



# Air Sensors International Conference 2022

## Session 5B: Performance Targets for Air Quality Sensors

AQ-SPEC: Our Transition to the Latest Sensor Testing Protocols and Standards

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May 13, 2022  
Pasadena, CA



# AQ-SPEC

## Air Quality Sensor Performance Evaluation Center

### Background – The AQ-SPEC Program

- Availability, interest, and use of air quality sensors continues to increase
- **AQ-SPEC** (Air Quality Sensor Performance Evaluation Center), established in 2014
- Main Goals:
  - Evaluate the performance of commercially available "low-cost" air quality sensors in both field and laboratory settings
  - Catalyze the successful evolution, development, and use of sensor technology
  - Provide guidance and clarity for ever-evolving sensor technology and data interpretation
- Evaluated 170+ sensors to date, with publicly-available reports on website

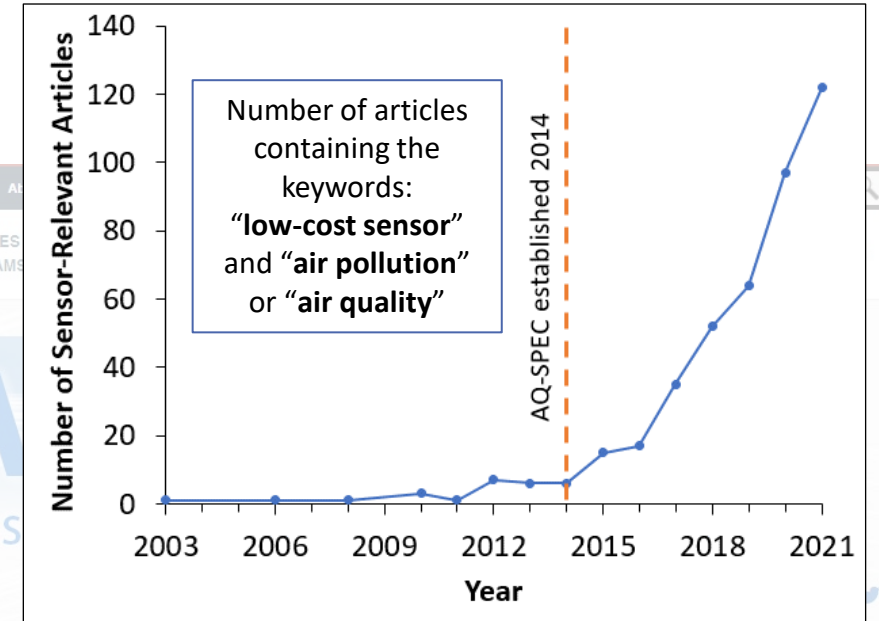


Figure adapted from Giordano et al., 2021





# AQ-SPEC

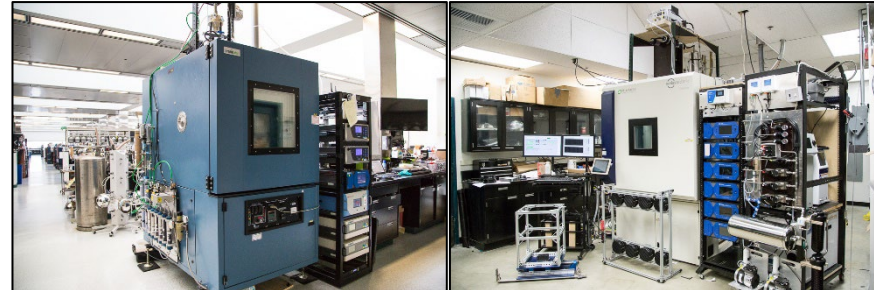
## Air Quality Sensor Performance Evaluation Center

### The Resources Behind Our Sensor Testing and Protocol Development Capabilities



#### 1. Field Testing

- Access to South Coast AQMD air monitoring sites
- Full suites of FRM/FEM monitors
- Other research-grade monitors for black carbon, VOCs, ultrafines
- Protected shelter for non-weatherproofed sensors



