AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Laboratory Evaluation Report for

Qingping – Air Monitor

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Revision History

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The laboratory evaluation was conducted in an AQ-SPEC environmental chamber with simulated pollutant and interferent concentrations that were generated from nebulizer solutions, dust dispensers, and/or gas dilution calibrators. Generated environments may not be able to fully replicate the conditions that may be experienced under ambient settings. The sensor assembly, installation, and use can also impact the reliability of the products evaluated by the AQ-SPEC program.

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Section 1: Background

Three **Qingping – Air Monitor** units (IDs: 39F5,37DA, and 3956) were deployed at the South Coast AQMD stationary ambient monitoring site in Rubidoux from 11/07/2022 to 01/07/2023. Following field-testing, the same units were evaluated in an AQ-SPEC environmental chamber under controlled temperatures, humidities and potassium chloride particle concentrations.

Note: *Only two out of three units that returned from field testing were still functional. Unit 37DA did not report any data during laboratory testing. In addition, Unit 3956 reverted to 15-minute time resolution after field testing for unknown reasons and its time resolution could not be modified for the lab test.*

Qingping - Air Monitor

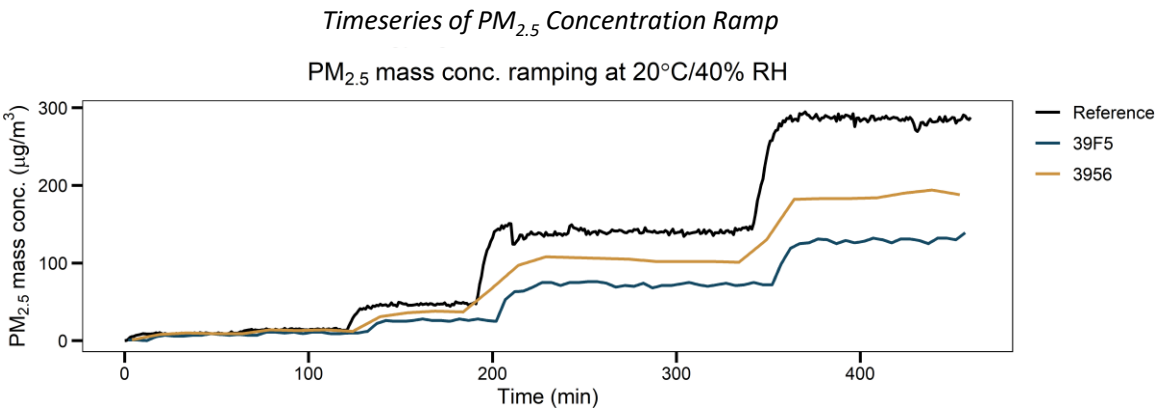
TeledyneT640x

Section 2: Manufacturer Specs

Parameter	Sensor: Qingping Air Monitor (raw sensor: Grandway Model P5500)	Reference Instrument: Teledyne T640x
Pollutant	$PM_{2.5}$	$PM_{1.0}$, $PM_{2.5}$ (FEM), PM_{10} (FEM)
Cost	$135 (at time of testing)	$21,000
Weight	0.6 pounds	19 pounds
Dimensions (LxWxD)	3.3 x 2.7 x 3.4 inches	7 x 17 x 14 inches
Power	5 VDC, 1A	100-240 VAC (360 W max)
Battery	Yes (1800mAh/3.7V)	No
Data transmission	Wi-Fi	Ethernet, USB
Internal memory	N/A	Yes; 4 GB (>1 year)
Operating temperature range	14 – 122 degrees F	32 – 122 degrees F
Operating RH range	0%-100%	0%-100%
Product website	https://www.qingping.co/air-monitor/overview	https://www.teledyne-api.com/en-us/products/t640
Operating principle	Optical light scattering	Optical light scattering
Time resolution	5- minute for Unit 39F5; 15-minute for Unit 3956	1 minute (as-configured)
Concentration range	0-999 µg/m^3	0.1-10,000 µg/m^3

Section 3: $PM_{2.5}$

Section 3.1: Data Overview



Section 3.2: Data Recovery

Basic QA/QC procedures such as removal of duplicate records was performed. Nulls, negatives, out of instrument bounds as specified by the manufacturer, and values flagged as invalid by the sensor were considered invalid. Data recovery was calculated as the percent of valid readings through the entire evaluation.

