



Afri-SET Field Evaluation Report for Kunak AIR Pro Sensor (PM_{2.5})

Background

- ❑ From 01/01/2024 to 14/05/2024, three Kunak AIR Pro sensors (herein called KunakAir sensors) were collocated with the Teledyne T640 Federal Equivalent Method (FEM) monitor in the ambient environment at the Afri-SET facility in the Department of Physics, University of Ghana, Legon-Accra
- ❑ Evaluation of the sensors for both dry and wet periods were from 08/01/2024 to 18/02/2024 and 01/04/2024 to 13/05/2024 respectively



Background

Specifications for KunakAir sensors

- ❑ Least time resolution : 10-min
- ❑ Measures: PM_{1.0}, PM_{2.5}, PM₁₀ (µg/m³); O₃, SO₂, CO, NO₂, NO (ppb); Temperature (°C), Pressure (hPa), Wind Direction (degree), Wind Speed (km/h) and RH (%); Particle sensor: Alphasense Optical Particle Counter (OPC-N3)
- ❑ Dimensions and weight: 25.0 (H) x 23.5 (W) x 27.0 (L) cm, 3.40 kg
- ❑ Power: Solar power (6 V, 12 W)
- ❑ Data communication: Multi-Band 2G/3G/4G or Ethernet
- ❑ Data logging/retrieval: API and Dashboard
- ❑ Units IDs: Sensor_001, Sensor_002, Sensor_003

Specifications for FEM T640

- ❑ Least time resolution : 1-min
- ❑ Measures: PM_{2.5}, PM₁₀ (µg/m³); Scattered light spectrometry for measurement of PM
- ❑ Dimensions and weight: 17.8 (H) × 43.2 (W) × 35.6 (D) cm, 8.60 kg
- ❑ Power: Continuous power from AC wall outlet
- ❑ Data communication: RS232, Ethernet, com ports
- ❑ Data logging/retrieval: Data logger

Data Cleaning and Quality Control

- ❑ Data cleaning and quality control techniques were performed on the dataset (such as removing outliers, negative values, duplicates, etc.)
- ❑ All analyses were done in unit of $\mu\text{g}/\text{m}^3$
- ❑ Data recovery for the evaluation period from the 3 sensor units averaged **94%**