#### 2. Laboratory Testing

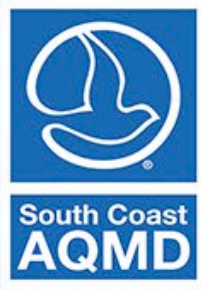
- Two state-of-the-art environmental test chambers
- Full suites of FRM/FEM monitors
- Other research-grade monitors for VOCs, ultrafines, CO<sub>2</sub>
- Control of T/RH, pollutant concentrations, introduction of multiple pollutants
- Automated test sequence capabilities
- Newest chamber features altitude simulation, vibration testing, and wind speed generation
- Chambers capable of testing under latest protocols released by EPA, ASTM, and can supplement mobile sensor testing evaluations



#### 3. Mobile Testing

- Custom-outfitted mobile sensor testing platform
- Suite of FRM/FEM monitors
- Other research-grade monitors for ultrafines, CO<sub>2</sub>
- 1-second resolution datalogging
- Custom-engineered particle sampling probe and sensor testing enclosures





# AQ-SPEC

## Air Quality Sensor Performance Evaluation Center

### Stationary Sensors for Ambient Air Monitoring – Criteria Pollutants

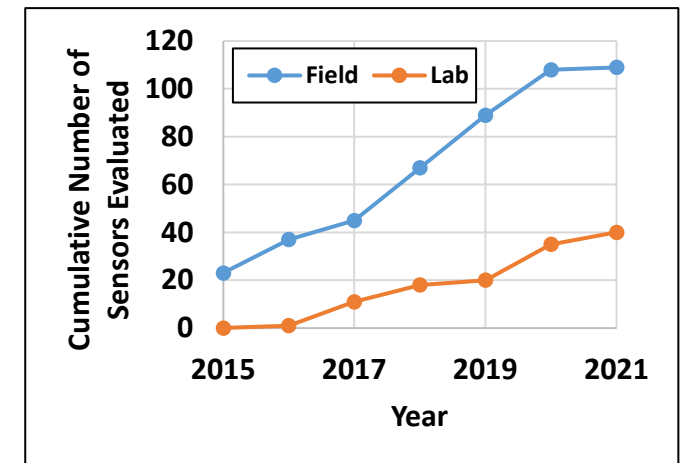
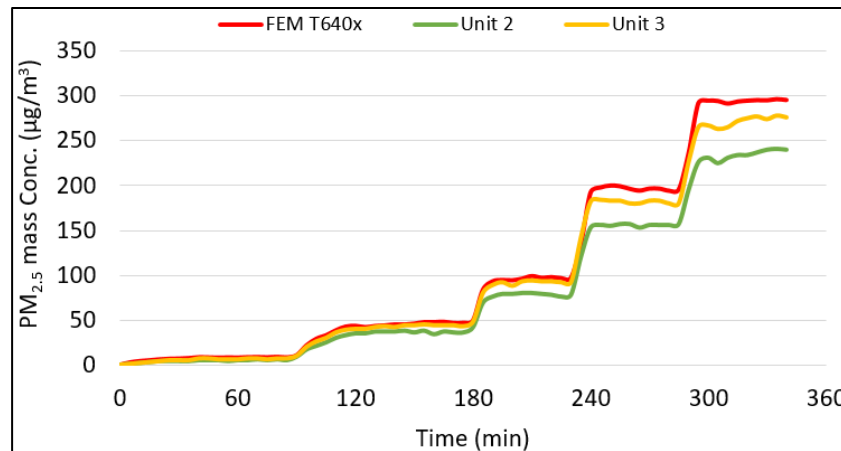
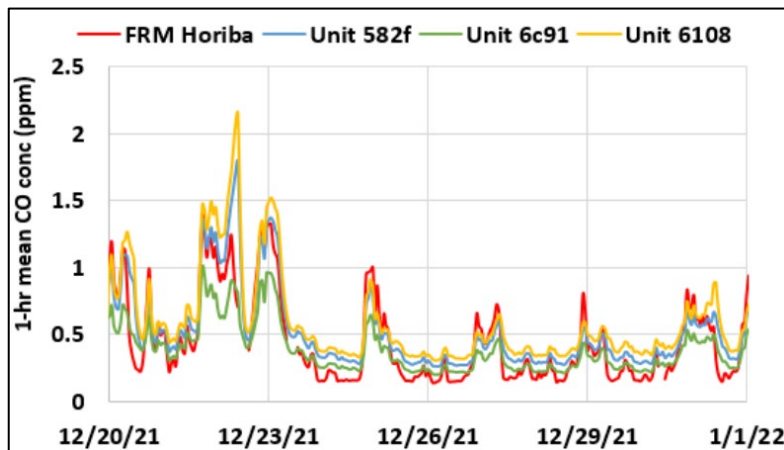
<http://www.aqmd.gov/aq-spec/evaluations/field>

