"Report on the Incidence of African dust intrusions at the Astronomical Observatories of the Canary Islands: characterization and temporal analysis."

Emilio Cuevas (ecuevas@inm.es; AEMET) and **José María Baldasano** (jose.baldasano@bsc.es; BSC-CNS) with contributions from **Sergio Rodríguez**, **Pedro Miguel Romero** and **Silvia Alonso-Perez** (AEMET), and from **Sara Basart** and **Carlos Pérez** (BSC-CNS)

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Summary

This report focuses on the incidence of the dust-loaded African air masses at the observatories of the Instituto de Astrofísica de Canarias: "the Observatorio del Teide" (OT), in Tenerife, and the "Observatorio del Roque de los Muchachos" (ORM), in La Palma. The study has been made using the high quality observations performed by the Izaña Atmospheric Research Center at the Izaña Atmospheric Observatory (IZO), located 1km distance from the OT, and the dust model simulations performed by the Earth Sciences Department of the Barcelona Supercomputing Center for these sites. Measurements of in-situ Total Suspended Particles (TSP) and PM10 data, as well as of Aerosol Optical Depth (AOD) performed at IZO, show an extremely clean air and pristine skies, only partially affected by some dust loaded African air mass intrusions in summer time (July-September). Long term simulations (1958-2006) of TSP for OT and RMO show that no positive trend has been detected since 1958, in good agreement with the in-situ observations of TSP (since 1987) and AOD (since 1992) at IZO-OT. All these results confirm no positive trend in the inter-annual variation of dust-loaded air masses over the IZO-OT and RMO scientific facilities. Model simulations shows a lower incidence of African air masses over ORM compared to OT, as it was expected by the geographical location of both observatories.

1. Background.

The Izaña Atmospheric Research Center (IARC) is part of the Planning, Strategy and Business Development Direction from the Meteorological State Agency of Spain (AEMET). The IARC, headed by Dr. Emilio Cuevas, manages the high altitude Izaña Atmospheric Observatory (IZO) in Tenerife Island (The Canary Islands), and the complementary background urban air quality research Observatory at Santa Cruz de Tenerife (SCO). The IARC's headquarters is in Santa Cruz de Tenerife (capital of Tenerife Island). The IARC conducts monitoring and research related to atmospheric constituents that are capable of forcing change in the climate of the Earth (greenhouse gases and aerosols), and may cause depletion of the global ozone layer, and those play key roles in air quality from local to global scale. The IARC is a Joint Research Unit (JRU) of the "Consejo Superior de Investigaciones Científicas" (CSIC), the National Research Council, through the Institute of Environmental Assessment and Water Research (IDAEA).

The IARC contributes to the World Meteorological Organization (WMO) Global Atmosphere Watch (GAW) system with the high altitude Izaña Atmospheric Observatory (IZO). The WMO GAW system was established in 1989 and has integrated a number of WMO research and monitoring activities in the field of atmospheric environment. The main objective of GAW is to provide data and other information on the chemical composition and related physical characteristics of the atmosphere and their trends, required to improve understanding of the behavior of the atmosphere and its interactions with the oceans and the biosphere. The data collected at the GAW monitoring stations are particularly essential to understand the relationship between changing atmospheric composition and changes of global and regional climate. IZO is also an observing site for the Network for the Detection of Atmospheric Composition Change (NDACC), former Network for the Detection the Stratospheric Change (NDSC). The NDACC is a set of high-quality remote-sounding research stations for observing and understanding the physical and chemical state of the stratosphere. Ozone and key ozone-related chemical compounds and parameters are targeted for measurement. The NDACC is a major component of the international upper atmosphere research effort and has been endorsed by national and international scientific agencies, including the International Ozone Commission, the United Nations Environment Programme (UNEP), and the WMO.

The Barcelona Supercomputing Center – Centro Nacional de Supercomputación (BSC-CNS) was created by the Ministry of Education and Science (Spanish Government), Generalitat de Catalunya (local Catalan Government) and Technical University of Catalonia (UPC) and was officially constituted in April 2005. BSC-CNS manages MareNostrum, one of the most powerful supercomputers in Europe (it has now 10240 processors with a final calculation capacity of 94.21 Teraflops), located at Barcelona. The mission of BSC-CNS is to investigate, develop and manage information technology in order to facilitate scientific progress. The organization of BSC has a main scientific structure divided into 3 Departments, which cover areas of: Computational Sciences, Life Sciences and Earth Sciences.

