**We would like to thank the anonymous reviewer for the comments that significantly improved the clarity and readability of the manuscript. Our point-by-point responses are found below in blue ink. The revised content is highlighted in yellow.**

1. You stated that "AQB-monitored PM concentration can be converted to dry particle mass concentration, aligning well with EPA data after OPC sensitivity correction. The derived hygroscopicity provides the relationship between ambient relative humidity and particle water content. By dividing $PM_{10}$ into $PM_{2.5}$ and $PM_{2.5-10}$, considering the composition heterogeneity, we achieved more precise dry $PM_{10}$ concentrations with lower MAPE." Please state differences clearly with 2 different observing packages.

A: Thank you for your constructive comments and for emphasizing the need for clarity in differentiating between the two observational packages used in our study. The EPA stations (using METONE BAM1020) report dry-state PM concentrations by controlling the measurement environment to maintain relative humidity (RH) below 50%. In contrast, the optical particle counter (OPC) in the AQB directly monitors ambient PM concentrations. The comparison of these two datasets illustrates the sensitivity variation of low-cost OPC sensors and the influence of hygroscopicity. The content of Section 4 (Lines 288-294) was rewritten to clarify this issue as follows: " In the PM analysis, $PM_{10}$ was divided into $PM_{2.5}$ and $PM_{2.5-10}$ to account for compositional heterogeneity among different particle sizes. Comparing the AQB-monitored ambient PM data and the TW-EPA data (for dry particles) at RH $\leq$ 50%, the derived sensitivity coefficients ($\alpha$) for $PM_{2.5-10}$ (10.58 - 12.37) were higher than those for $PM_{2.5}$ (1.26 - 1.44) likely due to the significant sensitivity variation in the OPC over time. By considering hygroscopicity with the κ-Köhler equation and assuming a constant composition density for sensitivity-corrected AQB data, the derived dry particle mass concentrations show improved consistency with TW-EPA data compared to the simple linear regression approach."

2. Provide units for the parameters in the equations.

A: Thank you for your kind reminder. All equations are labeled with units to ensure correct use. The adjusted revisions for the descriptions of equations (Eqs.1 and 2) in the paragraph as follows: "

$$\alpha = \frac{M_{EPA}}{M_{OPC}} \quad (1)$$

where $M_{EPA}$ and $M_{OPC}$ are PM concentrations ($\mu g\ m^{-3}$) measured by TW-EPA and OPC, respectively.

$$S = \frac{D_{amb}^3 - D_d^3}{D_{amb}^3 - D_d^3(1-\kappa)} exp\left(\frac{4\sigma_{s/a}M_w}{RT\rho_w D_{amb}}\right) \quad (2)$$

where $D_{amb}$ and $D_d$ are the diameters (m) of the ambient and dry particulate matter, respectively, $\sigma_{s/a}$ is the surface tension of the particle ($J\ m^{-2}$), $M_w$ is the molecular weight

of water (g mole$^{-1}$), $R$ is the gas constant (J mole$^{-1}$ K$^{-1}$), and $\rho_w$ is the density of liquid water (1.0 g m$^{-3}$). The first term is the solute effect, while the second term is the Kelvin effect."

In Eqs.3 and 4, units for the parameters in the equations have already been provided in Eqs. 1 and 2 or the paragraph. For Eq.5, the volume mixing ratio (ε) and hygroscopicity (κ) is a dimensionless quantity.

3. How accurate your hygroscopicity calculation that needs to be discussed.

A: In this study, the low-cost sensors acquired data for a certain period to cover a more comprehensive RH range for the hygroscopicity calculation. In the studied case, the analysis successfully showed different mean κ values between $PM_{2.5}$ and $PM_{2.5-10}$ based on the data of the monitored period. Even though there was no intensive filter sample collection during the studied period, the comparison of two IC analysis results from other studies (2013 and 2021 winter campaigns) shows similar hygroscopicity of $PM_{2.5}$, ranging from 0.18 to 0.25, which might represent a typical winter $PM_{2.5}$ hygroscopic characteristics in Kaohsiung city. The consistent results between the two winter campaigns might suggest the overall soluble species fraction in $PM_{2.5}$ is generally within a similar range. Therefore, the derived mean κ range under the specific assumption (solute density and ignorance of Kelvin effect) from AQB data was discussed for the range consistency compared to the results of available two winter campaigns for $PM_{2.5}$ and the 2013 winter campaign for $PM_{2.5-10}$. However, the accuracy improvement of dry particle mass concentration derived from the AQB monitored data after applying the OPC sensitivity coefficient and derived κ values can be evaluated as illustrated in Section 3.2 and summarized in a new table (Table 2).

