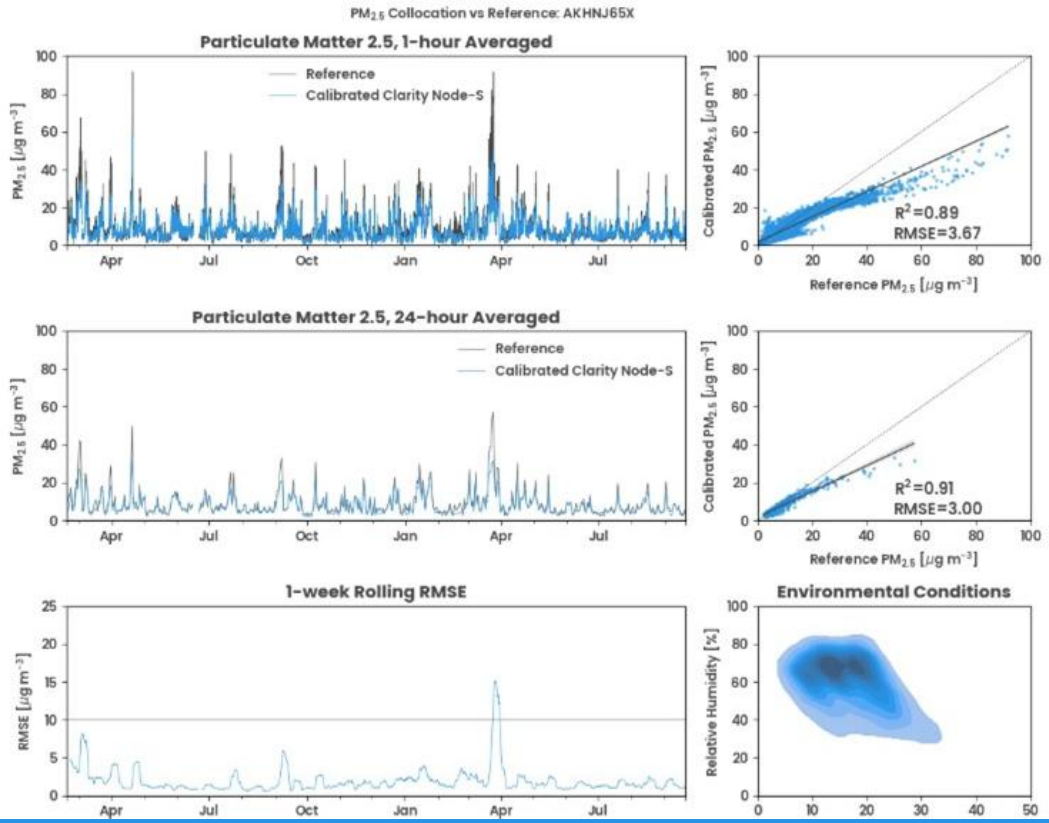
Wet Period; 1 hour mean, µg/m3



Dry Period;1 hour mean, µg/m3



Custom Collocation $PM_{2.5}$ Calibration Example

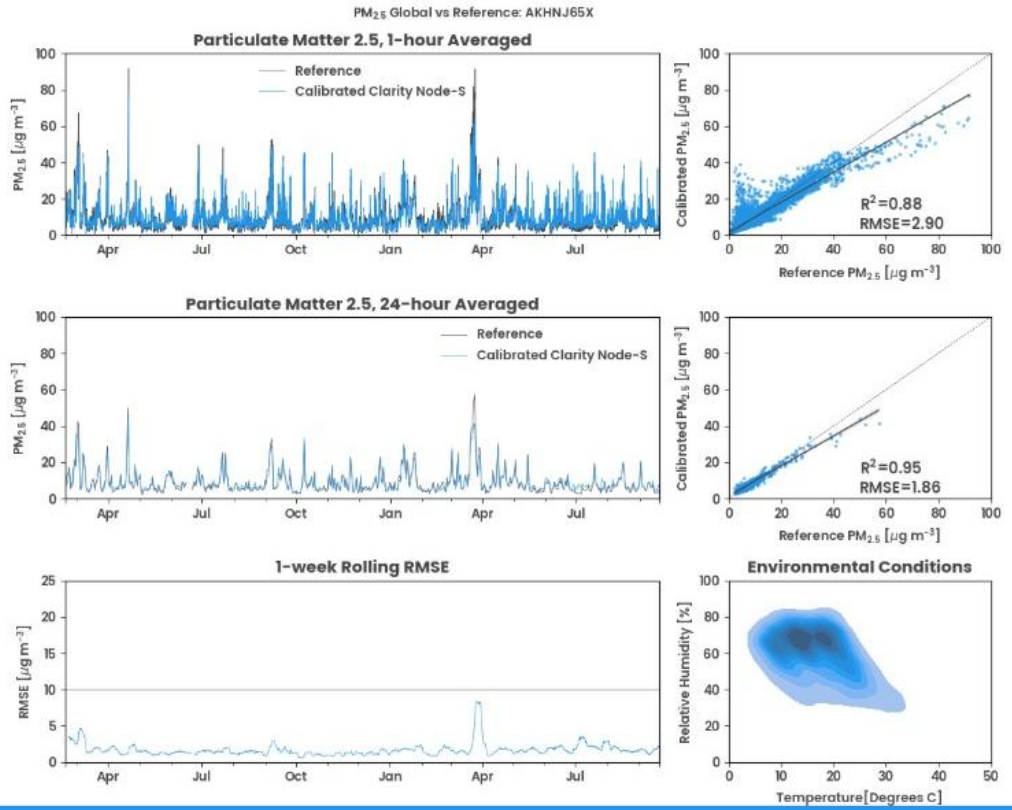


United Kingdom

Performance of air quality measurement equipment as compared to reference-grade air pollution monitors.

https://www.clarity.io/collocation-results-library

Global $PM_{2.5}$ Calibration Example



United Kingdom

Performance of air quality measurement equipment as compared to reference-grade air pollution monitors.

