# MULTI-SENSOR PM10 AND PM2.5 EVALUATION AT SANTA CRUZ DE TENERIFE

BDRC-2023-003


Name of the Author(s)

*Africa Barreto - AEMET*



22 May 2023


TECHNICAL REPORT

Series: Barcelona Dust Forecast Center (BDFC) Technical Report

A full list of BDRC Publications can be found on our website under: http://dust.aemet.es/about-us/technical-reports



C/Jordi Girona, 29 | 08034 Barcelona (Spain)

# Summary

This report outlines the methodology employed for the intercomparison and calibration between three Low-Cost PM10 sensors, which has been developed by the Barcelona Dust Regional Center as part of CREWS project.

# Contents

# 1.Introduction

The Climate Risk and Early Warning Systems (CREWS, https://crews-initiative.org) Initiative is a global partnership that aims to significantly increase the availability of, and access to, multi-hazard early warning systems in Least Developed Countries (LDCs) and Small Island Developing States (SIDS). These nations are often the most vulnerable to the impacts of climate change and extreme weather events.

Its core mission is to save lives, protect assets, and secure livelihoods by ensuring these communities have timely, understandable, and actionable warnings about extreme weather and climate events. CREWS achieves this by supporting projects that strengthen all four pillars of effective early warning systems: disaster risk knowledge, hazard monitoring and forecasting, warning dissemination, and preparedness/response capabilities.

Implemented by key partners including the World Meteorological Organization (WMO), the UN Office for Disaster Risk Reduction (UNDRR), and the World Bank (via GFDRR), CREWS is a multi-donor trust fund. The Barcelona Dust Regional Center, for instance, contributes to CREWS by developing and disseminating crucial dust storm forecasts, aiding in early warning for a specific, impactful hazard. Ultimately, CREWS aims to close the capacity gap in climate services and build global resilience against increasing climate risks.

The Role of the Barcelona Dust Regional Center within CREWS:

- The Barcelona Dust Regional Center, hosted by AEMET (Spanish State Meteorological Agency) and BSC (Barcelona Supercomputing Center), plays a vital role within the WMO's Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) program. This system is crucial for providing early warnings for sand and dust storms, which are significant meteorological hazards with wide-ranging impacts on health, environment, and various socio-economic sectors.
- Supporting Early Warning Systems: Their work directly supports the "Detection, Observation, Monitoring, Analysis, and Forecasting" pillar for dust-related hazards in regions affected by sand and dust storms, like Northern Africa, the Middle East, and Europe. This is precisely where your low-cost PM10 sensor calibration work fits in, as it aims to improve local monitoring and prediction of dust.

In essence, the CREWS Initiative is a critical global effort to enhance resilience against climate and weather-related disasters by ensuring that vulnerable communities receive timely and actionable warnings, with specialized centers like the Barcelona Dust Regional Center contributing expertise in specific hazards like dust storms.

# 2. Low-Cost sensors

In the context of the CREWS project, we conducted a comprehensive intercomparison analysis of various low-cost PM sensors (listed in Table 1) against the PM reference measurements. These three low-cost sensors are widely found in the literature in field measurements of PM. The reference measurements were obtained from the Gobierno de Canarias (https://www3.gobiernodecanarias.org/medioambiente/calidaddelaire/datosOnLine.do) and followed the protocols and reference methods specified in the European air-quality directive 2008/50/EC. Hourly measurements of PM10 and PM2.5 were conducted using a Beta Attenuation Monitor (Met One Instruments-BAM 1020). The primary objective of this intercomparison analysis was to identify the low-cost sensor that exhibited superior performance in detecting air quality for the CREWS project.

| | | |
|---|---|---|
|  |  |  |
| Sensirion SPS30 – DUST010 | Plantower PMS5003 – DUST011 | Nova SDS011– DUST012 |

Table 1: Different low-cost sensors used in the intercomparison analysis.

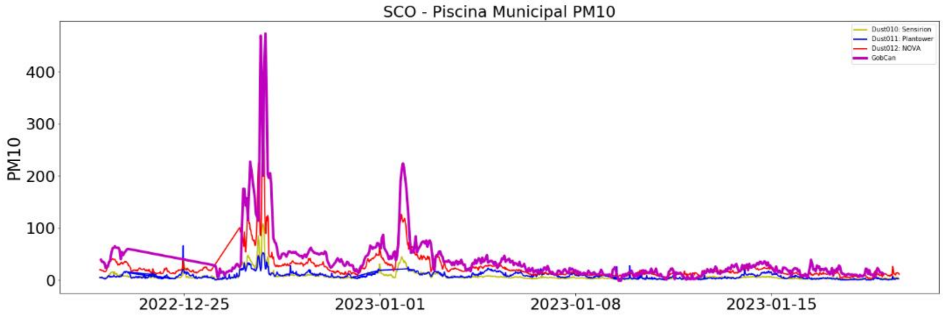
.