Parameter	Unit 39F5	Unit 3956
$PM_{2.5}$	100%	100%

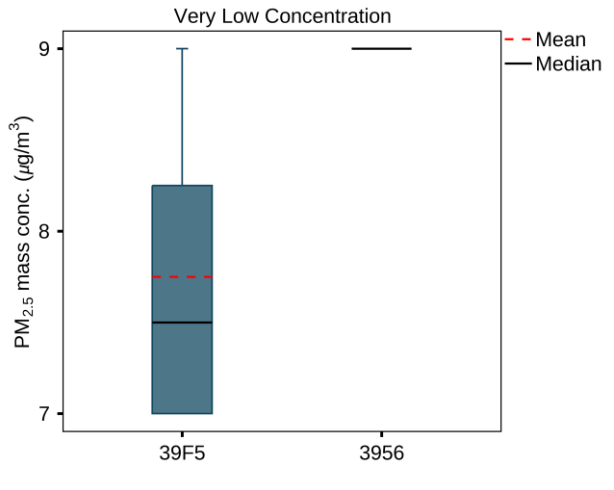
Section 3.3: Intra-Model Variability

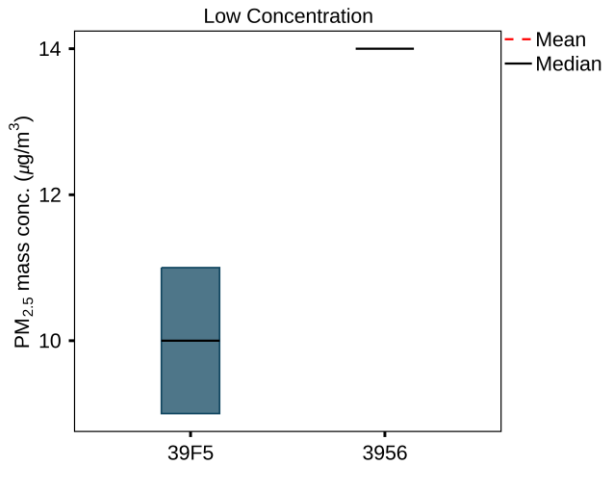
Absolute intra-model variability was calculated as the standard deviation of the mean values of the sensors. Relative intra-model variability was calculated as the absolute intra-model variability divided by the sensor grand mean. Calculations were performed using 20 measurements from each steady-state period.

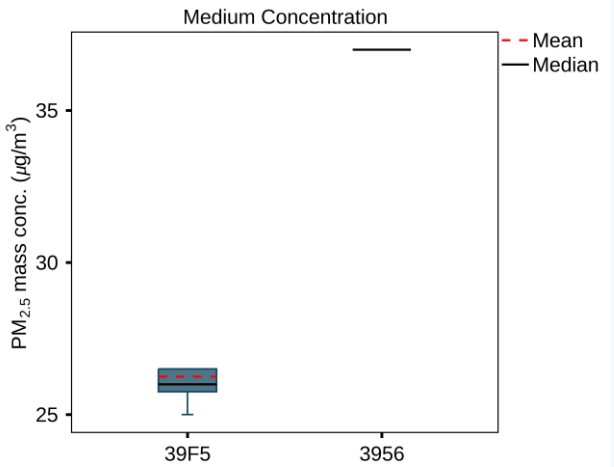
$PM_{2.5}$ Concentration (µg/m³)	Absolute intra-model variability (µg/m³)	Relative intra-model variability (%)
Very Low (9.6)	0.9	10.6
Low (14.6)	2.8	23.6
Medium (47.5)	7.6	24.0
High (142.1)	20.3	23.5
Very High (285.3)	38.7	24.1