Earth Sciences Department of BSC (ES-BSC), lead by Dr. Jose M. Baldasano, coming from the Environmental Modelling Laboratory of the Technical University of Catalonia (LMA-UPC), is devoted to modelling and understanding the behaviour of the Earth System (ES), mainly focusing on climate and atmospheric processes. Its main topics of research are: high-resolution air quality forecasts modelling, meteorological modelling; global and regional mineral dust modelling; and global and regional climate modelling. Other research activities involve the diagnosis of the behaviour of the ES modelling codes in a supercomputer framework and the improvement of the parallel versions of atmospheric models. Also, develops research on atmospheric aerosol with a direct link to global and regional observations networks, like AERONET (supporting the Barcelona station) and EARLINET.

ES-BSC has extended knowledge in: natural and anthropogenic emissions, improvement of air quality modelling, transport and dispersion of pollutants in complex terrain, aerosol (optical properties and radiative effects) and feedback between meteorology and air pollution. Currently, the group maintains daily high-resolution operational air quality forecasts for Europe -12 km- and the Iberian Peninsula -4 km- (Caliope project funded by the Environment Spanish Ministry) and mineral dust forecasts for the Euro-Mediterranean region and East Asia.

Both groups constitute the core of the WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS WAS) Regional Center (RC) for Northern Africa, Middle East and Europe. The Regional Center is a Spanish consortium formed by the BSC-CNS and AEMET. The SDS-WAS mission is to enhance the ability of countries to deliver timely and quality sand and dust storm forecasts, observations, information and knowledge to users through an international partnership of research and operational communities. The Regional Node partners include Meteo-France, UK Met Office, ECMWF, LISA, LSCE, IFT, EUMETSAT, CNR, AERONET/PHOTONS, Tunisian Met Service, University of Athens, University of Tel Aviv, Egyptian Meteorological Agency, METU and National Meteorological and Hydrological Services in the region.

2. Results

2.1. In-situ particulate matter

PM10 is a notation used to describe particulate matter with an aerodynamic diameter of 10 microns or less. In our case the PM10 is basically constituted by mineral dust. PM10 particulate concentrations are monitored since 2002 at IZO (2400 m a.s.l.). The PM10 hourly-values frequency distribution at IZO for the 2002-2008 period is shown in Figure 1. In table 1 the percentile distribution of PM10 is indicated for the same period.

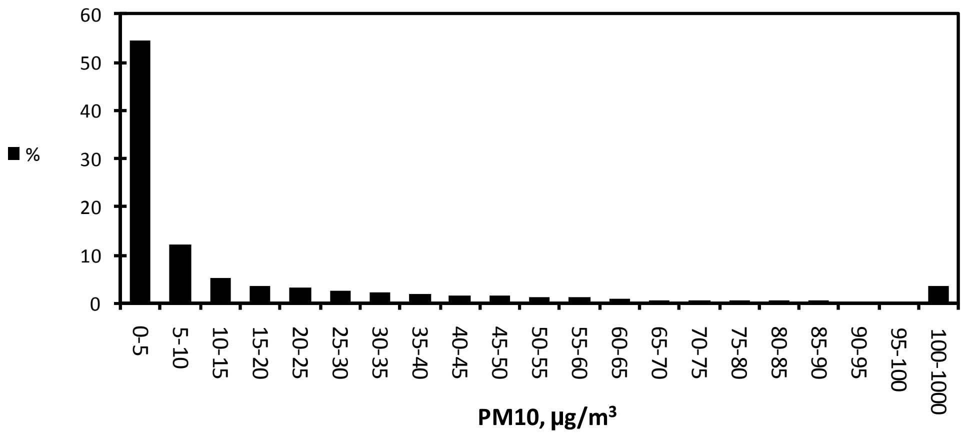

Figure 1; PM10 hourly-values frequency distribution at IZO (2400 m a.s.l.) for the 2002-2008 period.

percentile	PM10, µg/m^3
10	0.2
20	0.5
30	1.0
40	2.0
50	3.9
60	6.5
70	12.5
80	26.5
90	54.8
95	85.4

Table 1; Percentiles of PM10 hourly concentrations at IZO (Period: 2002-2008).

PM10 concentrations lower than 10µg/m3 correspond to extremely clean environment. For example, ambient PM10 mass averages ranged from 3.4-4.1µg/m3 at the remote and clean McMurdo Antarctic base (Mazzera, 2000). Around of 50% of hourly PM10 values at IZO are observed below this mean value. A 67% of the hourly records at IZO are lower than 10µg/m3. In figure 2 the seasonal variation of PM10 percentiles at IZO is shown. Monthly means of PM10 Percentile 75 are below 10µg/m3 through the year, except in summertime. Significant PM10 concentrations are observed only above the 80 percentile

(26µg/m³). PM10 concentrations above 36µg/m³ are recorded in 85 percentile due to the presence of dust-loaded Saharan air mass intrusions. These show a marked seasonal distribution being predominantly observed in summer time (July-September) (Chiapello et al., 1999). The very low PM10 concentrations at Izaña Observatory permit Studies of nanoparticles and nucleation processes in this Observatory (Rodríguez et al., 2009).