# 3. Results

The analysis using low-cost sensors was conducted during the time period from December 22, 2022, to March 4, 2023. A total of 3464, 3442, and 3389 measurements were taken every 30 minutes. The three sensor instruments, named DUST010, DUST011, and DUST012 respectively (shown in Figure 1), were installed at the AEMET Headquarters in Santa Cruz de Tenerife. Hourly measurements from the Gobierno de Canarias were taken at Piscina Municipal in Santa Cruz (SCO), which is located approximately 2.5 km away from the three DUST sensors' location.

Figure 1: (a) Location of the three DUST sensors at the roof of AEMET's Headquarters measuring collocated with the Micropulse Lidar MPL belonging to MPLNet-NASA network (dome at the left) and the Cimel CE318-TS photometer belonging to AERONET-NASA network (on the right). (b) View of the three DUST prototypes installed in Santa Cruz.

The evolution of PM10 and PM2.5, measured by the three DUST prototypes and the reference measurements from Gobierno de Canarias at Piscina Municipal (GobCan), is depicted in Figure 2. The measurements indicate a consistent trend of underestimation by the low-cost sensors for both PM10 and PM2.5. Notably, two significant dust events were recorded in December and January, which are highlighted in Figure 2. It is evident from the figure that the NOVA sensor (DUST012 prototype) performs the best in terms of PM10 measurements. However, the DUST011 (Plantower) sensor demonstrates higher instrumental noise, particularly for PM2.5 measurements.



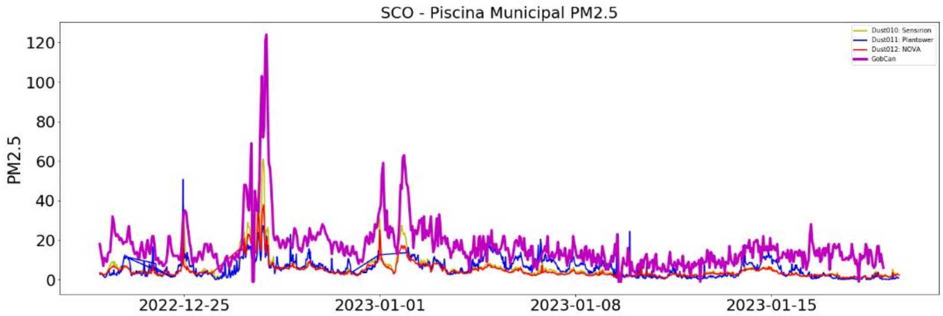
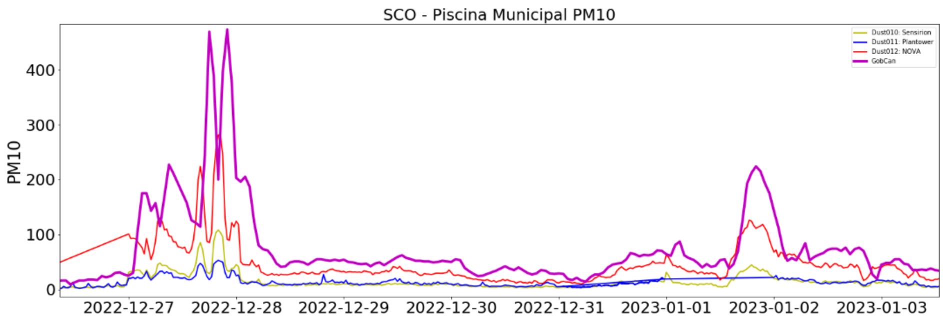




Figure 2: PM10 (at the top) and PM2.5 (at the bottom) evolution measured at Gobierno de Canarias Piscina Municipal (GobCan) and AEMET Headquarters (DUST sensors) during the period 2022-12-22 and 2023-03-04.