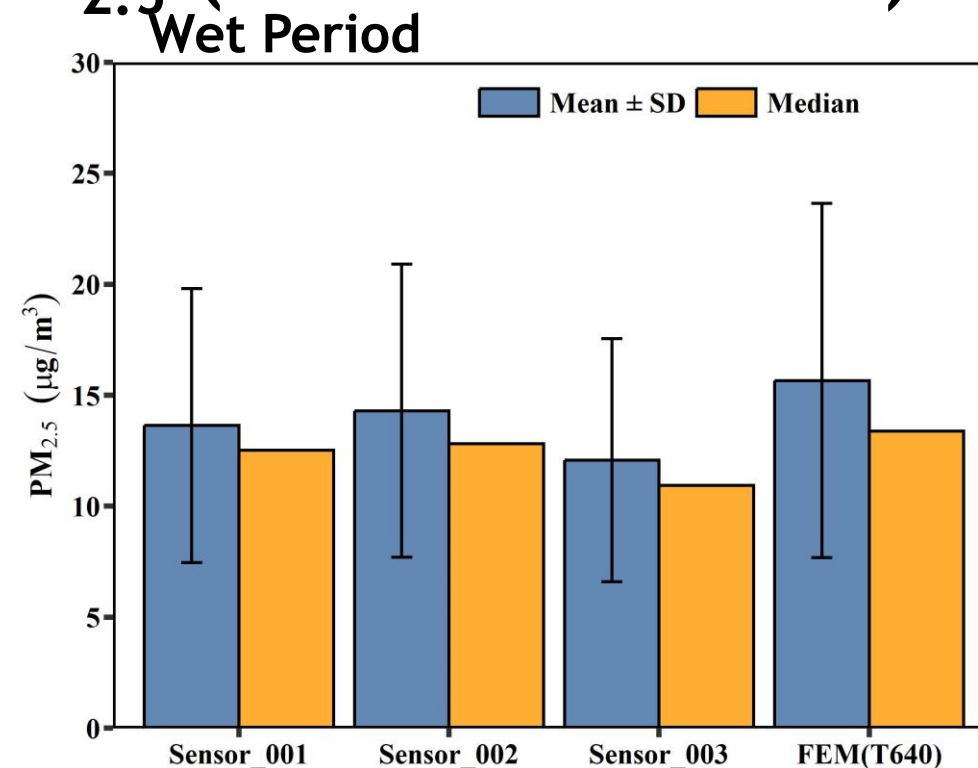
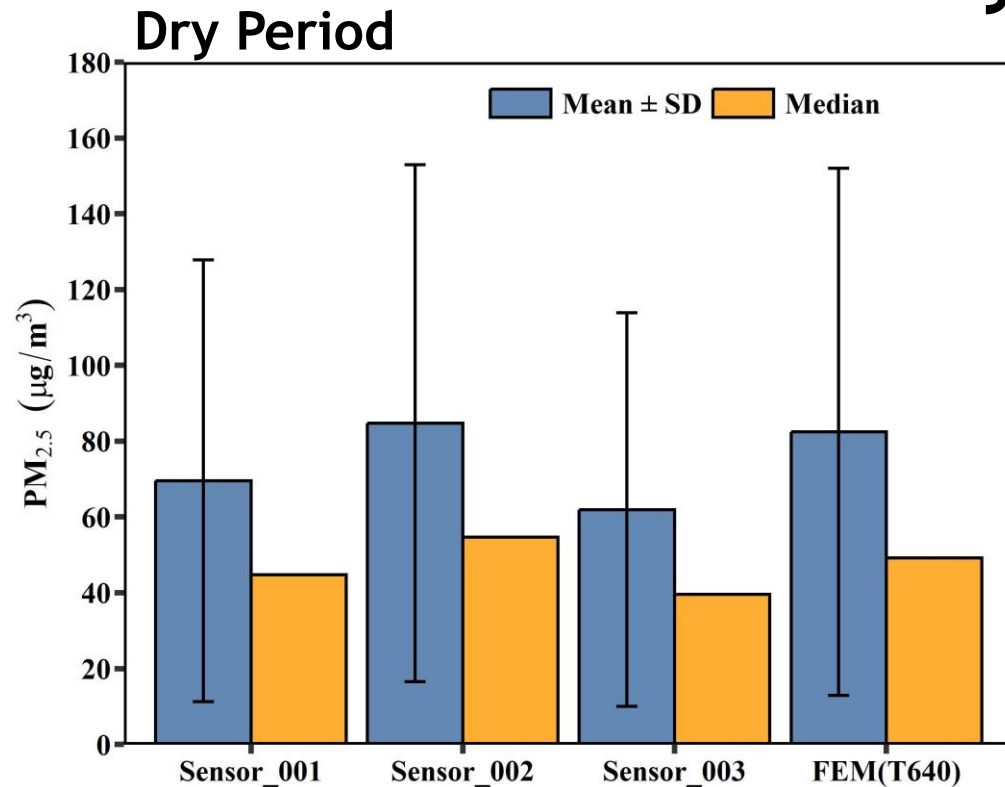