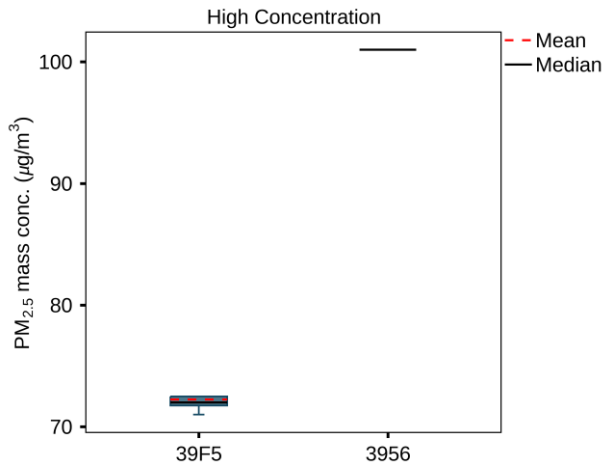
Section 3: $PM_{2.5}$

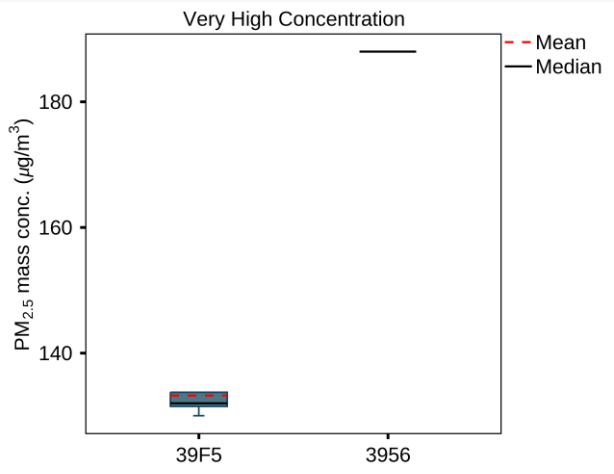
Section 3.3: Intra-Model Variability











Interpretation: No interpretation can be made when comparing the distributions of only two units. In addition, Unit 3956 only reported one reading during steady-state periods due to its reversion to 15-minute time resolution.

Section 3: $PM_{2.5}$

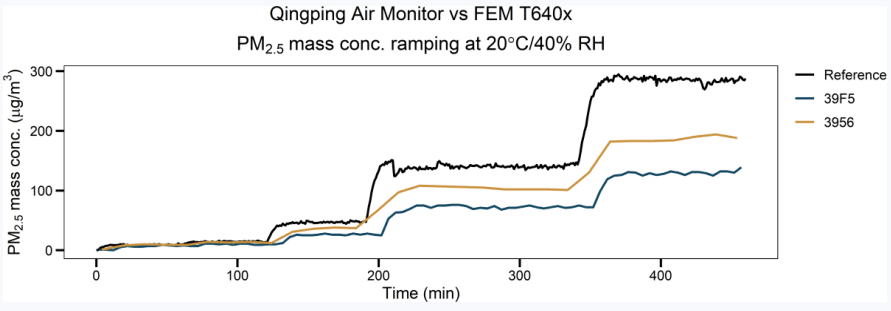
Section 3.4: Linearity (R^2)

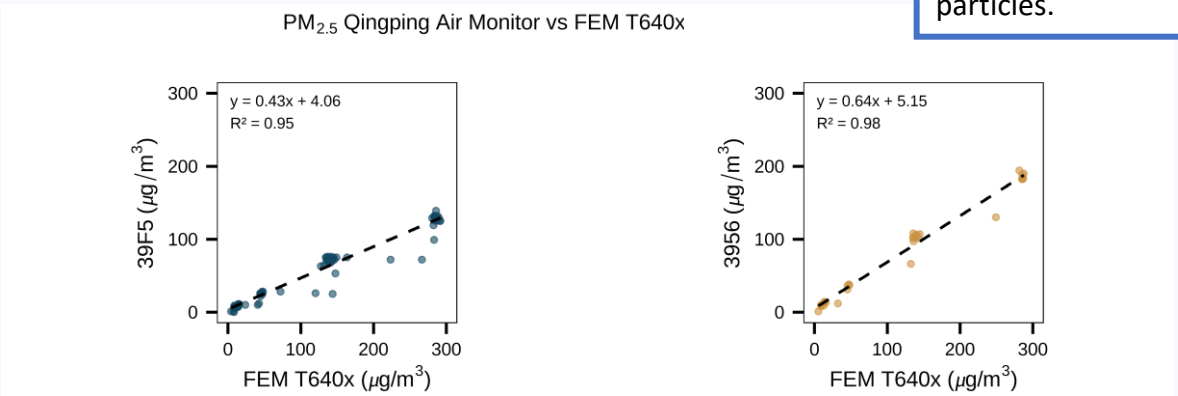
Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, readings flagged by the sensor, and invalid data points were eliminated from the data-set.

A summary of the mean R^2 between the sensor and FEM T640x across all units tested.