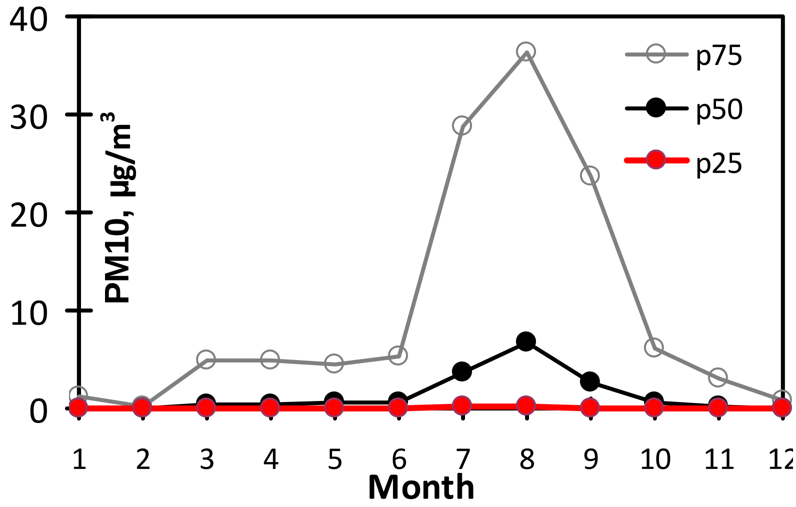

Figure 2; Seasonal variation of the 25th, 50th and 75th PM10 percentiles at IZO.

The longest record in the world of Total Suspended Particles (TSP) series in the free troposphere has been obtained at Izaña Observatory (see Figure 3). As the name suggests, TSP are all aerosol particles (sometimes even above 100 mm sizes) suspended in the air. A detailed analysis of the TSP series shows no trend in the period 1987-2008. So, we can confirm that the in-situ dust concentration at IZO has not increased in the last 21 years. It is worth to mention that in this period of time, dramatic changes in meteorological parameters (i.e. temperature increase) have been recorded worldwide. Concerning ORM, we estimate that PM10 and TSP records should be lower than at IZO. ORM is located at the same altitude than IZO but about 120 km to the Northwest. IZO is definitely more affected by Saharan dust intrusions than ORM.

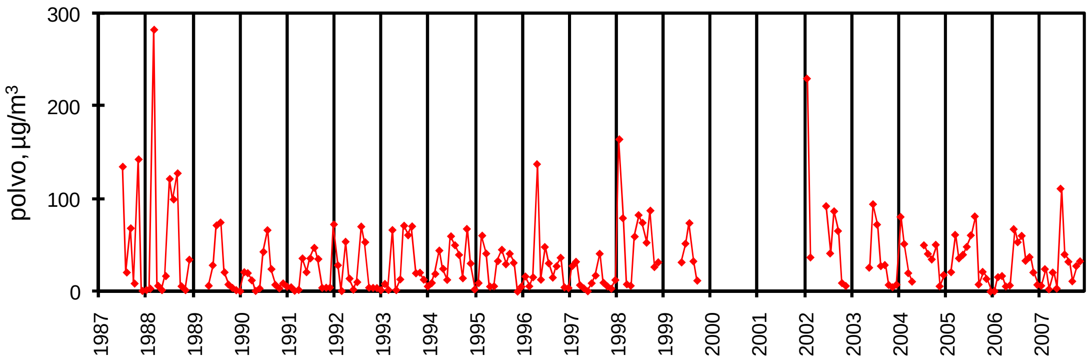

Figure 3; Monthly mean Total Suspended Particles (TSP) at IZO for the 1987-2008 period.

2.2. Aerosol Optical Depth (AOD)

Aerosol optical depth (AOD) is a quantitative measure of the extinction of solar radiation by aerosol scattering and absorption between the point of observation and the top of the atmosphere (direct sun measurements). It is a measure of the integrated columnar aerosol load and the single most important parameter for evaluating direct radiative forcing.

Figure 4; Histogram of Aerosol Optical Depth (AOD) at IZO for each month of the year for the 2002-2008 period. AOD<0.06 correspond to pristine skies.