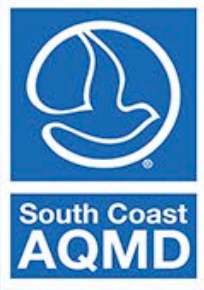
<http://www.aqmd.gov/aq-spec/evaluations/laboratory>



Pollutant / Level	PM ( $\mu\text{g}/\text{m}^3$ )	CO (ppm)	O <sub>3</sub> (ppb)	NO <sub>2</sub> (ppb)	SO <sub>2</sub> (ppb)
Very Low	10	1	30	30	30
Low	15	4	50	50	50
Medium	50	7	90	70	70
High	150	15	150	100	150
Very High	300	20	250	200	300

Temp/RH	Low (15%)	Medium (40%)	High (65%)
Low (5 °C)	5 °C, 15%	5 °C, 40%	5 °C, 65%
Medium (20 °C)	20 °C, 15%	20 °C, 40%	20 °C, 65%
High (35 °C)	35 °C, 15%	35 °C, 40%	35 °C, 65%

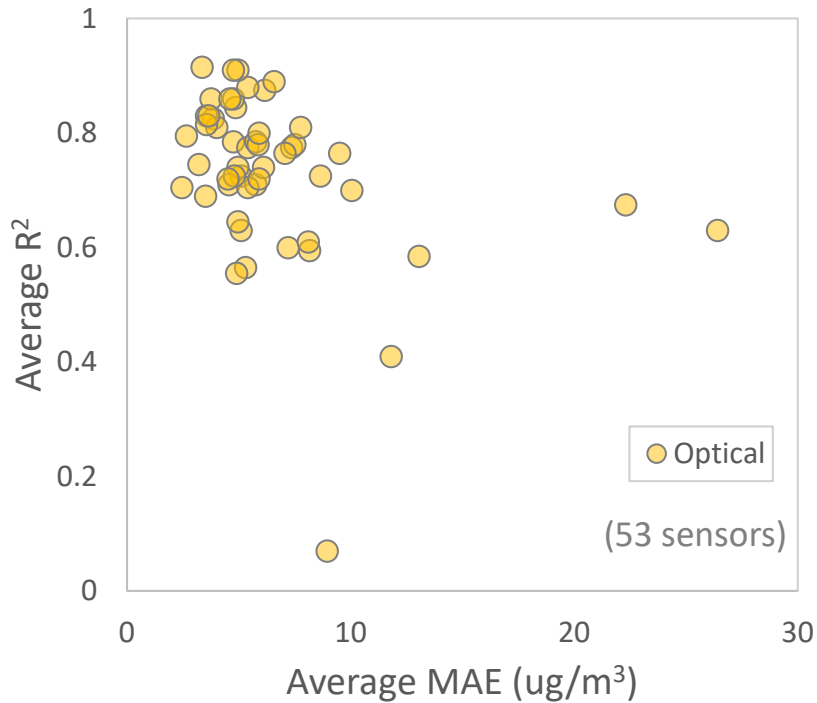




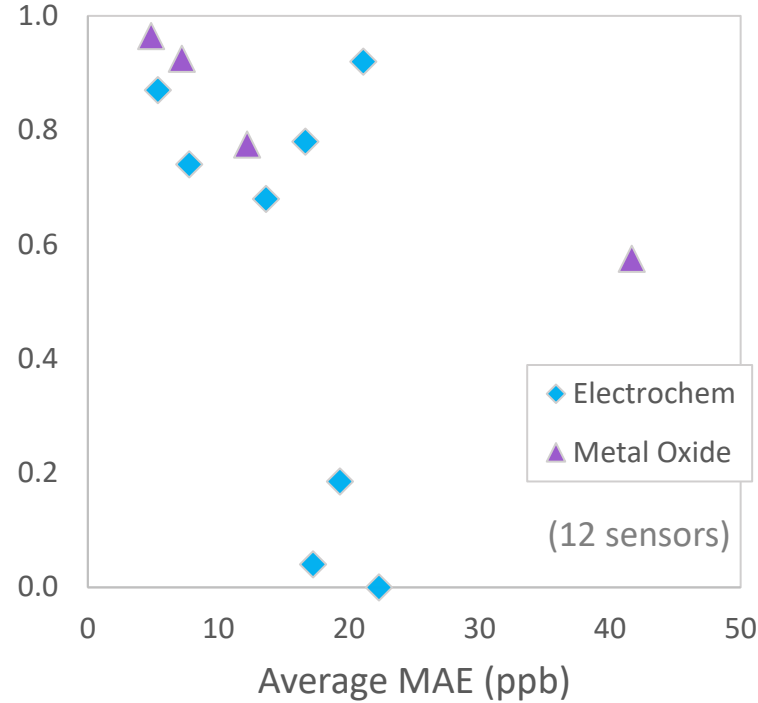
# AQ-SPEC

Air Quality Sensor Performance Evaluation Center

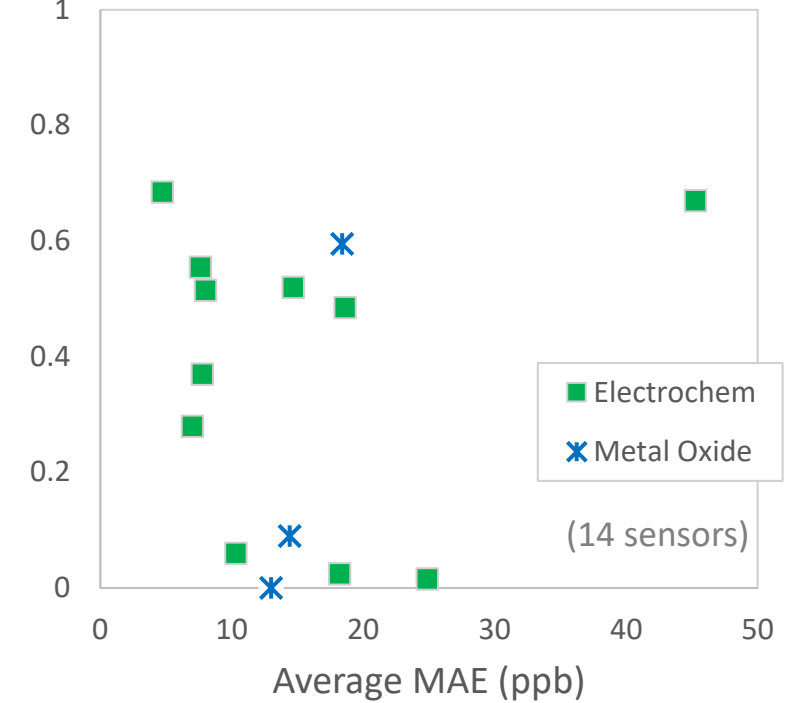
Summary PM<sub>2.5</sub> Field Results



Summary O<sub>3</sub> Field Results



Summary NO<sub>2</sub> Field Results



- Relatively consistent performance across different PM sensors for PM<sub>2.5</sub> (~81% have R<sup>2</sup> > 0.6 and MAE < 10 μg/m<sup>3</sup>)
- Results for gas-phase sensors have been variable, though in general O<sub>3</sub> sensors tend to exhibit higher correlation with data from reference instruments (~67% have R<sup>2</sup> > 0.6) as compared to the NO<sub>2</sub> sensors tested
- *Note – not all sensors tested are included above as the addition of the MAE statistic for all previously tested sensors is in progress* <sup>5</sup>