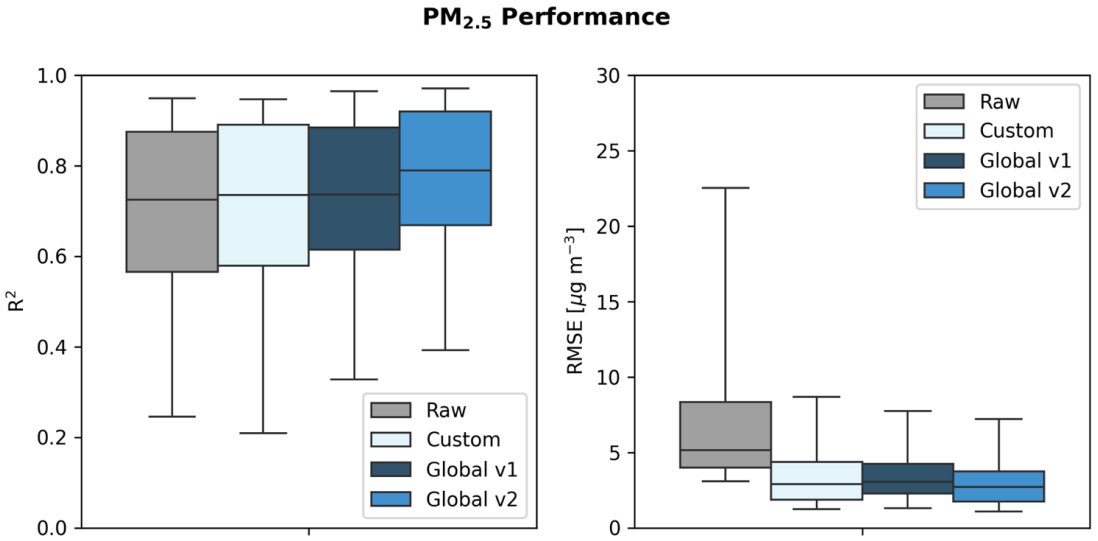
Many organizations chose to use it year-round because of its good performance

https://www.clarity.io/collocation-results-library

v2 Global Calibration

Model Performance

- v2 represented a significant improvement in performance compared to the v1 Global Calibration *and* most custom calibrations
- The median R^2 increases to 0.79 (+7% from v1), and the median RMSE decreases to 2.7 µg/m³ (-12% from v1)