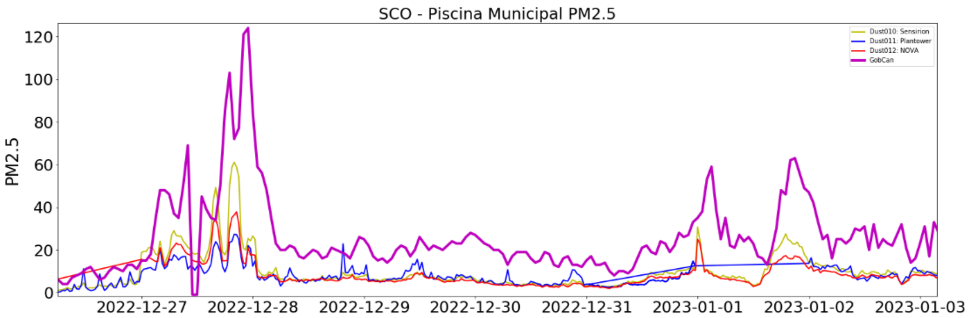



Figure 3: Zoom of Figure 1 in two events of high PM10 (at the top) and PM2.5 (at the bottom) conditions. Measurements are taken at Gobierno de Canarias Piscina Municipal (GobCan) and AEMET Headquarters (Dust sensors) during the period 2022-12-26 and 2023-01-04.

The analysis was also conducted for a period characterized by low PM conditions, as depicted in Figure 4 for PM10 and PM2.5 evolution. In terms of PM10, DUST012 demonstrates the highest agreement with the reference measurements. However, determining the best DUST prototype for PM2.5 is not straightforward.

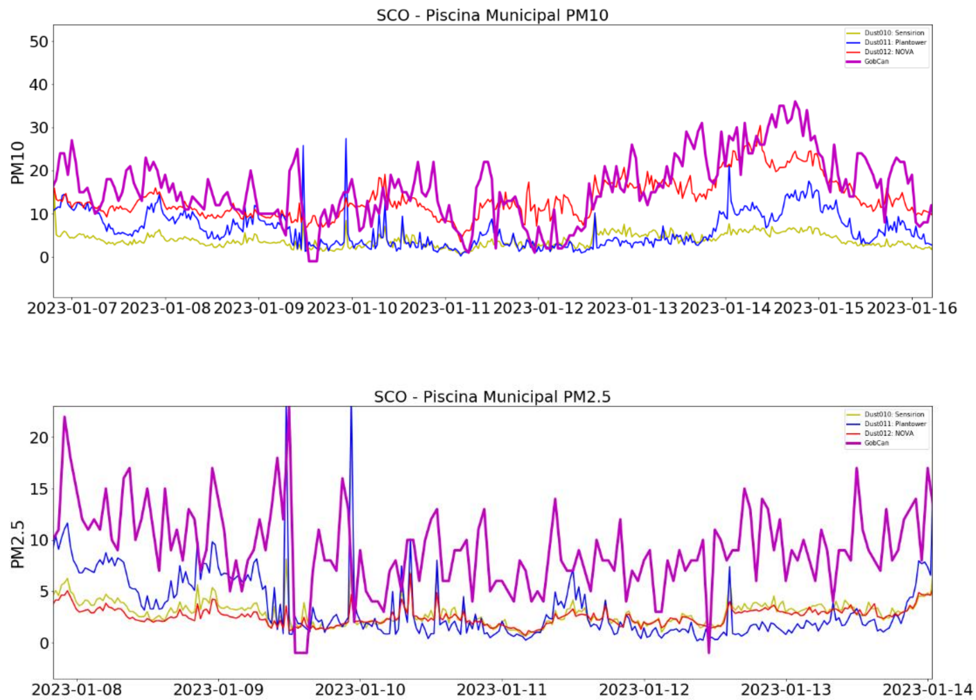



Figure 4: Zoom of Figure 1 in some events of low PM10 (at the top) and PM2.5 (at the bottom) conditions. Measurements are taken at Gobierno de Canarias Piscina Municipal (GobCan) and AEMET Headquarters (Dust sensors) during the period 2023-01-06 and 2023-01-16 for PM10 and between 2023-01-06 and 2023-01-14 for PM2.5.

Figure 5 displays scatterplots illustrating the relationship between coincident PM measurements obtained with the DUST prototypes and our reference measurements from Gobierno de Canarias (PM GC). The legend includes relevant statistics such as the number of data points and the correlation coefficient (r), along with the results of the regression analysis for each prototype.

It is noticeable that the regression slopes deviate significantly from one, indicating the presence of calibration errors in the prototypes ranging from 9% to 90%.

