9th International Workshop on Sand/Duststorms and Associated Dustfall, 22-24 May 2018, Tenerife, Spain

Assessing the response of continuous PM_x monitors TEOM and BETA to aerosol dust within the Saharan Air Layer

E. SOSA[1], S. RODRÍGUEZ[1], M.I. GARCÍA[1,2], J. LÓPEZ-SOLANO[1], N. PRATS[1]

[1] Izaña Atmospheric Research Centre, AEMET; C/ La Marina 20, 6th floor, 38001, Tenerife, Spain; esosat@aemet.es

[2] Department of Chemistry (T.U. Analytical Chemistry), Faculty of Science, University of La Laguna; Avda. Astrofísico Francisco Sánchez s/n. 38071, Tenerife, Spain

1. Introduction

Desert dust is a major atmospheric aerosol that influences climate, air quality and other environmental fields. North Africa is the largest and most active dust source in the world (Engelstaedter et al., 2007). Dust export has a strong variability during the year. The transport of dust in summertime is shifted to subtropical latitudes (20-30ºN).

The location of the Canary Islands allows to monitor the Saharan dust export in summertime, when Izaña Observatory (~2400 m.a.s.l.) is within the Saharan Air Layer (SAL). At Izaña, samples of PM_x on filter have been collected, for subsequent chemical analysis, during the last three decades. In this period, PM_x has been determined by manual gravimetric methods. Recently, two automatic PM_x monitors - a TEOM dichotomous 1405 $PM_{2.5}$ and $PM_{2.5\text{-}10}$ monitor and a BETA 5014i measure PM_{10} monitor - have been incorporated to the Izaña in-situ aerosol observation program.

The goal of this work is to assess the response of these instruments with respect to the gravimetric standard method EN-14907, as part of the QA/QC protocol of the Izaña aerosol program.