KunakAir sensor unit



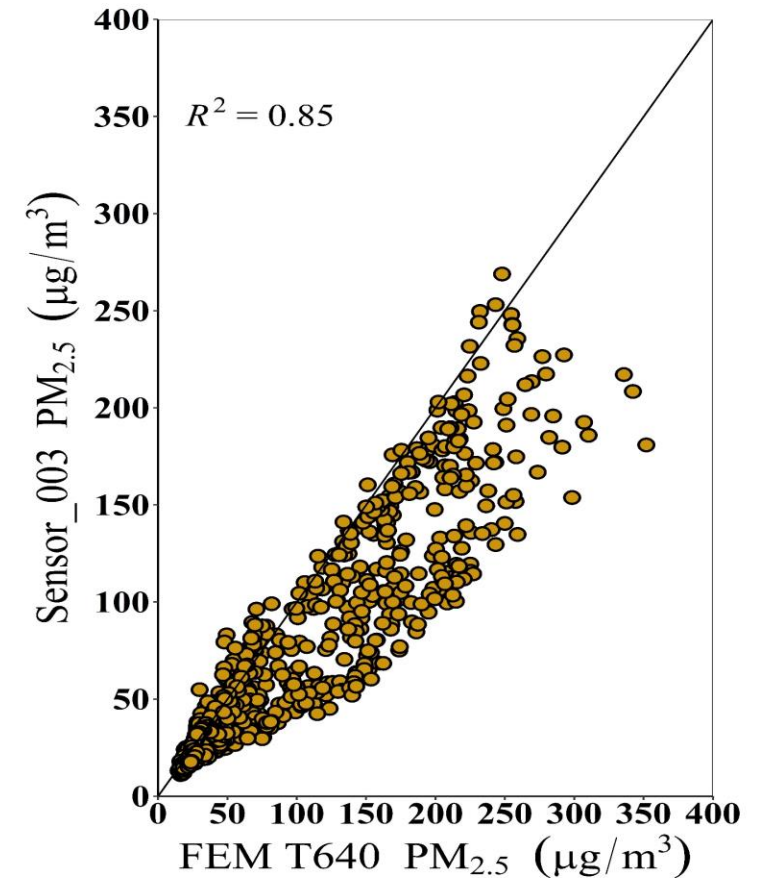
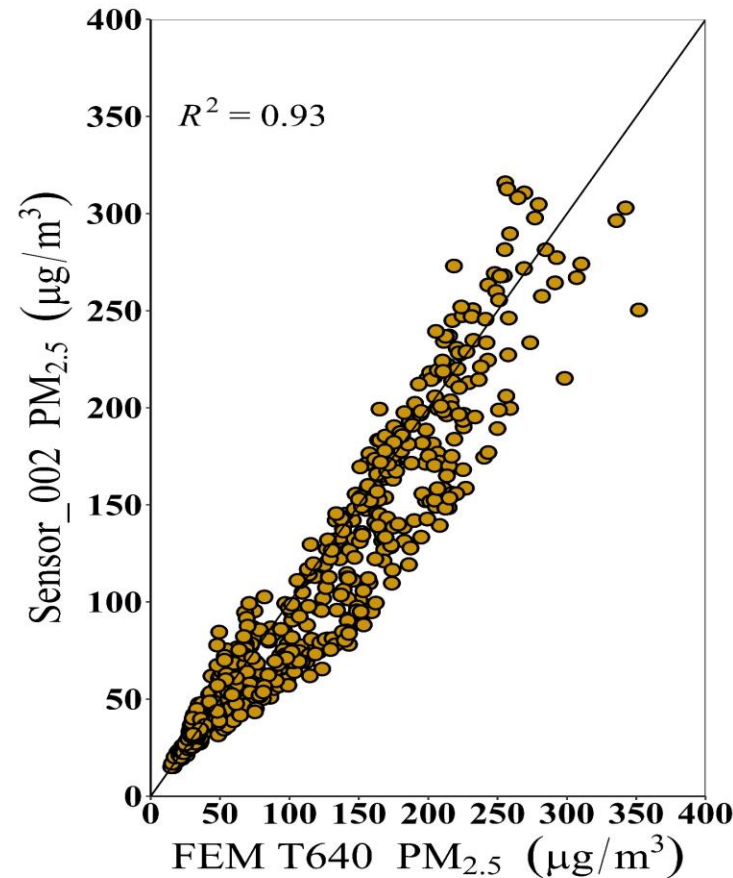
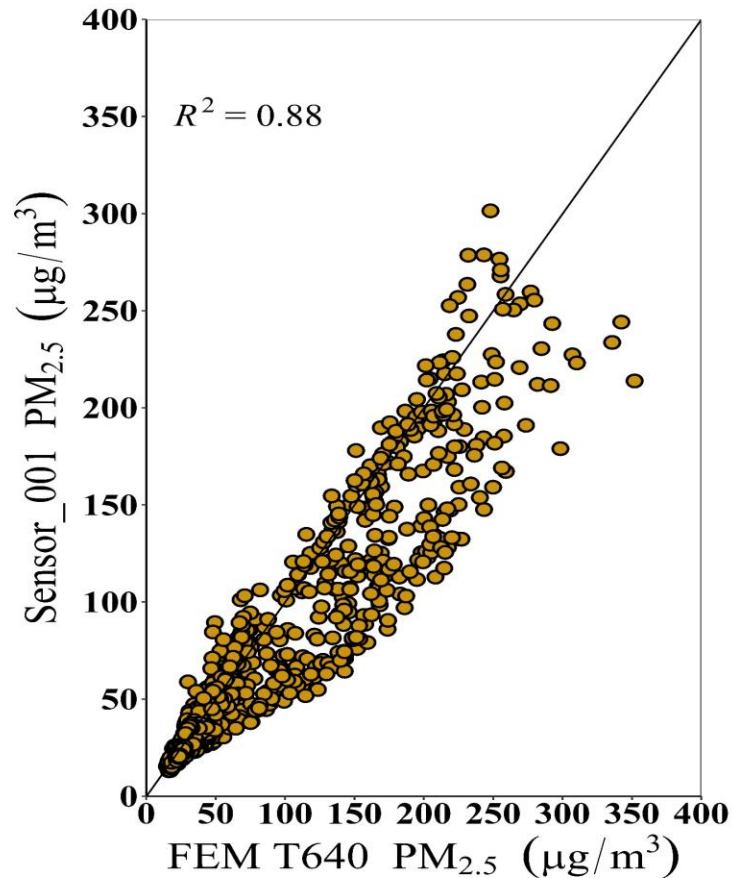
Teledyne T640 FEM