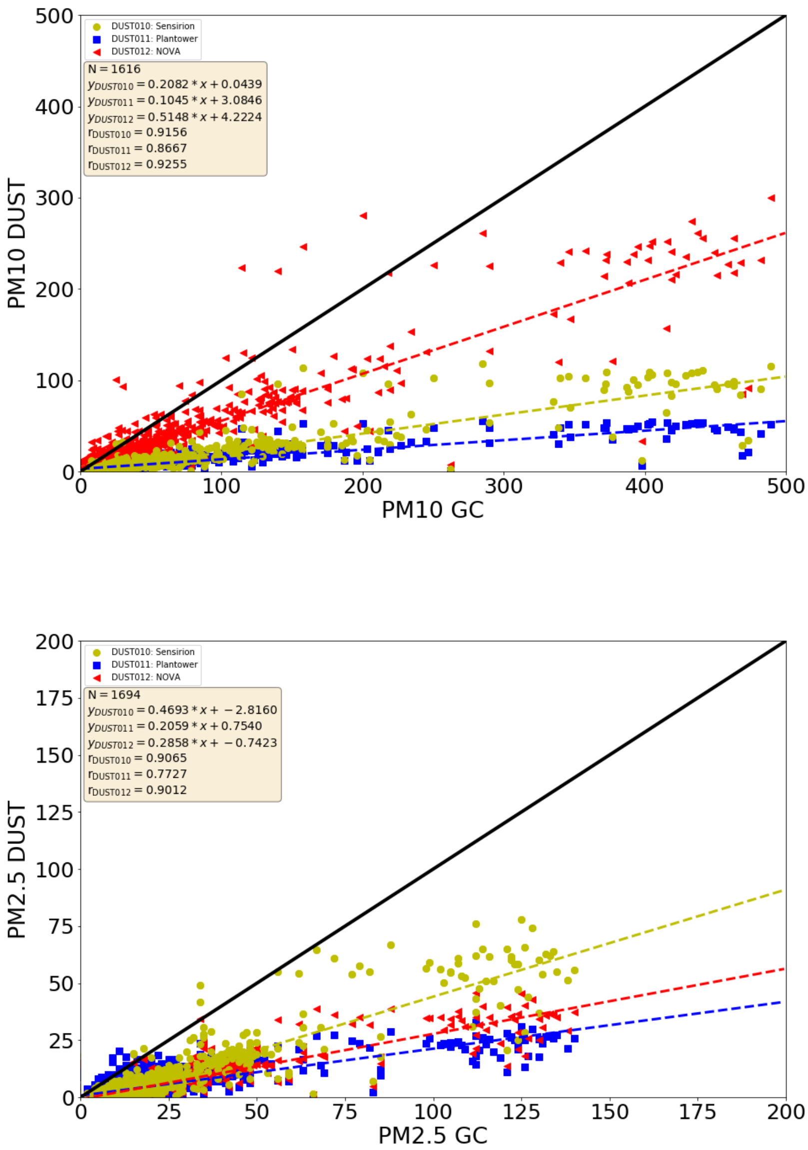
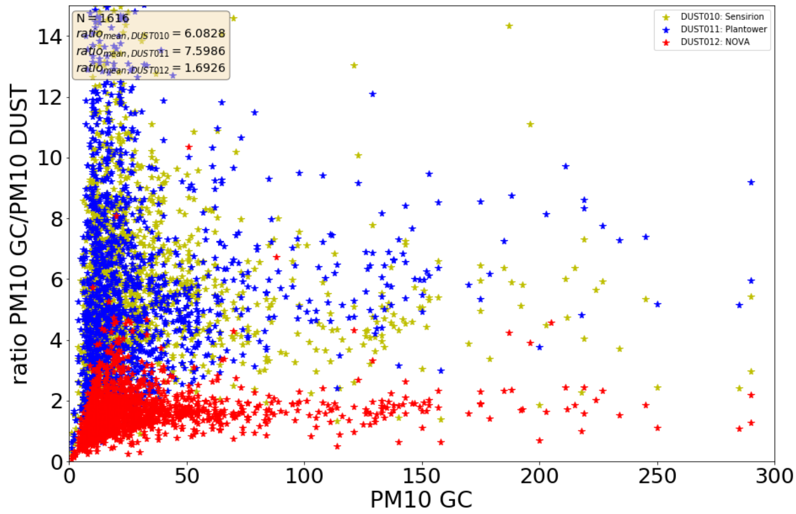



Figure 5: Scatterplot of coincident PM10 (at the top) and PM2.5 (at the bottom) measured with the DUST sensors against PM measured by the reference (Gobierno de Canarias, PM10 GC) in the whole period. Number of measurements (N), regression analysis and coefficient of regression (r) are included in the legend for the three DUST sensors.