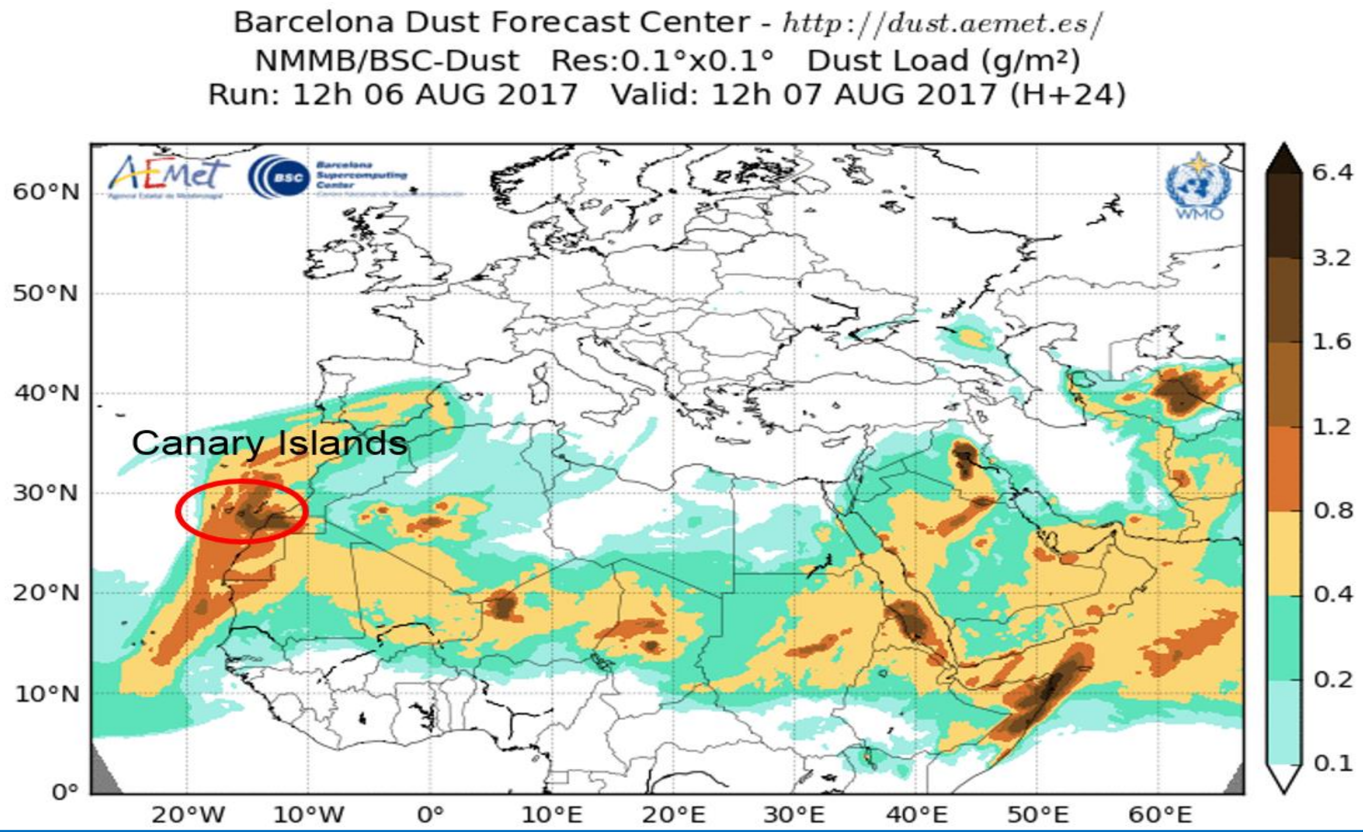

Figure 1. Location of the Izaña Observatory (red circle). The image of the Barcelona Dust Forecast Center (http://dust.aemet.es/) shows a typical dust event during summer in the Observatory.

2. Methodology

Gravimetric method. Pre-heated (at 205ºC) micro-fibber quartz filters (Pall Science 150 mm diameter) and high volume air samplers (Hi-Vol; MCZ™) at a flow rate of 30 m^3/h, were used to collect the sample during night time (22pm to 6am). Night-time sampling allows free troposphere conditions, avoiding the daylight influence of the boundary layer (Rodríguez et al., 2009).The EN-14907 standard for filter handling procedure was followed, except that filter conditioning was performed (20ºC) at 30% RH and not at 50% RH. This method is time-consuming because labor-intensive procedures (pre-conditioning, pre-weighing, filter installation, removal, post-conditioning and post-weighing) are necessary.

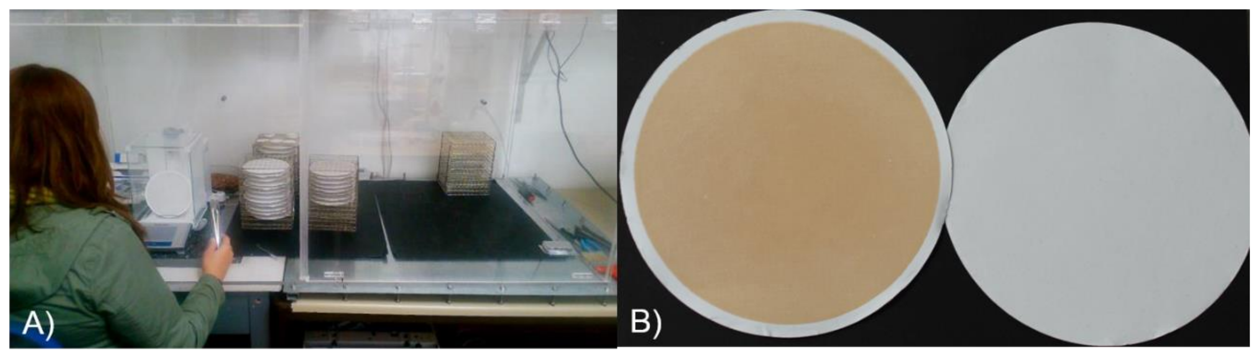

Figure 2. A) Aerosol filter laboratory. **B)** Filter with aerosol samples (PM_{10}) collected at Izaña.

TEOM dichotomous 1405 FDMS. This tapered element oscillating microbalance (TEOM) model allows the simultaneous monitoring of the fine - $PM_{2.5}$ and coarse - $PM_{2.5\text{-}10}$ fractions of PM. The physical splitting of the samples is performed by a virtual impactor. Then, the aerosol sample is dried by a diffusion dry backflow (30%), as part of the Filter Dynamic Measurement System (FDMS). The mass concentrations of PM_x are determined as a function of the decrease in the frequency of oscillation of the microbalance linked to the sample accumulation in each PM_x filter:

$$dm = K_0 \frac{1}{f_1^2} - \frac{1}{f_0^2}$$

, where dm is change in mass; K_0 spring constant; f_0 and f_1 initial and final frequency, respectively (Hz).