**Table 2: Performance metrics of different calibration methods for $PM_{2.5}$, $PM_{2.5-10}$, and $PM_{10}$.**

| | $PM_{2.5}$ | | | $PM_{2.5-10}$ | | | $PM_{10}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | RH≤50% Only[a] | All data (no κ) | All data (κ= 0.29) | RH≤50% Only[a] | All data (no κ) | All data (κ= 0.09) | RH≤50% Only[a] | All data (no κ) | All data (κ= 0.36) | ($PM_{2.5}$+ $PM_{2.5-10}$)[c] |
| applied α | 1.26±0.16 | 1.04 | 1.40 | 12.37±1.33 | 10.77 | 13.16 | 2.02±0.34 | 1.69 | 2.36 | — |
| MAPE (%) | 21.3 (12.8) | 48.8 | 24.8 | 15.9 (11.5) | 37.9 | 31.8 | 32.8 (18.5) | 62.5 | 29.2 | 18.2 |
| RMSE (μg cm$^{-3}$) | 20.5 (3.7) | 29.1 | 11.3 | 4.9 (2.8) | 9.4 | 9.1 | 42.6 (10.3) | 54.7 | 26.9 | 15.9 |
| $R^{2}$ [b] | .0.55 (0.51) | -3.49 | 0.32 | 0.31 (0.78) | 0.57 | 0.59 | -4.18 (-0.58) | -4.74 | -0.38 | 0.51 |

**[a] Only for data points at RH ≤50%. The value in parentheses is the performance result without two significant outliers shown in Fig. 3**

**[b] Coefficient of determination ($R^2$) is calculated as the proportion of variation in the calibrated dry mass concentration.**

**[c] The combination of calibrated data from $PM_{2.5}$ All data (κ= 0.29) and $PM_{2.5-10}$ All data (κ= 0.09).**

To clarify this approach, Sections 3.2 and 3.3 were revised as follows: in Section 3.2 (Lines 172-211): “Figures 3(a) and 3(c) show the scatter distribution of the mass concentrations between AQB #1 (with no calibration) and TW-EPA data for $PM_{2.5}$ and $PM_{10}$, respectively. Overall, the PM mass concentrations measured by AQB system appear to be higher than

those reported by TW-EPA. The results reveal an apparent influence of ambient RH, indicating the contribution of water content. The red-shaded area represents a regression line with a slope corresponding to the inverse of the sensitivity coefficients (α) derived from data points at ambient RH ≤ 50% (17 out of 356 points, 5%). The notable deviation of the red shaded area from the 1:1 line towards the right side indicates the requirement of $\alpha > 1$ corrections, contributed by the different measurement principles and calibration techniques, which may result from the assuming particle density and refractive index (RI) (dust, density: 1.65 g $cm^{-3}$, RI: 1.5 + 0i). The estimated α, as summarized in Table 1, are higher for $PM_{10}$ than for $PM_{2.5}$, i.e., 2.02 ± 0.34 vs 1.26 ± 0.16, which are reasonably conclusive as tested with more data points selected at higher RH thresholds (Fig. S2). The α difference between $PM_{2.5}$ and $PM_{10}$ might be attributed to the complex composition of ambient particles, which differs from the samples used for instrument calibration, as well as possible sensitivity variations in OPC over time. With sensitivity calibration, the performance at ambient RH ≤ 50% exhibits a strong correlation with MAPE at 12.8%, 18.5%, and Root Mean Squared Error (RMSE) at 3.7 μg $m^{-3}$, 10.3 μg $m^{-3}$ for $PM_{2.5}$ and $PM_{10}$, respectively, as summarized in Table 2 excluding the two significant outliers (shown as hollow circles in Fig. 3). The results confirm the effectiveness of OPCs in capturing PM concentrations, consistent with previous real-time outdoor field studies (Gillooly et al., 2019; Demanega et al., 2021; Sá et al., 2022; Crilley et al., 2018). Additionally, the OPC sampling flow rate has an impact on measurement performance. AQB #1 maintained a steady rate at 3.6 ± 0.2 LPM, whereas AQB #2 exhibits two distinct time periods with sampling flow rates of 3.6-4.2 LPM for the first period and 3.2-3.6 LPM for the second period. …With the derived α, the hygroscopicities were retrieved using Eq. (3), resulting in κ ranging from 0.18 to 0.29 for $PM_{2.5}$ and 0.20 to 0.39 for $PM_{10}$ (Table 1) during the studied period. Figures 3(d) and 3(f) show the scatter distribution of the derived dry concentration vs. TW-EPA concentration for $PM_{2.5}$ and $PM_{10}$, respectively. The results from the two AQB systems exhibit slight differences but are consistent overall. Considering both the sensitivity coefficient and hygroscopicity, the performance of AQB in deriving dry PM concentration is significantly improved with lower MAPE, RMSE, and higher $R^2$ than the results obtained using only the sensitivity coefficient, as summarized in Table 2. … The lower κ for $PM_{2.5-10}$ might suggest a significant contribution from dust or other less hygroscopic species, consistent with the IC analyses in Table 3 and discussed further in Sect. 3.3. With the retrieved α and κ for $PM_{2.5}$ and $PM_{2.5-10}$, Fig. 3(e) shows the scatter distribution between the derived dry $PM_{2.5-10}$ from AQB data and TW-EPA data, exhibiting a MAPE of 31.8%, more significant than the 24.8% for $PM_{2.5}$. … Detection efficiency may be influenced by notable spatial variations, aligning with the findings of Kaliszewski et al. (2020), which showed a reduced correlation between OPC-N3 measurements and reference instruments for larger particles. The dry $PM_{10}$ derived from AQB through the divided $PM_{2.5}$ and $PM_{2.5-10}$ analysis demonstrates better consistency with the reported TW-EPA data than the direct calibration method. This is evidenced by a lower MAPE in Fig. 3(g) (18.2%) compared to Fig. 3(f) (29.2%) and a significant improvement than the simple linear regression method, which has a higher MAPE at 62.5% (Table 2). This substantiates the importance of considering composition heterogeneity among particle sizes for accurate dry PM derivation. “; and in Section 3.3 (Lines 222-235): “A similar analysis for the winter of 2021 yielded a consistent κ range for $PM_{2.5}$, as illustrated in Fig. S5. This consistency across distinct study periods indicates typical ambient $PM_{2.5}$