## Stationary Sensors for Ambient Air Monitoring – Criteria Pollutants

- AQ-SPEC Field and Lab test protocols still in use and provide useful information to public
- Additional test protocols inspired by the AQ-SPEC testing framework, e.g. US EPA testing protocols for PM<sub>2.5</sub> and O<sub>3</sub> sensors (published Feb. 2021)
- Opportunities for AQ-SPEC:
  - Update AQ-SPEC Field and Lab test protocols with additional tests and metrics
  - Capability to provide evaluation services following US EPA sensor testing protocols

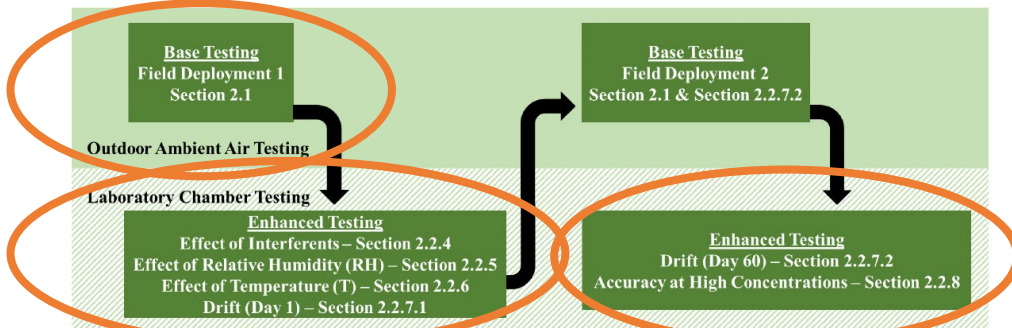
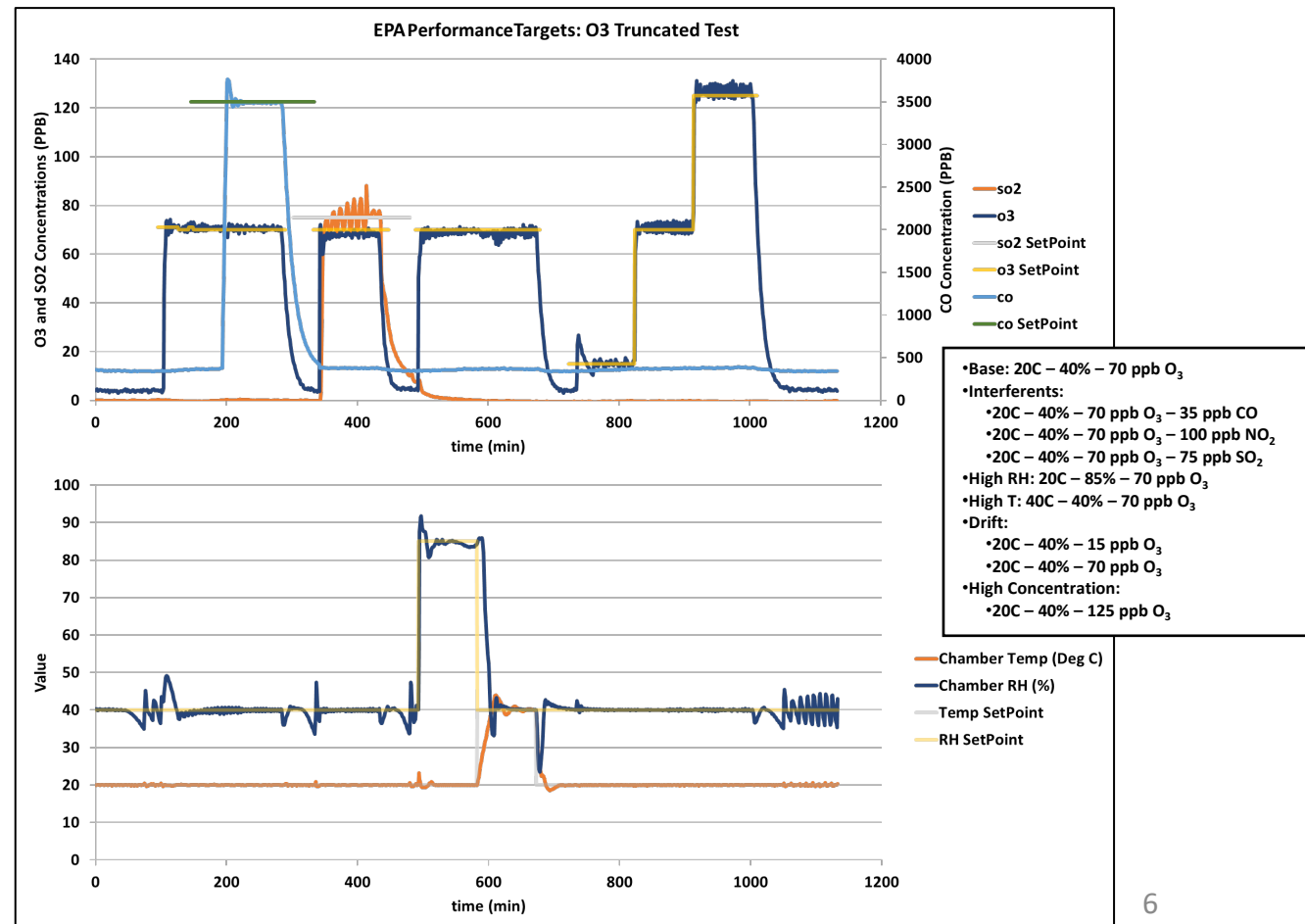
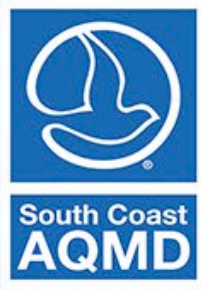