BETA-Thermo 5014i. In this PM_{10} monitor the sample is drawn (1 m^3/h) by an sub-10µm selective impactor, and then deposited onto the auto-advancing filter tape, where it is illuminated with beta radiation (C-14 source). The attenuation of the beta radiation across the filter + samples system is used to determine the PM_x mass concentrations:

$$C_\beta = \frac{A}{\mu_m Q t}(\ln f_0 - \ln f_1)$$

, where A is particle collection area ; μ_m mass attenuation coefficient; Q sample volumetric flow rate; t = sampling time; f_0 = initial beta count (s^{-1}); f_1 = final beta count (s^{-1}).

EU standards impactors were used. Airflows of all instruments were weekly checked.

3. Results

We illustrate our results with the dust events of summer (July and August) 2017. Concentrations of PM_x were determined with the gravimetric reference method and with the automatic TEOM and BETA monitors.

In this period several intense dust episodes occurred, which resulted in PM_{10} concentrations within the range 100-350 µg/m³ (Fig.3A). As expected, most of the dust mass occurred in the coarse fraction, with $PM_{2.5\text{-}10}$ concentrations exceeding 200 µg/m³ in some events (Fig.3B). Concentrations of $PM_{2.5}$ reached values within 75 – 100 µg/m³ (Fig.3C).