Intra-unit variability of PM_{2.5} (10-minute mean)



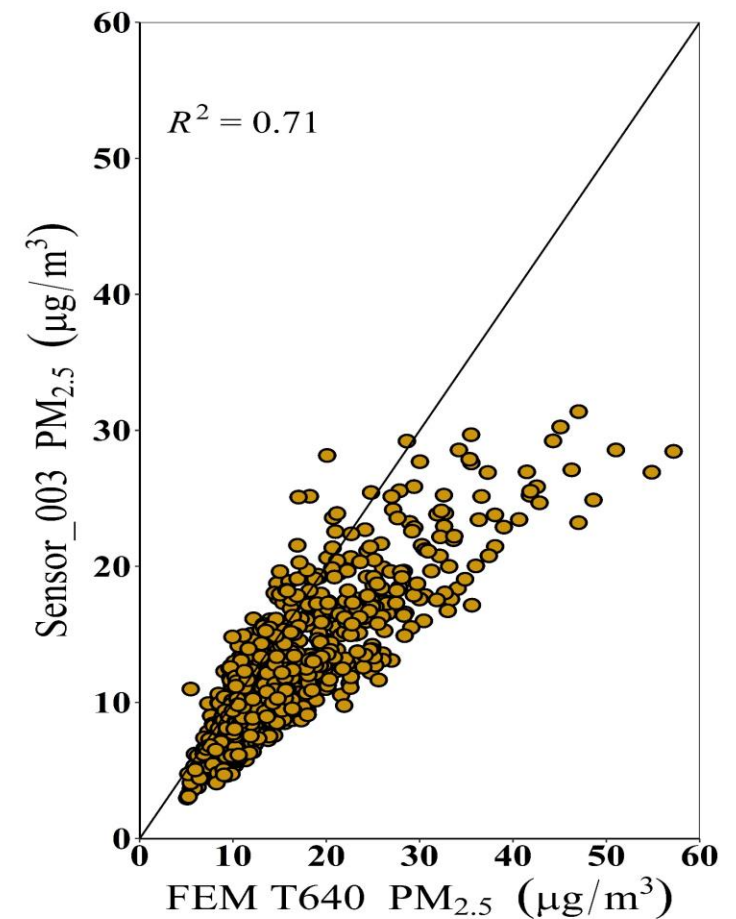
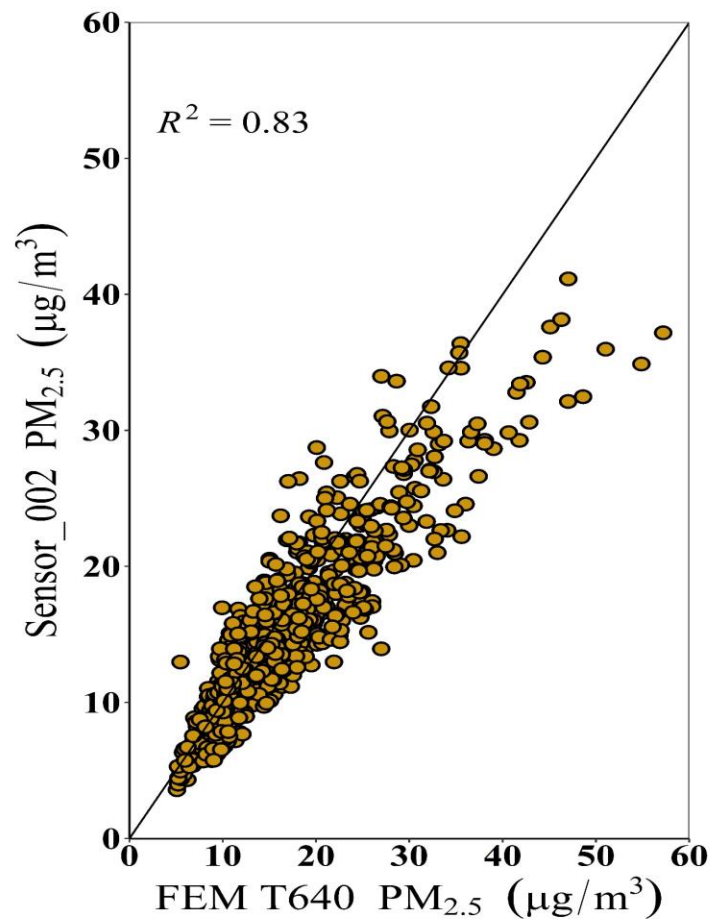
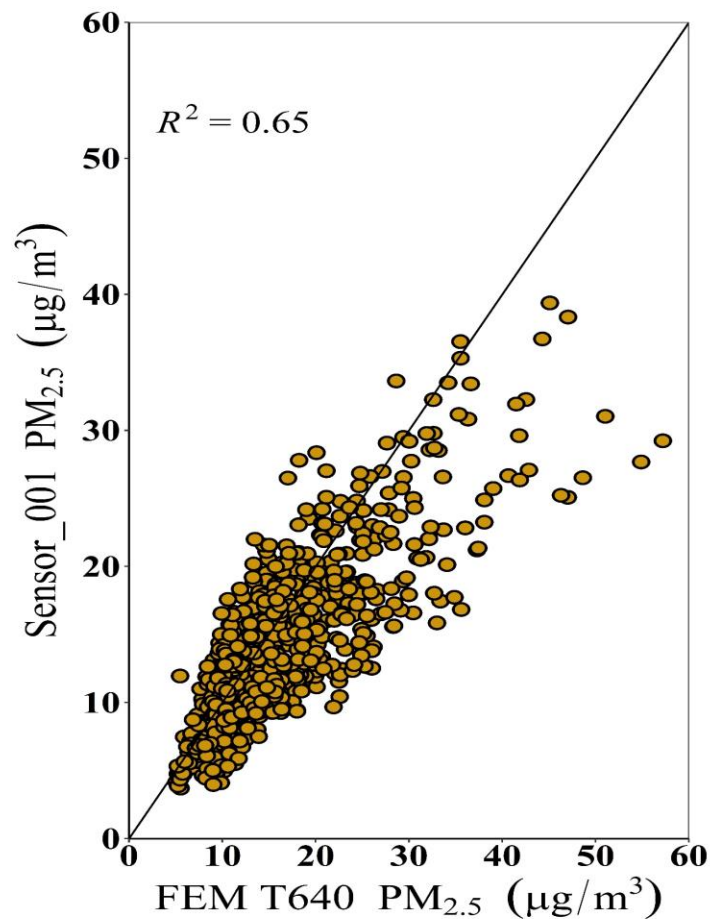
- ❑ Low intra-unit measurement variability was observed among the three KunakAir sensors during both dry and wet periods
- ❑ For Sensor_001 and Sensor_003, moderate measurement variability difference was observed when compared with the FEM T640 during the dry period
- ❑ During the dry period, low measurement variability difference was observed between Sensor_002 and the FEM T640.
- ❑ Low measurement variability difference was observed between all the KunakAir sensors and the FEM T640 during the wet period

KunakAir vs FEM T640 PM_{2.5} (Dry Period, 1 hour mean)



- During the dry period, hourly PM_{2.5} data from all KunakAir sensors exhibited a strong correlation ($R^2 = 0.85$ to 0.93) with the PM_{2.5} data from the FEM T640 monitor