Parameter	Time Resolution	Qingping Air Monitor (mean ± SD)
$PM_{2.5}$	Variable*	0.97 ± 0.01

**Unit 39F5 reported at 5-minute time resolution, while Unit 3956 reverted to 15-minute time resolution after field testing for unknown reasons and its time resolution could not be modified for the lab test. The reference T640x monitor reported at 1-minute time resolution. Due to the variable time resolutions of the devices in this lab test, the scatterplots and regression results are based on non-averaged reference monitor readings that are nearest in time to each sensor's reading timestamps.*

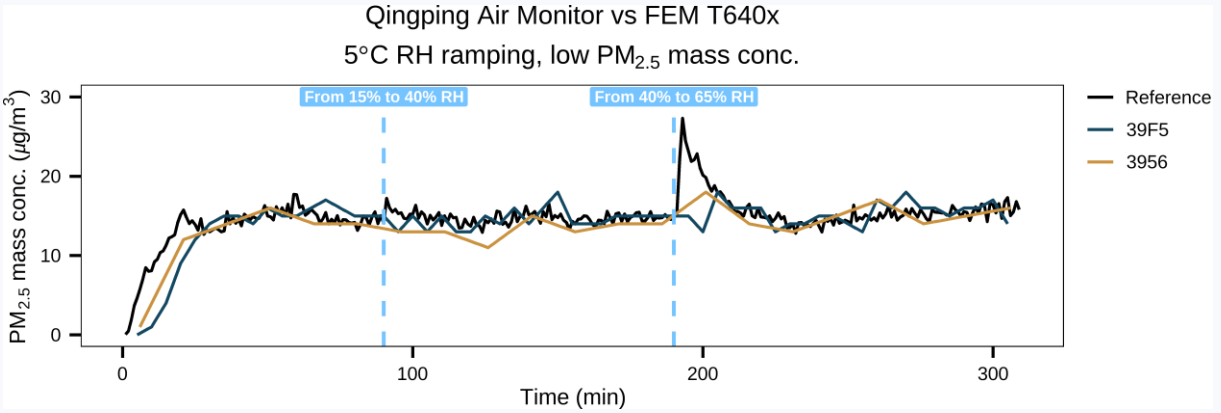


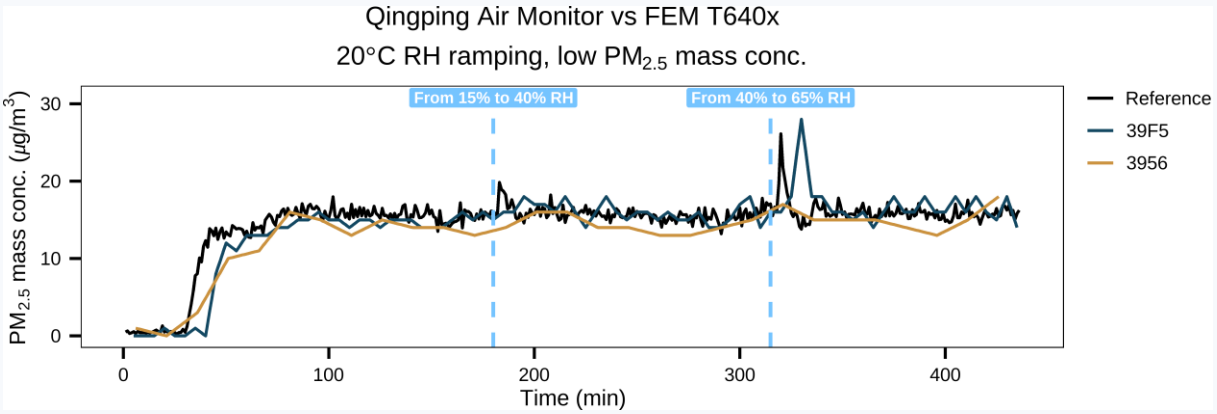


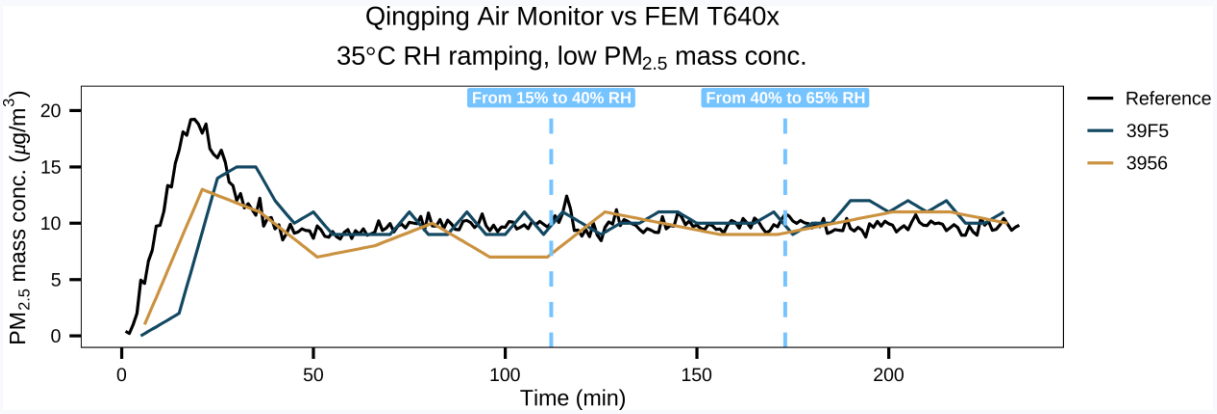
Interpretation: The Qingping Air Monitor showed very strong correlation with the corresponding FEM T640x data ($0.95 < R^2 < 0.98$), for potassium chloride particles.