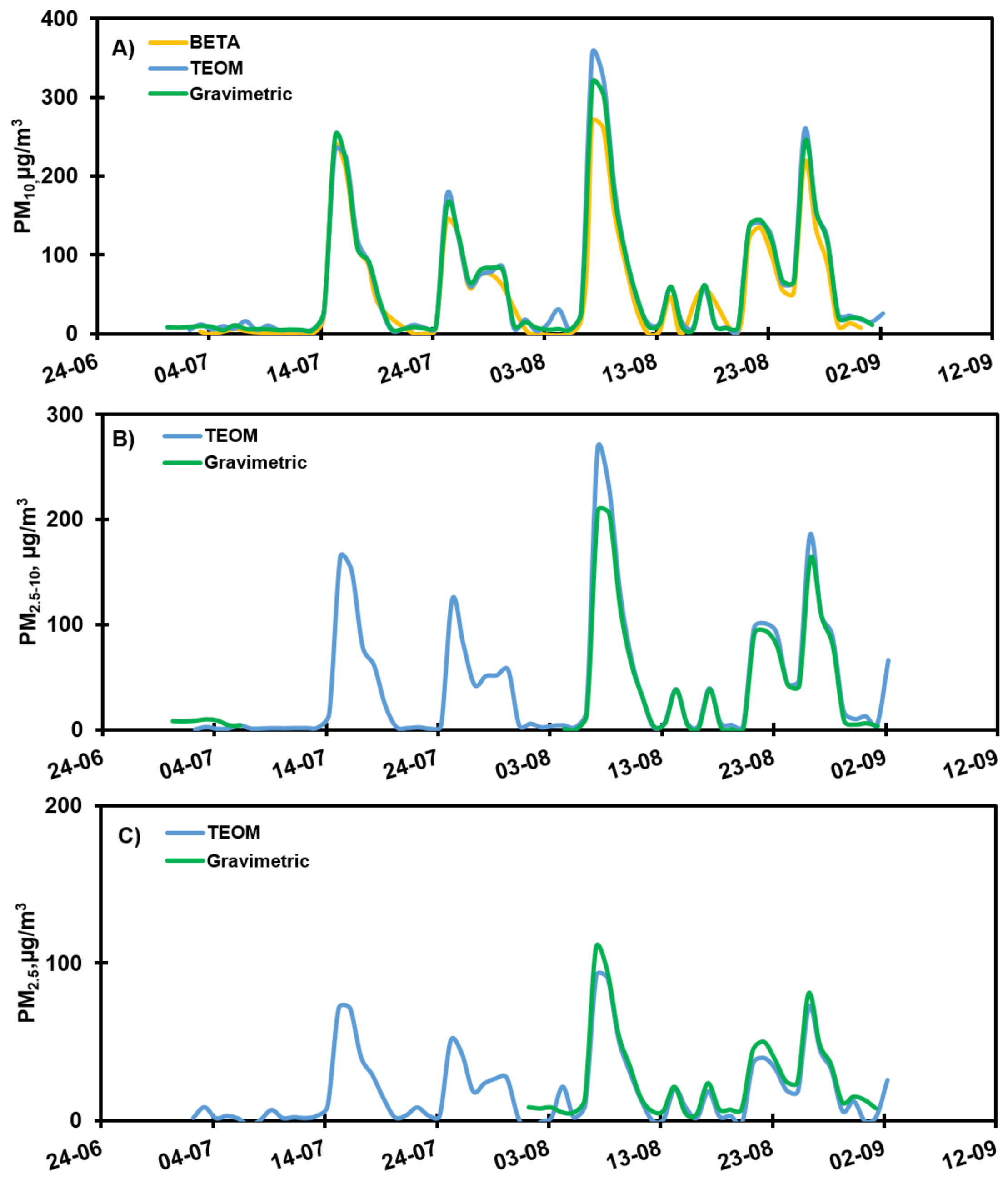

Figure 3. A) PM_{10}, **B)** $PM_{2.5\text{-}10}$ and **C)** $PM_{2.5}$ nighttime (22:00-06:00 GMT) average for July and August 2017 measured by BETA, TEOM and high volume quartz filters sampler.