Figure from US EPA "Performance Testing Protocols, Metrics, and Target Values for Ozone Air Sensors: Use in Ambient, Outdoor, Fixed Site, Non-Regulatory Supplemental and Informational Monitoring Applications", 2021

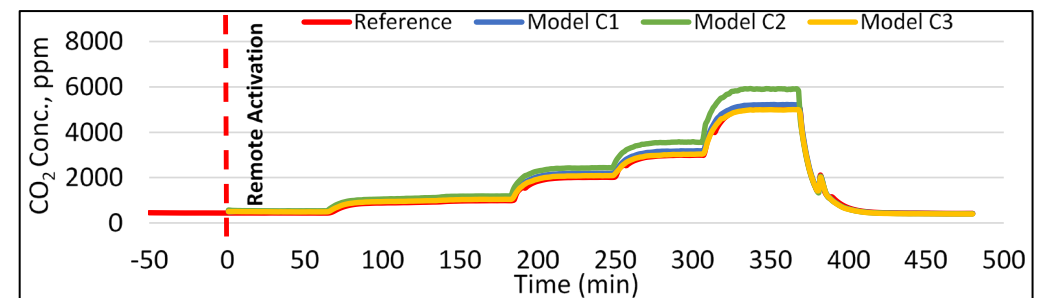
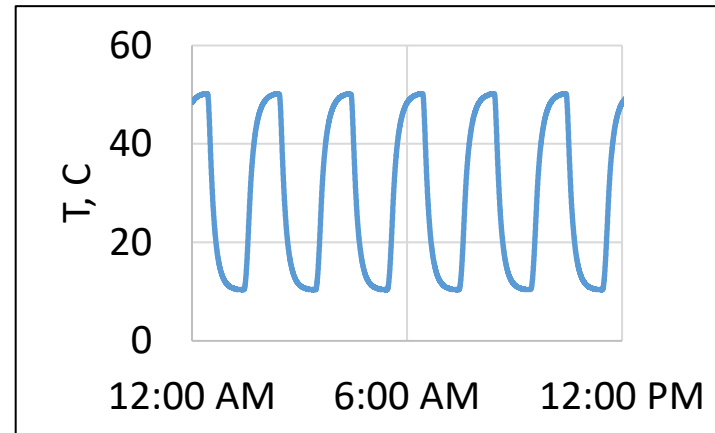