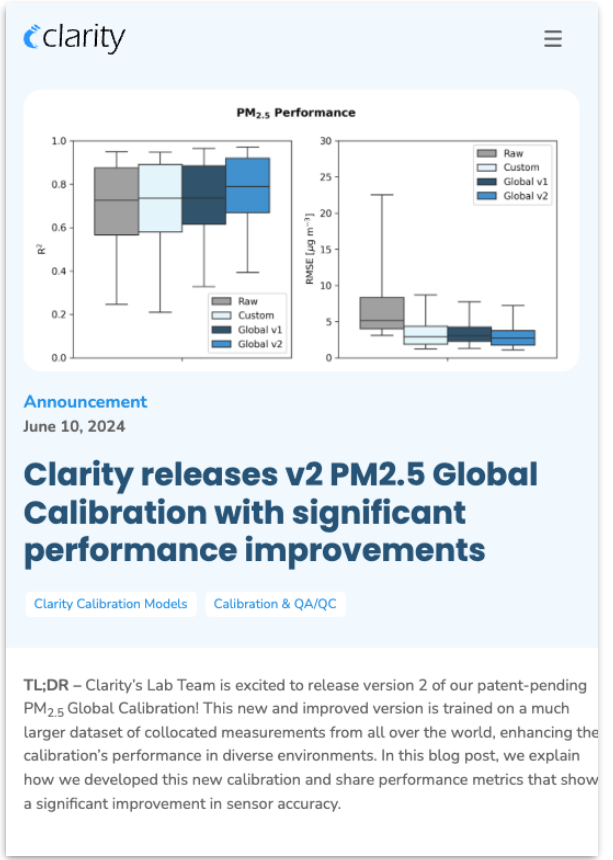


v2 was the first of Clarity's Global Calibrations to exceed the performance of custom calibrations

Evolution of Clarity's Global $PM_{2.5}$ Calibration

v2 Global Calibration

- v1 served our clients well, but since its development our clients had collocated **hundreds** of Node-S devices with Federal Equivalent Methods worldwide
- Clarity's Lab Team set out to leverage the learnings over the previous three years as well as the vastly expanded collocation dataset to improve Global Calibration performance



Developing the V2.1 Global calibration

623
Node-S sensors

84
Unique cities

98
Reference sites

>6 million
Measurements

Evolution of Clarity's Global $PM_{2.5}$ Calibration

v2.1 Global Calibration

- v2 represented a substantial improvement in accuracy and scalability for Clarity
- In general, it performs superbly across a wide range of conditions
- However, as more collocation data were gathered, it became evident that it tended to underestimate higher concentration events
- Motivated by this, Clarity's Lab Team set out to develop an updated version of the model that removes this bias

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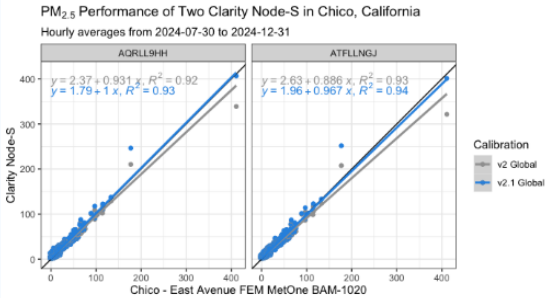