The same analysis as in Figure 5 was conducted in Figure 6 using the ratios of PM between the PM prototypes and the reference measurements. This information allows us to estimate the potential bias in the DUST measurements and subsequently correct the prototype's outputs. Correction factors of 5.5, 6.2, and 1.5 were utilized to adjust the DUST measurements.



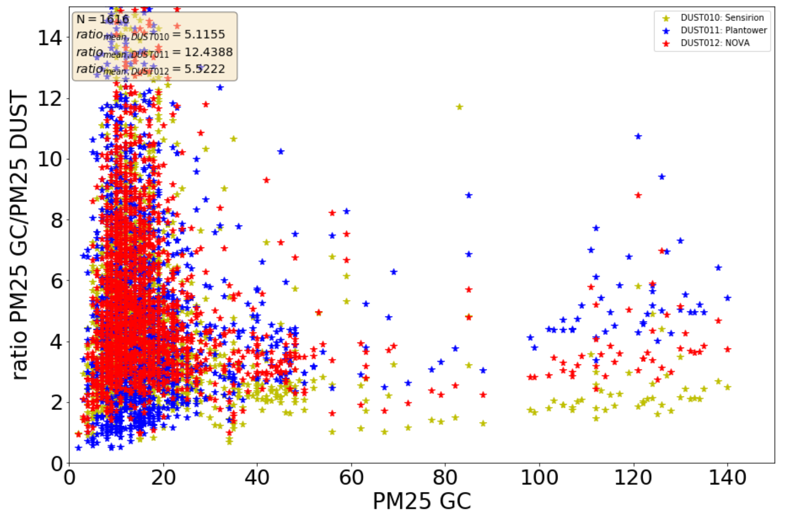




Figure 6: Ratios of PM10 (at the top) and PM2.5 (at the bottom) measured by the reference (Gobierno de Canarias, PM10 GC) and those values measured by the three DUST sensors in the whole period. Number of measurements (N) and ratios are included in the legend for the three DUST sensors.

With this information, a new representation of corrected PM10 and PM2.5 evolution is presented in Figure 7. Notably, there is a strong agreement observed between the PM measurements of DUST010 and DUST012 in comparison to the reference measurements. On the other hand, the records from DUST011 exhibit more noise, and the applied correction to this prototype appears to be non-linear with respect to the PM levels.

Scatterplots shown in Figure 8 further illustrate the coherence between DUST measurements and the PM10 reference, with the slopes of the linear fitting approaching one (low expected relative errors), particularly for DUST012, which exhibits an excellent regression coefficient of

0.92. The same analysis conducted using PM2.5 data confirms that DUST012 performs the best in comparison to the PM reference.