## Stationary Sensors for Indoor Air Quality Monitoring – PM<sub>2.5</sub> & CO<sub>2</sub>

- Interest in indoor air quality (IAQ) sensors (demand-controlled ventilation, disease transmission prevention)
- PM<sub>2.5</sub> and CO<sub>2</sub> are important markers of IAQ
- Need rigorous, comprehensive, and traceable standard test methods to evaluate sensor performance
- Newly developed ASTM PM<sub>2.5</sub> and CO<sub>2</sub> standard test methods serve this purpose
- AQ-SPEC led technical development and lab activities
- PM<sub>2.5</sub> standard test method published in October 2021 as ASTM D8405 (<https://www.astm.org/d8405-21.html>)
- CO<sub>2</sub> standard test method lab activities concluded and undergoing balloting activities
- AQ-SPEC has capabilities to provide this ASTM testing service for sensor vendors



## Mobile Sensors for Ambient Air Monitoring

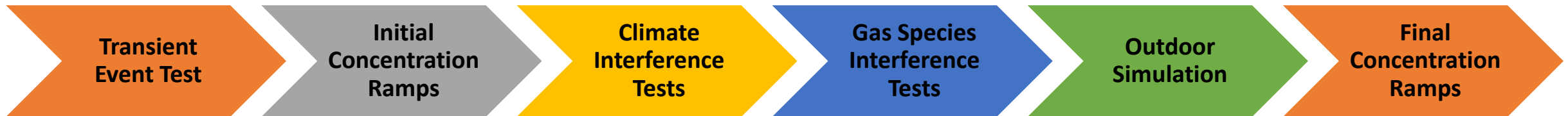
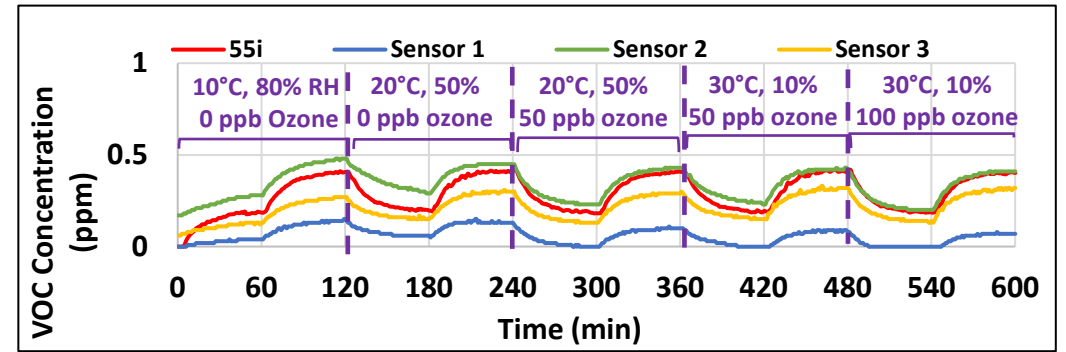
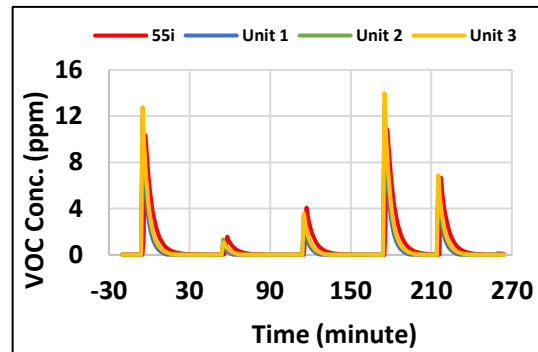
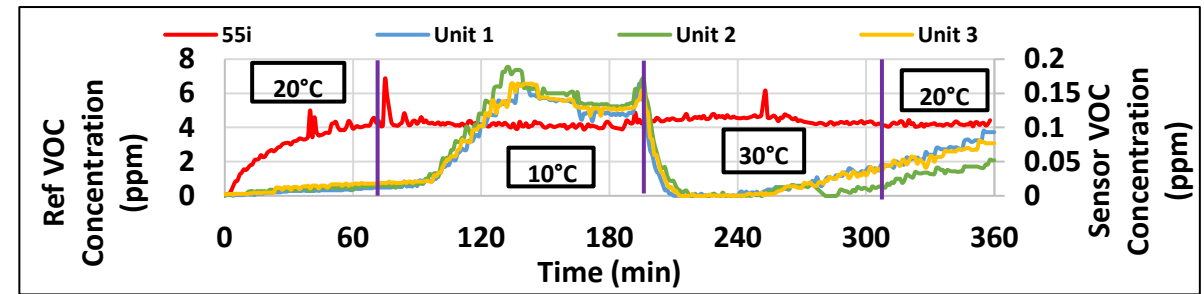
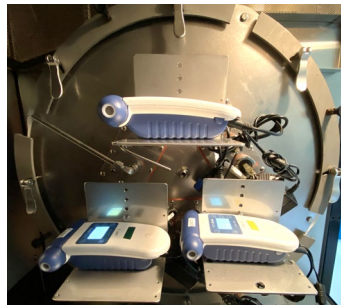
- Higher spatial resolution and coverage for less capital cost
- Can sample challenging locations, detect hotspots
- Data interpretation can be difficult due to sampling point movement, turbulence and sensor positioning effects
- First-ever mobile sensor testing protocol published in 2020
  - Tests sensors in 3 broad use-case scenarios
- Next-Gen Mobile Platform Under Development
  - Computational Fluid Dynamics (CFD) and particle trajectory simulations inform new designs
  - Reference particle monitors to sample from custom-engineered double-shrouded probe
  - Controlled-flow sensor duct and partially-controlled sensor box custom-designed with CFD
  - Unprotected vehicle rooftop sensor testing informed by CFD modeling around vehicle