Section 3: $PM_{2.5}$

Section 3.5: Climate Susceptibility – Low Concentrations

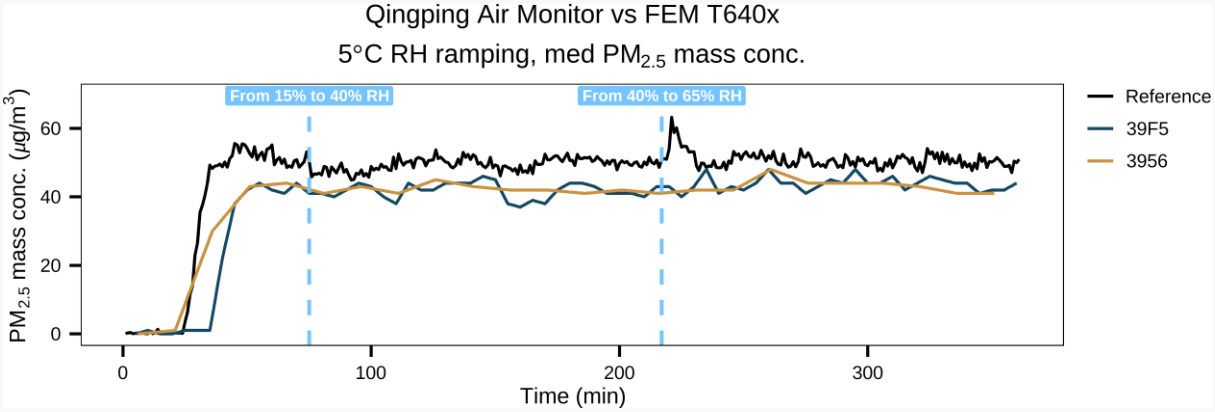


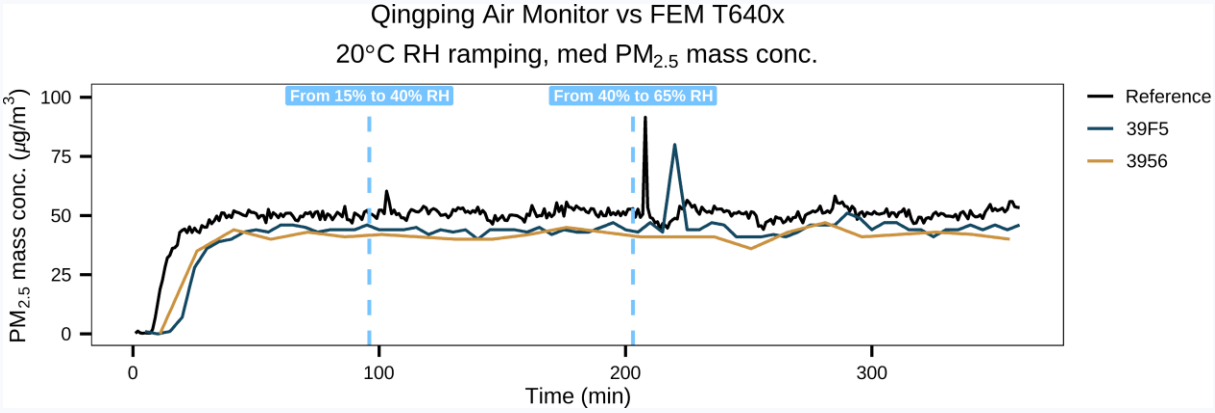


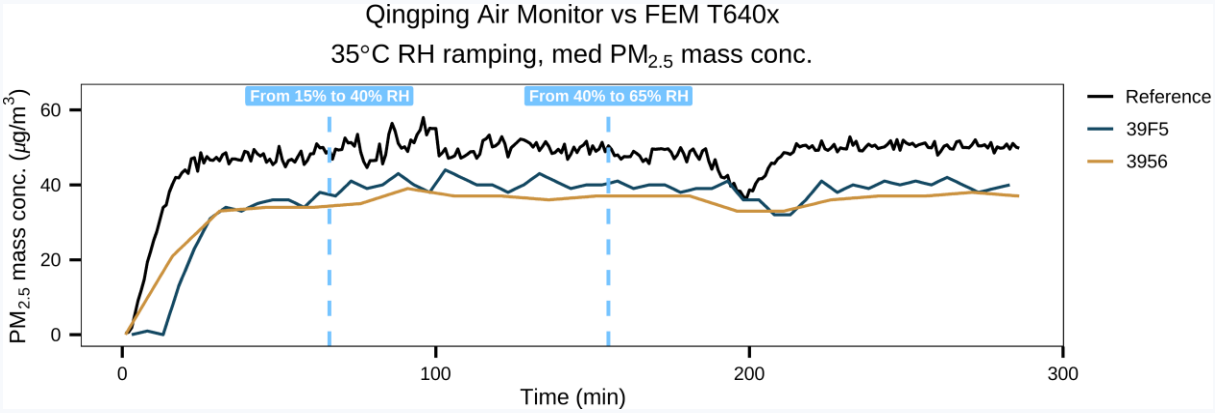


Section 3: $PM_{2.5}$

Section 3.5: Climate Susceptibility – Med. Concentrations

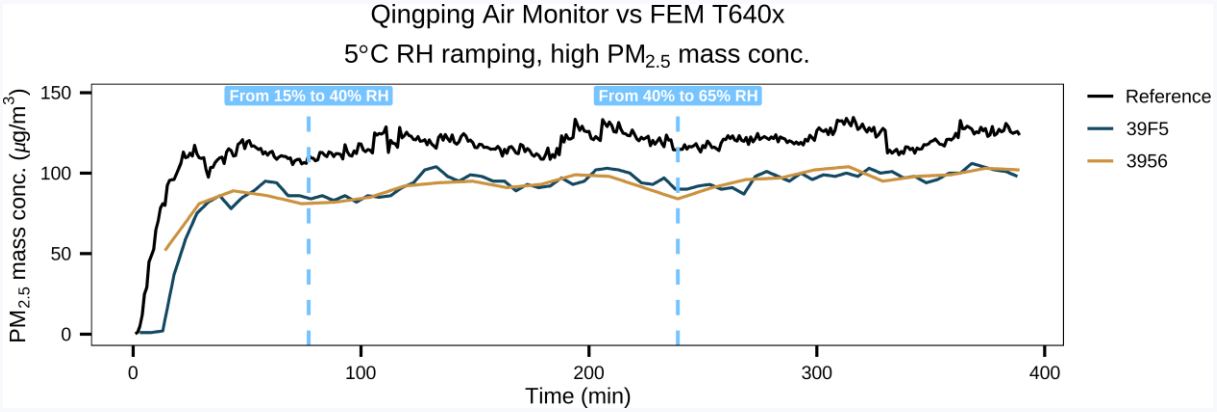


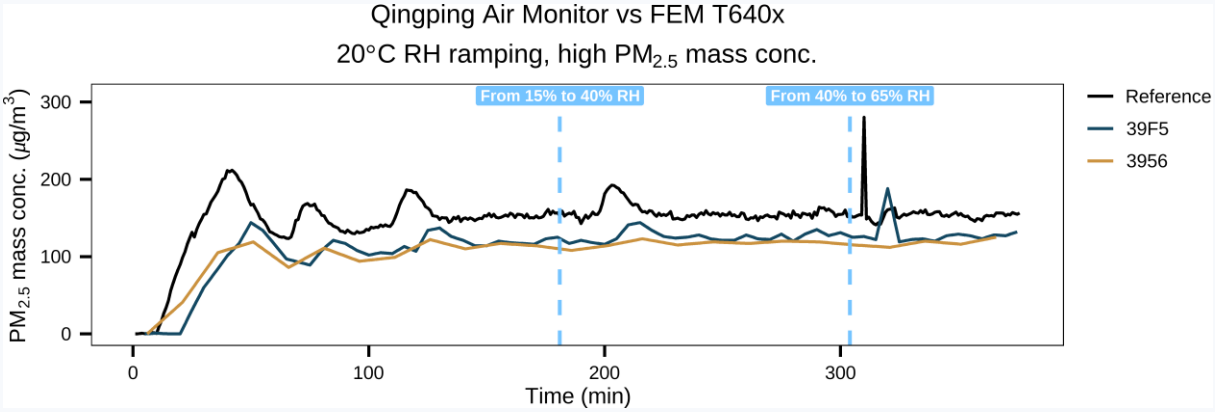


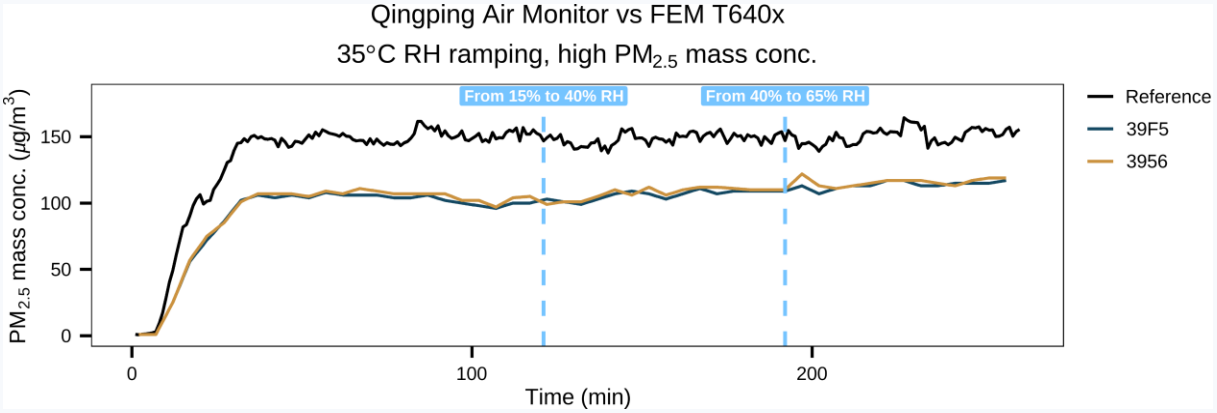


Section 3: $PM_{2.5}$

Section 3.5: Climate Susceptibility – High Concentrations



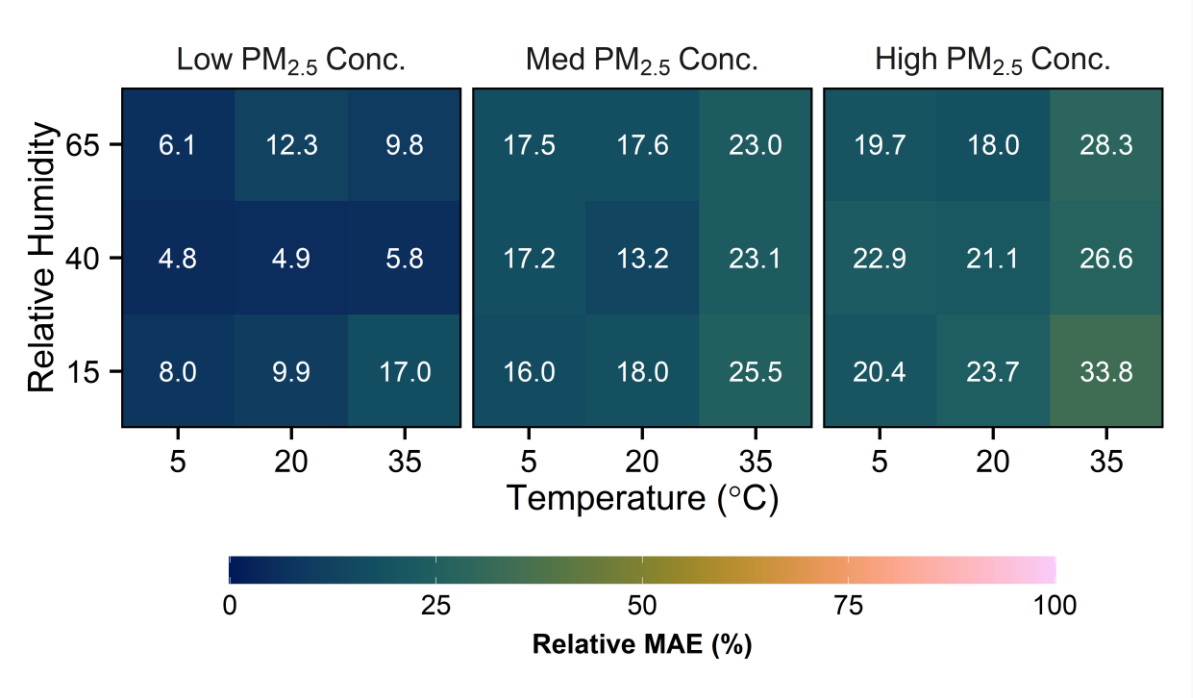




Section 3: $PM_{2.5}$

Section 3.5: Climate Susceptibility – Heat Maps

Relative MAE: effect of $PM_{2.5}$ concentration, temperature and RH



Interpretation: The Qingping Air Monitor generally showed higher relative MAE values at medium and high $PM_{2.5}$ concentrations compared to low $PM_{2.5}$ concentrations, for potassium chloride particles. In addition, higher temperatures appear to result in higher relative MAE values.