hygroscopic characteristics in Kaohsiung City during winter, which can be applied for further discussion with the AQB data. For coarse particles, the more significant variability in κ for $PM_{2.5-10}$ compared to $PM_{2.5}$ can be attributed to the significant fluctuations in the soluble composition of coarse particles, primarily driven by substantial quantities of thenardite ($Na_2SO_4$) and halite (NaCl) (Tang et al., 2019). …The derived κ value for $PM_{2.5}$ from IC analysis (0.14-0.27) is consistent with that obtained from AQB analysis (~0.22), while the κ value for $PM_{2.5-10}$ from IC analysis (0.06-0.21) is relatively higher than that from AQB analysis (~0.09) (Table 1 and Fig. 4(a)). The κ differences between the IC and AQB analyses could be attributed to the spatial and temporal variations in aerosols, as well as the different campaign years and locations (~20 km apart, as shown in Fig. S1). These differences might also be influenced by technique uncertainties, such as ammonia and nitrate sampling evaporation during filter sampling (Hering and Cass, 1999; Chen et al., 2021), as well as OPC detection uncertainties and the required parameter assumption in the calculation. Overall, the derived κ values from the OPC data in AQB likely reflect the mean hygroscopicity of both integrated fine and coarse particles. ". Additionally, Fig. S5 is revised as follows:

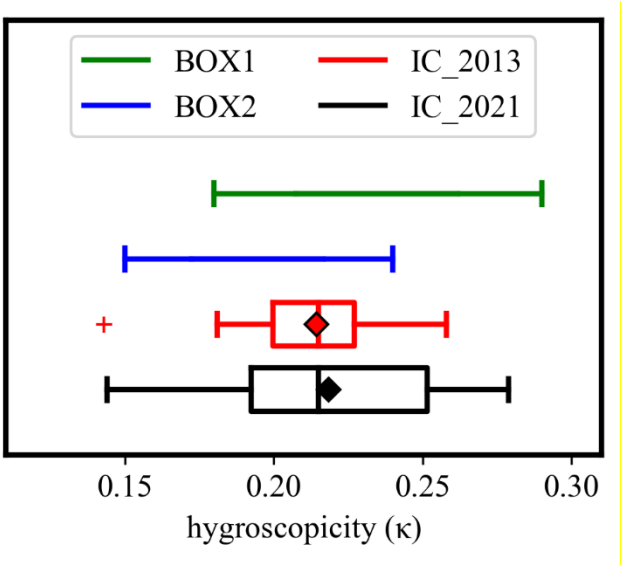


Figure S5: The hygroscopicity of $PM_{2.5}$ derived from AQB and IC data with an assumed particle density of 1.2 g $cm^{-3}$. The IC_2021 is from 2021 samples collected at the National Kaohsiung University of Science and Technology (22°46'22.4" N 120°24'03.4" E) in Kaohsiung for the period of 8 – 18 December 2021 (diamond: mean value; outliers: < 1st quartile Q1-1.5 interquartile range (IQR) or > 3rd quartile Q3+1.5 IQR).

4. please provide how did you convert ppm to mass for various species?