Article

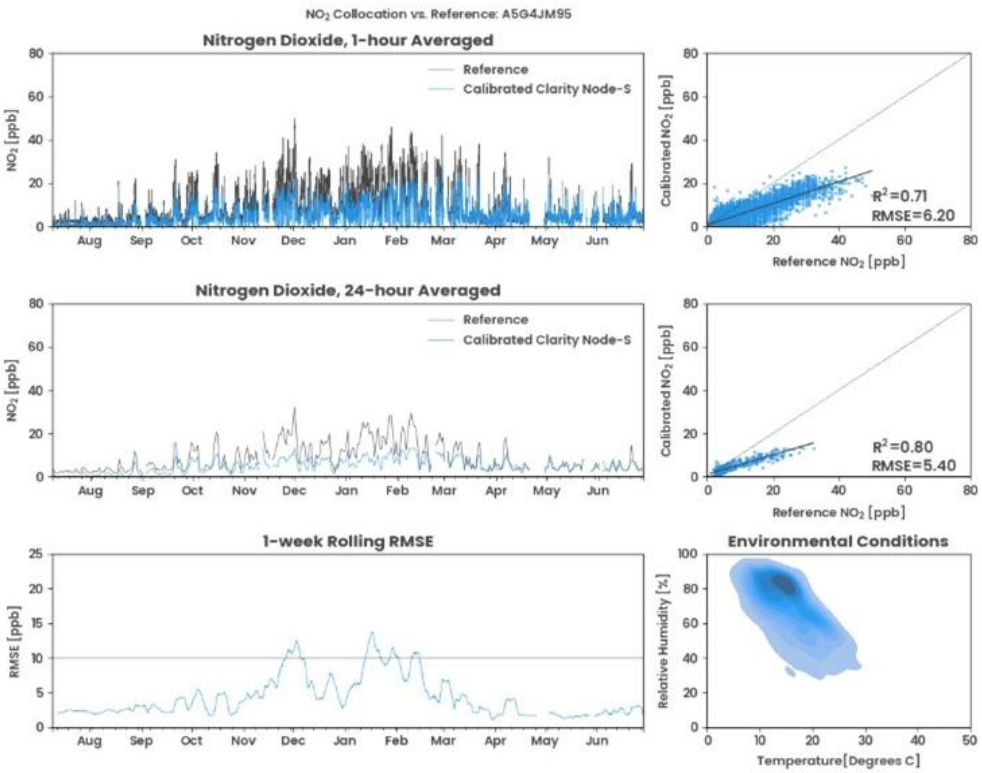
April 23, 2025

Clarity releases v2.1 PM2.5 Global Calibration with improved performance during wildfires and high-pollution events

Clarity Calibration Models | Calibration & QA/QC

TL;DR – Clarity's Lab Team is excited to release version 2.1 of our $PM_{2.5}$ Global Calibration! v2.1 improves upon the powerful v2 $PM_{2.5}$ Global Calibration by increasing accuracy during high-pollution events. In this blog post, we explain how we developed this new calibration and share performance metrics that show a significant improvement in sensor accuracy, especially during periods with elevated pollutant concentrations.