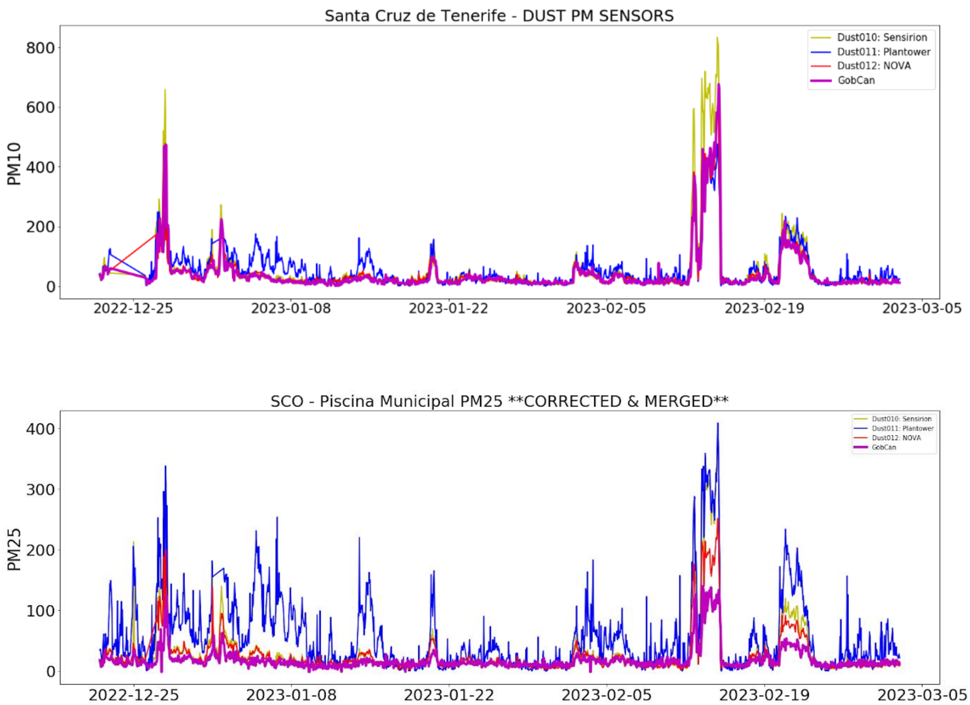
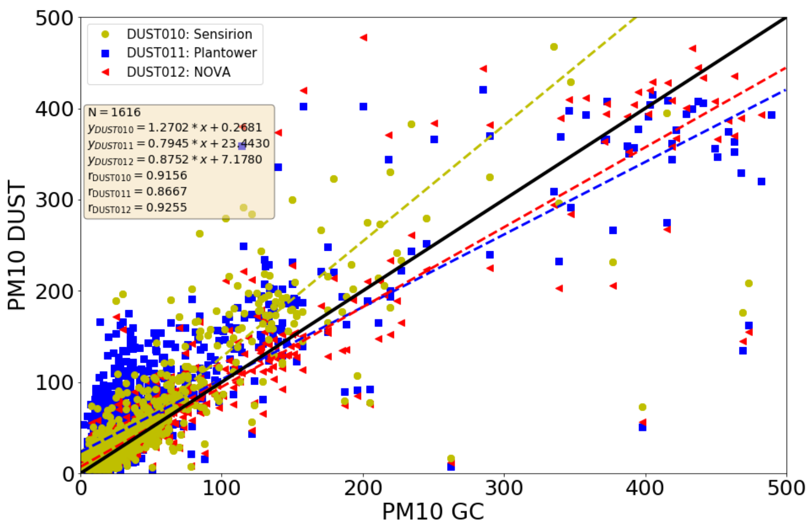



Figure 7: PM10 (at the top) and PM2.5 (at the bottom) evolution measured at Gobierno de Canarias Piscina Municipal (GobCan) and AEMET Headquarters (Dust sensors) during the period 2022-12-22 and 2023-03-04 corrected using the ratios retrieved in Figure 5.



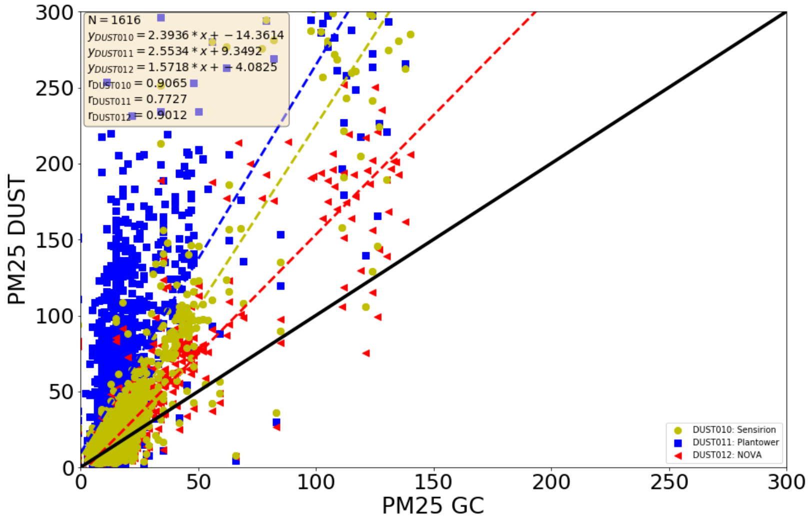



Figure 8: Scatterplot and statistics of corrected PM10 (at the top) and PM2.5 (at the bottom) measured with the DUST sensors (PM10 DUST) against those values measured at Piscina Municipal by Gobierno de Canarias (PM10 GC) and AEMET Headquarters (Dust sensors) during the period 2022-12-22 and 2023-03-04.

# 4. Conclusions

Based on this analysis, we can conclude that among three of the most commonly used PM sensors in the literature, the NOVA SDS011 (DUST012) is the best low-cost PM sensor to be utilized in the CREWS project. This low-cost sensor has demonstrated a close agreement in measuring PM10 and PM2.5 compared to a Beta Attenuation Monitor, across various PM levels. The applied correction to the raw data from this sensor has proven to be effective in minimizing relative errors when compared to the reference measurements