Section 4: Summary Metrics

		$PM_{2.5}$ Concentration				
		Very low	Low	Medium	High	Very High
Qingping Air Monitor	Average*	8.4	12.0	31.6	86.6	160.6
	SD*	0.9	2.8	7.6	20.3	38.7
	CV (RSD, %)	10.6	23.6	24.0	23.5	24.1
	Absolute IMV*	0.9	2.8	7.6	20.3	38.7
	Relative IMV (%)	10.6	23.6	24.0	23.5	24.1
T640x	Average*	9.6	14.6	47.5	142.1	285.3
	SD*	0.6	0.7	1.4	2.9	2.8
	CV (RSD, %)	6.0	5.1	3.0	2.0	1.0
Qingping Air Monitor vs. T640x	Pearson R^2	0.95 to 0.98				
	Slope	0.43 to 0.64				
	Intercept	4.06 to 5.15				
	MBE*	-2.1 to -0.2	-4.5 to -0.7	-21.1 to -11.1	-70.0 to -41.9	-152.1 to -97.5
	$nMBE_{mean}$	-0.02 to 0.21	-0.31 to 0.05	-0.44 to -0.23	-0.49 to 0.29	-0.53 to -0.34
	MAE*	0.2 to 2.1	0.7 to 4.5	11.1 to 21.1	41.9 to 70.0	97.5 to 152.1
	$nMAE_{mean}$	0.02 to 0.22	0.05 to 0.31	0.23 to 0.44	0.29 to 0.49	0.34 to 0.53
	RMSE*	0.2 to 2.6	0.7 to 4.5	11.1 to 21.1	41.9 to 70.1	97.5 to 152.2
	$nRMSE_{mean}$	0.02 to 0.27	0.05 to 0.31	0.23 to 0.44	0.29 to 0.49	0.34 to 0.53