Custom NO_2 Calibration

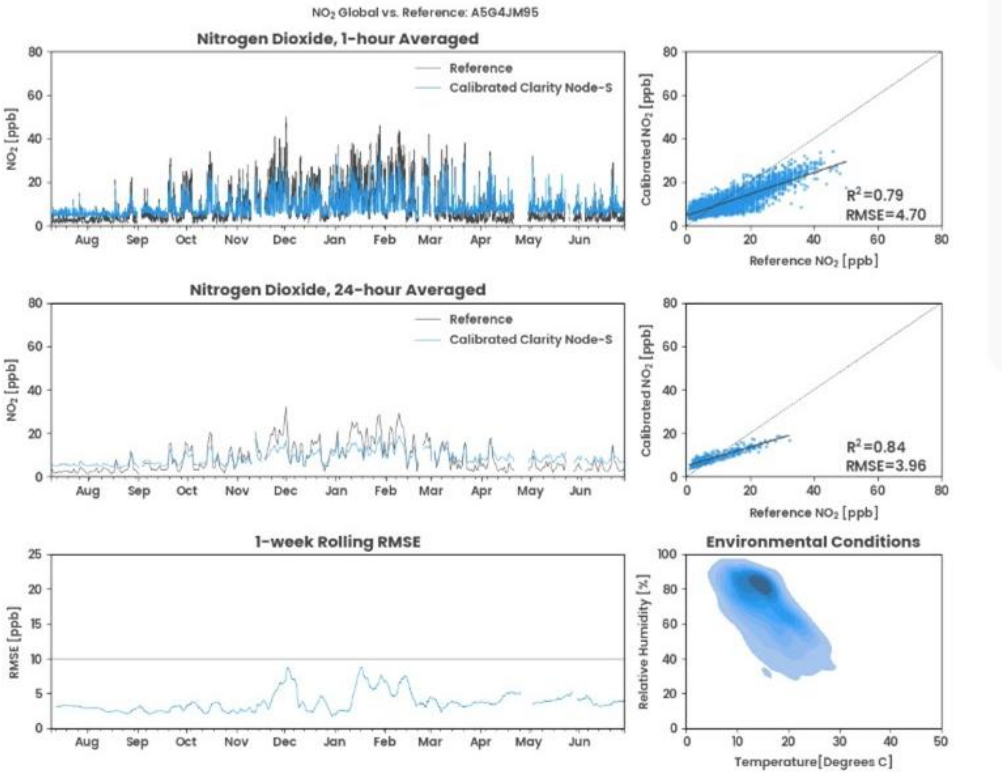


San Francisco, California

Performance of air quality measurement equipment as compared to reference-grade air pollution monitors.

https://www.clarity.io/collocation-results-library

Global NO_2 Calibration



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Collocation v2 Global Calibration

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Node-S Technical Specifications

mCERTS
CSA MC230425/00

AIR QUALITY MEASUREMENTS

PERFORMANCE BY CALIBRATION TYPE*

PARAMETER	TECHNOLOGY	RANGE	PRE-CALIBRATED[1]	CUSTOM COLLOCATION
Particulate Matter $PM_{2.5}$ [µg/m³] MCERTS-Certified CSA MC230425/00	Laser Light Scattering with Remote Calibration	• 0-1000 µg/m³ • 1 µg/m³ resolution	R^2 { Optimal Conditions: 0.97; Typical Conditions: > 0.7 } RMSE { Optimal Conditions: 1.4; Typical Conditions: < 4 }	R^2 { Optimal Conditions: 0.94; Typical Conditions: > 0.7 } RMSE { Optimal Conditions: 1.3; Typical Conditions: < 3 }
Nitrogen Dioxide NO_2 [ppb]	Electrochemical Cell with Remote Calibration	• 0-3000 ppb • 1 ppb resolution	R^2 { Optimal Conditions: 0.83; Typical Conditions: > 0.5 } RMSE { Optimal Conditions: 3.8; Typical Conditions: < 8 }	R^2 { Optimal Conditions: 0.86; Typical Conditions: > 0.6 } RMSE { Optimal Conditions: 2.4; Typical Conditions: < 6 }

*** About Performance Specifications:** Calculated from Clarity's dataset of > 6,000,000 measurements. **Optimal** refers to the 95th percentile of performance Clarity has observed under ideal or favorable conditions. **Typical** refers to common performance under various conditions. For more information on Clarity Node performance and why we don't cherry-pick performance results, **see our calibration explainer here**.

Additional Node-S Parameters: $PM_{2.5}$ Number Concentration [#/cm³] | PM_1 Mass Concentration [µg/m³] | PM_1 Number Concentration [#/cm³] PM_{10} Mass Concentration [µg/m³] | PM_{10} Number Concentration [#/cm³] | Internal Temperature [°C] | Internal Relative Humidity [%]

Additional Parameters with Add-On Modules: Wind Speed | Wind Direction | Ambient Temperature | Ambient Relative Humidity Atmospheric Pressure | FEM-Grade Ozone Concentration | Black Carbon Concentration

Find out more: https://www.clarity.io/air-quality-monitoring-resources

Conclusion

- Clarity's Global Calibrations have steadily improved over time
- v2.1 provides excellent $PM_{2.5}$ measurement accuracy at a wide-range of concentrations and in a wide variety of climates
- v2.1 Global Calibration, when combined with other advanced network-management tools and Clarity's expert support enable robust, accurate air quality measurements at scale
- v1 Global NO2 Calibration provides good out-of-the-box option if collocation not available

Thank you!

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