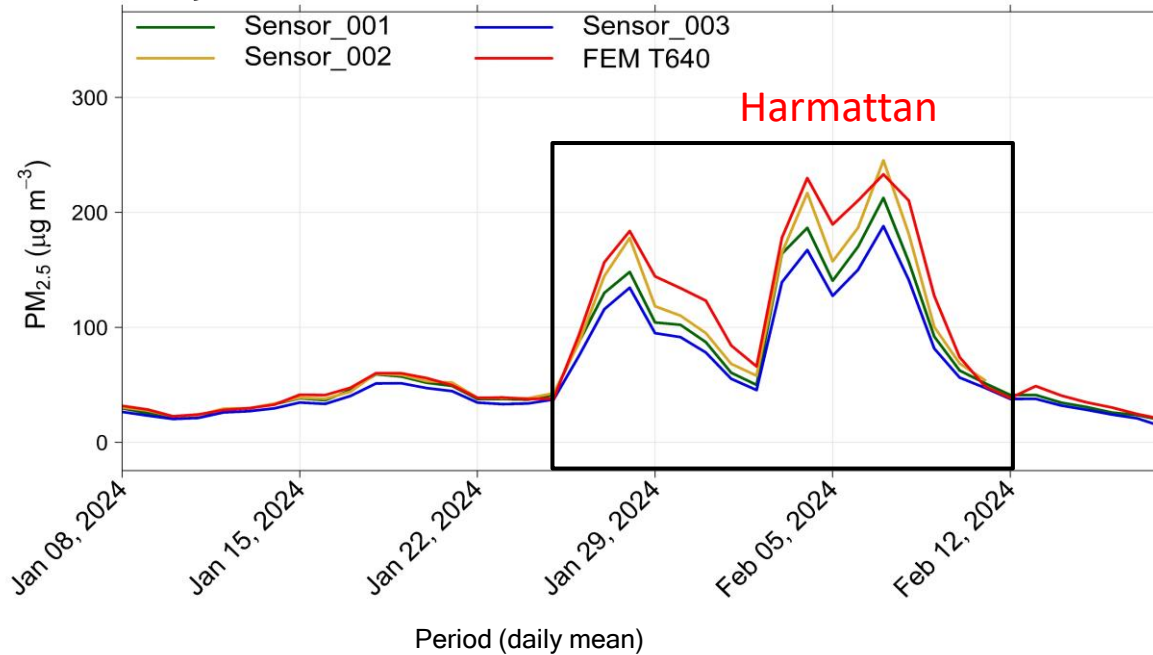
KunakAir vs FEM T640 PM_{2.5} (Wet Period, 1 hour mean)



- Hourly PM_{2.5} data from all KunakAir sensors showed strong correlation ($R^2 = 0.65$ to 0.83) with the PM_{2.5} data from the FEM T640 monitor during the wet period

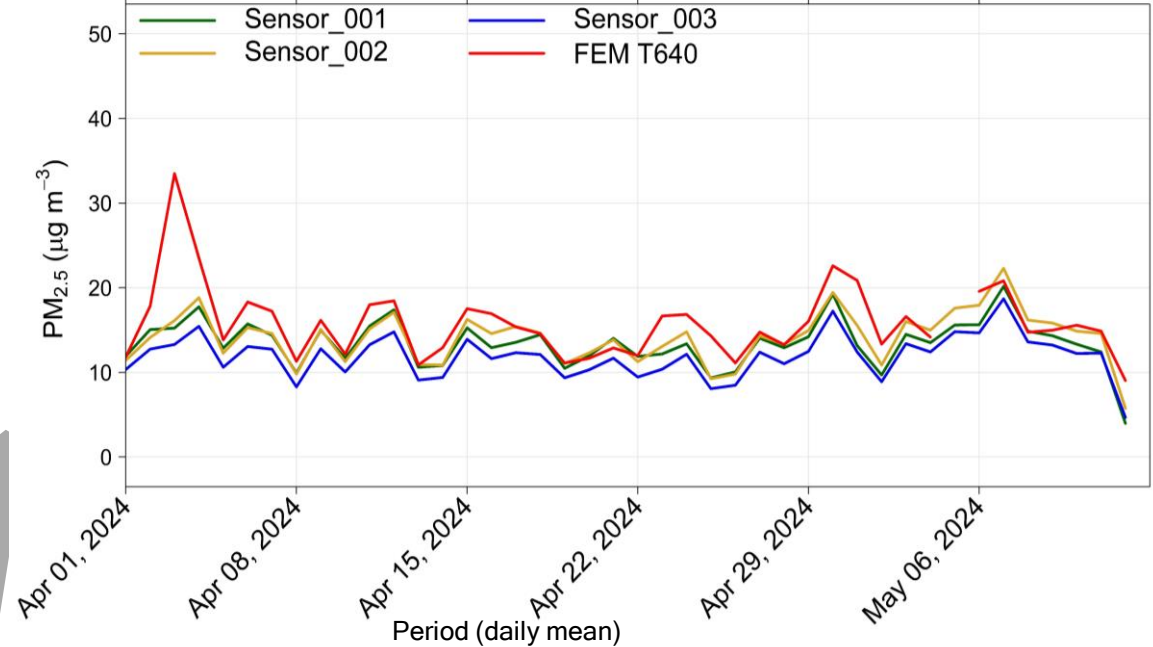
KunakAir vs FEM T640 PM_{2.5} (Daily mean)