*Units in $\mu g/m^3$

Summary Metrics Guide

Average:	mean of individual sensor means at a given steady-state concentration; the grand mean
SD:	mean of individual sensor standard deviations (σ; measure of variation of the values about its mean) at a given steady-state concentration
CV (RSD):	mean of individual sensor coefficient of variations (relative standard deviation; the ratio of the standard deviation to the mean, expressed as a percentage) at a given steady-state concentration
Absolute IMV	intra-model variability expressed in absolute terms; standard deviation of individual sensor means at a given steady-state concentration
Relative IMV	intra-model variability expressed in relative terms; the ratio of the *Absolute IMV* to the *Average* at a given-steady-state concentration
Pearson R^2:	the squared value of the Pearson correlation coefficient; the square of the covariance of the reference and sensor measurements divided by the product of their standard deviations (a value from 0 to 1)
Slope:	change in the sensor's value per unit increase in the reference monitor's value
Intercept:	the sensor's predicted value when the reference monitor observes zero
MBE:	mean bias error; mean of the differences between reference and sensor measurements at a given steady-state concentration
$nMBE_{mean}$:	mean bias error normalized with respect to the reference mean value at a given steady-state concentration
MAE:	mean absolute error; mean of the absolute differences between reference and sensor measurements at a given steady-state concentration
$nMAE_{mean}$:	mean absolute error normalized with respect to the reference mean value at a given steady-state concentration
RMSE:	root mean square error; the square root of the average squared differences between reference and sensor measurements at a given steady-state concentration
$nRMSE_{mean}$:	root mean square error normalized with respect to the reference mean value at a given steady-state concentration