## Stationary Sensors for Indoor/Ambient VOC Monitoring

- VOC sensors offer potential of detection of air toxics at much lower cost compared to traditional methods like GC-FID
- Potential for fence-line monitoring and hotspot detection
- Accuracy a challenge due to diversity of VOC species
- VOC sensors can be very susceptible to interferent species and temperature





## Conclusions and Outlook

- AQ-SPEC pioneered development of air quality sensor performance evaluation protocols
- AQ-SPEC Field and Lab testing protocols have been used to evaluate 170+ sensors to date
- These two protocols have served as frameworks upon which new sensor testing protocols have been built:
  - US EPA performance testing protocols for PM<sub>2.5</sub> and O<sub>3</sub> sensors (2021)
  - ASTM International standard test methods for PM<sub>2.5</sub> and CO<sub>2</sub> sensors in indoor applications (2021)
  - AQ-SPEC mobile sensor testing protocol (2020)
  - AQ-SPEC VOC sensor lab and field testing protocols (coming soon)
- AQ-SPEC has the infrastructure and capabilities to carry out these new sensor testing protocols and aims to expand functions to include these new protocols



## Contact AQ-SPEC

[www.aqmd.gov/aq-spec](http://www.aqmd.gov/aq-spec)

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## Contact the Speaker

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## Acknowledgements

- South Coast AQMD Staff:
  - Ashley Collier-Oxandale, Ph.D., Air Quality Specialist
  - Berj Der Boghossian, M.Sc., Air Quality Specialist
  - Brandon Feenstra, Ph.D., Air Quality Specialist
  - Michelle Kuang, Ph.D., Air Quality Instrument Specialist II
  - Randy Lam, M.A., Air Quality Instrument Specialist II
  - Wilton Mui, Ph.D., Air Quality Specialist
  - Andrea Polidori, Ph.D., Director of Monitoring and Analysis
  - Jason Low, Ph.D., Asst. Deputy Executive Officer of Science & Technology Advancement



# Session Q&A Discussion

**Please submit your questions for the session speakers through Whova – on your mobile or desktop device.**

Make sure to note WHOM your question should be addressed to.

Thank you for participating in  
Session 5B, Part 1.

Part 2 of the session, Performance  
Targets for Air Quality Sensors,  
will begin momentarily.