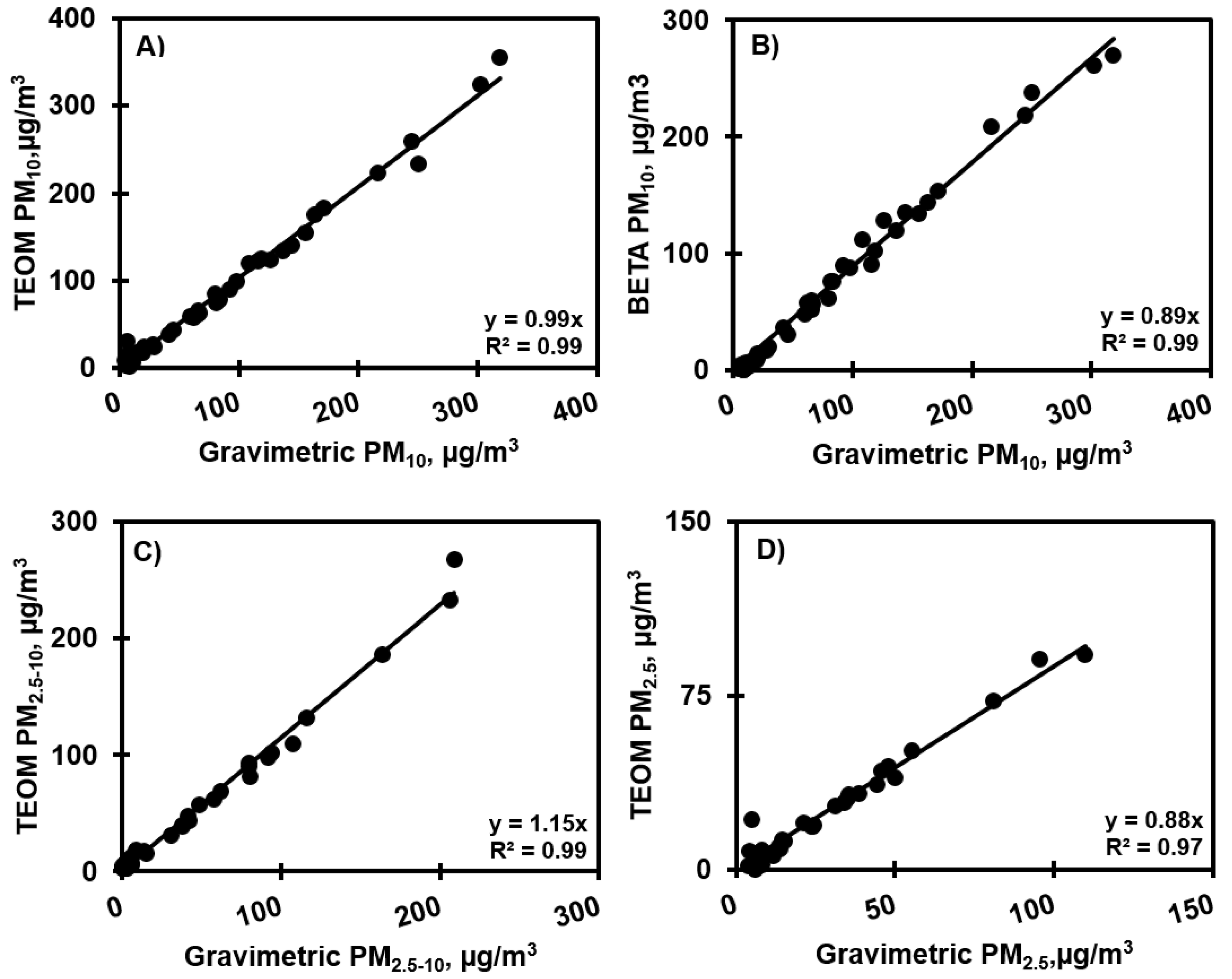

Figure 4. Plot of: **A)** high volume sampler PM_{10} versus TEOM PM_{10} (n=63), **B)** high volume sampler PM_{10} versus BETA PM_{10} (n=48), **C)** high volume sampler $PM_{2.5\text{-}10}$ versus TEOM $PM_{2.5\text{-}10}$ (n=36), **D)** high volume sampler $PM_{2.5}$ versus TEOM $PM_{2.5}$ (n=39).

Fig. 4 shows the scatter plots of each PM_x metric measured with the automatic monitor versus the gravimetric reference method.

The response of both automatic PM_{10} monitors shows a high linearity with respect to the gravimetric method (r^2=0.99). The slope observed in the PM_{10} intercomparison for the TEOM (0.99) vs the gravimetric, is almost 1.0 (Fig. 4A). For the case of the BETA PM_{10} intercomparison, the slightly lower -than 1.0- observed slope (0.89) could be linked to the <mass attenuation coefficient> used by the instrument or the sampling efficiency of the inlet (Fig.4B).

A high linearity is also observed in the intercomparison of the TEOM vs gravimetric coarse and fine PM fractions, with r^2 = 0.99 and 0.97, respectively. However the slope differs with respect to 1, with a value of 1.15 (Fig.4C) and 0.88 (Fig.4D) for the coarse and fine fractions, respectively.

The fact that the difference - with respect to 1.0 - is higher in the fine (0.88) and coarse (0.15) than in the PM_{10} fraction (0.99), when comparing the TEOM vs gravimetric, is probably related to the efficiency of the used impactors at the cut-size diameter of 2.5µm. Size distribution of aerosols have usually a minimum at about 10µm and 1µm, and not at 2.5 µm. Because of this, slight variability in the efficiency curve of the impactors at 2.5µm have a higher impact in $PM_{2.5}$ and $PM_{2.5\text{-}10}$ than in PM_{10}.

Figure 5. Inlets of: high volume samplers (1), TEOM dichotomous 1405 FDMS (2) and BETA-Thermo 5014i (3).

4. Conclusion

The response of the automatic TEOM Dichotomous FDMS and BETA - Thermo 5014i vs gravimetric reference system was assessed into the dusty Saharan Air Layer, under dust concentrations reaching up to 350 µg/m³.

Both instruments showed a high linearity with respect to the gravimetric reference method.

The slope (s) of the TEOM vs manual gravimetric reference method shows a higher difference to 1.0 when measuring $PM_{2.5}$ (s=0.88) and $PM_{2.5\text{-}10}$ (s=1.15), than when measuring PM_{10} (s=0.99). This is probably related to the efficiency of the impactors at 2.5 µm.

These intercomparisons exercises are necessary for assessing consistency of long term records.

5. Acknowledgement

This study is part of the project AEROATLAN (CGL2015-66299-P), funded by the Ministry of Economy and Competitiveness of Spain and the European Regional Development Fund (ERDF).

6. Bibliography

- Engelstaedter, S., and R. Washington (2007). Atmospheric controls on the annual cycle of North African dust, J. Geophys. Res., 112, D03103,doi:10.1029/2006JD007195.
- Rodríguez, S., Y. González, E. Cuevas, R. Ramos, P. M. Romero, J. Abreu-Afonso and A. Redondas (2009). Atmospheric nanoparticle observations in the low free troposphere during upward orographic flows at Izaña Mountain Observatory, Atmos. Chem. Phys., 9, 6319–6335, doi:10.5194/acpd-9-10913-2009.