A: For particulate matter, OPC in the AQB and BAM1020 in the TW-EPA station monitor PM mass concentrations in micrograms per cubic meter (μg/m³); hence, there is no need for unit conversion from ppm to mass concentration. For gaseous species monitored in this study, the concentration is calibrated and expressed in volume mixing ratio as ppm or ppb,

the same as EPA data. In our study, conversions from ppm to mass were not performed for gaseous species.

If there is a need for the unit conversion of monitored gas species, it can be calculated using the ideal gas equation as follows:

$$Mass\ concentration = C \times \frac{M_{gas} \cdot P}{R \cdot T}$$

where the unit of *Mass concentration* here uses μg $m^{-3}$ as an example, $C$ is the volume mixing ratio (ppmv), $M_{gas}$ is the molecular weight of selected gas (g $mole^{-1}$), $R$ is the gas constant (J $mole^{-1}$ $K^{-1}$), $T$ is the temperature of air parcel (K), and $P$ is the pressure of air parcel (Pa). AQB system monitors meteorological parameters temperature (T) and pressure (P), which can convert the gaseous air pollutant concentration from volume mixing ratio to mass concentration. Furthermore, we replaced "ppm" by "ppmv" and "ppb" by "ppbv" to avoid any potential misunderstanding throughout the whole manuscript.

5. please provide your final conclusions in an itemized list.

A: Thank you for your suggestion to present the final conclusions of our study in an itemized list. In this study, we emphasize our study in three main points:

1. Effectiveness of low-cost systems: The performance of home-built Air Quality Box (AQB) systems was evaluated, demonstrating their effectiveness in capturing meteorological parameters and various pollutant concentrations.
2. Sensitivity analysis and hygroscopicity derivation: $PM_{10}$ was divided into $PM_{2.5}$ and $PM_{2.5-10}$ to account for sensor detection sensitivity and compositional heterogeneity among different particle sizes. With the consideration of sensor sensitivity and hygroscopicity of particles, the derived dry particle mass concentrations showed improved consistency with TW-EPA data than those derived from simple linear regression.
3. Derived hygroscopicity and error discussion: The derived hygroscopicity values align with results from the soluble composition analysis using ion chromatography. This study also emphasizes the need for careful consideration of uncertainties and calibration techniques to interpret low-cost sensor data in atmospheric research accurately.

We prefer to choose the narrative conclusion section by reconstructing the logic in revision: " In this study, we evaluated the performances of home-built Air Quality Box (AQB) systems equipped with low-cost sensors and focused on the ambient variability of particulate matter (PM) concentrations to derive the hygroscopicity of PM and the conversion to dry particle concentrations. The AQB systems revealed their effectiveness in capturing meteorological parameters and most pollutant concentrations with high correlations ($r \geq 0.96$) for temperature, relative humidity, CO, and Ox ($O_3$ + $NO_2$) and moderate correlations ($r \geq 0.48$) for NOx and PM, as compared to TW-EPA data. In the PM analysis, $PM_{10}$ was divided into $PM_{2.5}$ and $PM_{2.5-10}$ to account for compositional heterogeneity among different particle sizes. Comparing the AQB-monitored ambient PM

data and the TW-EPA data (for dry particles) at RH ≤ 50%, the derived sensitivity coefficients (α) for $PM_{2.5-10}$ (10.58 - 12.37) were higher than those for $PM_{2.5}$ (1.26 - 1.44) likely due to the significant sensitivity variation in the OPC over time. By considering hygroscopicity with the κ-Köhler equation and assuming a constant composition density for sensitivity-corrected AQB data, the derived dry particle mass concentrations show improved consistency with TW-EPA data compared to the simple linear regression approach. The derived κ values range from 0.15 to 0.29 for $PM_{2.5}$ and 0.05 to 0.13 for $PM_{2.5-10}$, consistent with those from IC soluble composition analysis (0.14 to 0.27 for $PM_{2.5}$ and 0.06 to 0.21 for $PM_{2.5-10}$) and primarily influenced by the proportion of soluble components, ~53% in $PM_{2.5}$ and ~30% in $PM_{2.5-10}$. The sensitivity analysis of various parameters showed that the effects of chosen deliquescence relative humidity (DRH) thresholds and Kelvin effects had a minor impact on κ values (less than 1%). Conversely, recalculating particle densities for $PM_{2.5}$ (1.42 ± 0.03 g $cm^{-3}$) and $PM_{2.5-10}$ (1.34 ± 0.07 g $cm^{-3}$) led to higher κ values by approximately 17% and 9%, respectively, compared to the results assuming 1.2 g $cm^{-3}$. Overall, the AQB systems are helpful in understanding the temporal and spatial variability of air quality by effectively monitoring pollutant concentrations and providing the capability for hygroscopicity derivation. This study also emphasizes the need for careful consideration of uncertainties and calibration techniques to accurately interpret low-cost sensor data in atmospheric research.“