Dry Period



- ❑ During the dry period, all the KunakAir sensors underestimated the PM_{2.5} mass concentrations of the FEM T640
- ❑ All three KunakAir sensors tracked the diurnal PM_{2.5} variations of the FEM T640 during the dry period

Wet Period



- ❑ The three KunakAir sensors underestimated the PM_{2.5} mass concentrations of the FEM T640 in the wet period
- ❑ During the wet period, all three KunakAir sensors tracked the diurnal PM_{2.5} variations of the FEM T640

SUMMARY STATISTICS (PM_{2.5})

	DRY PERIOD (1-hour mean)				WET PERIOD (1-hour mean)			
	R ²	MAE	MBE	RMSE	R ²	MAE	MBE	RMSE
Sensor_001	0.88	16.93	-12.63	28.12	0.65	3.44	- 1.89	4.94
Sensor_002	0.93	12.99	-7.73	21.15	0.83	2.38	- 1.26	3.51
Sensor_003	0.85	21.96	-19.98	35.33	0.71	4.08	- 3.57	5.64

- ❑ Coefficient of Determination (R²): Metric ranging from 0 to 1. The higher the value, the stronger the relationship and vice versa
- ❑ Correlation: It shows the linear relationship between sensor data and FEM T640 data
- ❑ Mean Absolute Error (MAE): The absolute difference between the sensors and the FEM T640. The larger the MAE values, the higher the measurement errors as compared to the FEM T640
- ❑ Mean Bias Error (MBE): The difference between the sensors and the FEM T640. MBE indicates the tendency of the sensors to underestimate (negative MBE values) or overestimate (positive MBE values)
- ❑ Outliers : Data points that significantly differ from other observations
- ❑ Root Mean Square Error (RMSE): A metric to calculate measurement errors and it is considered sensitive to outliers

Discussion

- ❑ Overall, the KunakAir sensors were reliable as they consistently recorded data during the evaluation period
- ❑ Low intra-unit measurement variability was observed among the three KunakAir sensors during both dry and wet periods
- ❑ For Sensor_001 and Sensor_003, moderate measurement variability difference was observed when compared with the FEM T640 during the dry period
- ❑ During the dry period, low measurement variability difference was observed between Sensor_002 and the FEM T640.
- ❑ Low measurement variability difference was observed between all the KunakAir sensors and the FEM T640 during the wet period
- ❑ Hourly $PM_{2.5}$ data from all KunakAir sensors exhibited a strong correlation ($R^2 = 0.85$ to 0.93) with the $PM_{2.5}$ data from the FEM T640 monitor during the dry period
- ❑ During the wet period, the hourly $PM_{2.5}$ data from all KunakAir sensors exhibited a strong correlation ($R^2 = 0.65$ to 0.83) with the $PM_{2.5}$ data from the FEM T640 monitor during the wet period

All results are preliminary.

Discussion

- ❑ During the wet period, the three KunakAir sensors underestimated the $PM_{2.5}$ mass concentrations of the FEM T640 ($-3.57 \leq MBE \leq -1.26$)
- ❑ The three KunakAir sensors underestimated the $PM_{2.5}$ mass concentrations of the FEM T640 in the dry period ($-19.98 \leq MBE \leq -7.73$)
- ❑ During the Harmattan, all KunakAir sensors slightly underestimated the $PM_{2.5}$ mass concentrations of the FEM T640
- ❑ The three KunakAir sensors tracked the diurnal $PM_{2.5}$ variations of the FEM T640 during both wet and dry periods

All results are preliminary.