The OAD is obtained at IZO with direct sun measurements using a Precision Filter Radiometer (PFR) from the World Radiation Center (WRC, Davos; Switzerland). It should be noted that IZO has been recently chosen to be the station where absolute calibrations for WRC-PFR reference instruments will be performed. In Figure 4 the histogram of Aerosol Optical Depth (AOD) at IZO (at 500 nm) for each month of the year for the 2002-2008 period. AOD<0.06 correspond to pristine skies with extremely low aerosol content in the atmospheric column. These conditions permit to obtain the extraterrestrial constants of the instruments. As it can be observed in Figure 4 an AOD<0.06 is recorded in, at least, 75% of the days through the year, except in summertime (July-September) when this percentage is reduced to 45%. It agrees quite well with the seasonal distribution of in-situ PM10. The impact on night-period observations is even lower since nights are short in summer, so the annual percentage of nocturnal observing period affected by dust-loaded episodes is very low. We have to add that we have reported AOD during light-time because our techniques use the sun as light source. However, during the night period the optical extinction is reduced due to the Katabatic regime (downward moving flows) typically observed at the high mountain sites with pronounced slopes, as it is the case for OT and ORM sites. Another outstanding result is that dust-loaded air mass intrusions are normally associated to middle clouds (5-6 km altitude). The astronomical observations are, in any case, prevented during these events by clouds, reason why the dust presence does not constitute, in many cases, an additional negative factor for the observation.

2.3. Simulated Total Suspended Particles (TSP)

Simulated TSP data series for Izaña Observatory (IZO) and El Roque de los Muchachos Observatory (ORM) have been obtained with the BSC-DREAM (Barcelona Supercomputing Center/Dust REgional Atmospheric Model) model (Nickovic et al., 2001). BSC-DREAM delivers operational dust forecast for North Africa, Middle East and Europe being verified that has been intensively tested and validated using available observational data (Perez et al., 2006; Perez et al., 2006b; Haustein et al., 2009). Data was taken from a 48-year reanalysis (1958-2006) at 0.3°×0.3° resolution (Perez et al., 2007).

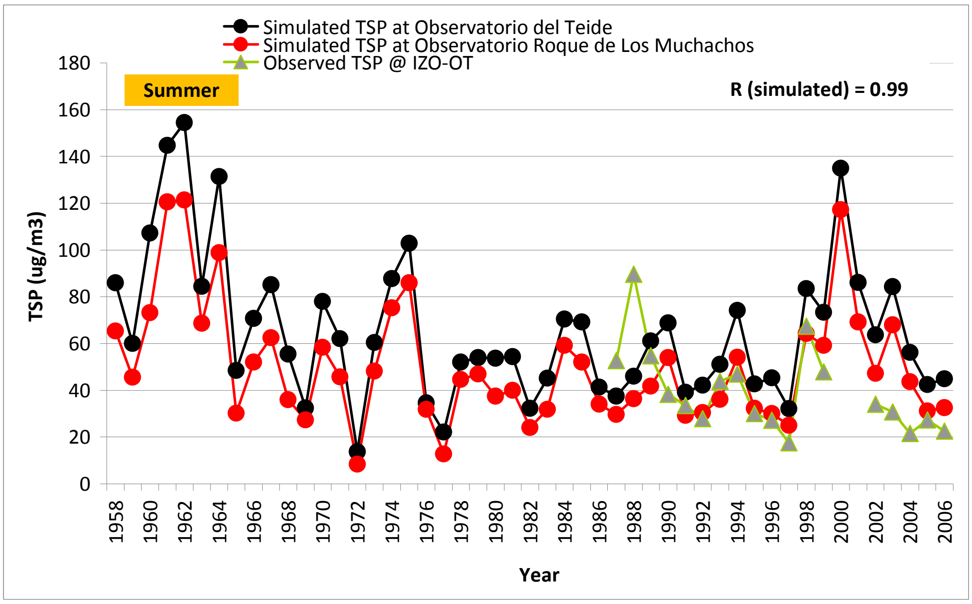

Figure 5; Annual averages of simulated TSP at OT and ORM, and observed TSP at IZO-OT for summer time (July-September) for the period 1958-2006.

In this simulation, meteorological fields were initialized every 24 hours and boundary conditions updated every 6 hours with the NCEP/NCAR reanalysis (2.5°x2.5° resolution). Observed TSP at IZO (1987-2006) has been used to validate the BSC-DREAM TSP simulations for this site showing a good agreement (see green triangles in Figure 5).

As it has been indicated in previous results obtained with PM10/TSP and OAD observations, only in summer the African air masses can affect some days the Izaña Observatory next to OT. The simulated TSP for OT and ORM (Figure 5) tell us that there is no positive trend in the African intrusions. In fact a higher impact of dust-loaded Saharan air masses in early sixties and an evident diminution in the frequency of African intrusions in the decade of 2000 is observed. Another outstanding result is the systematic lower TSP simulated values at the ORM compared to OT, as it is expected by their relative geographical situation.

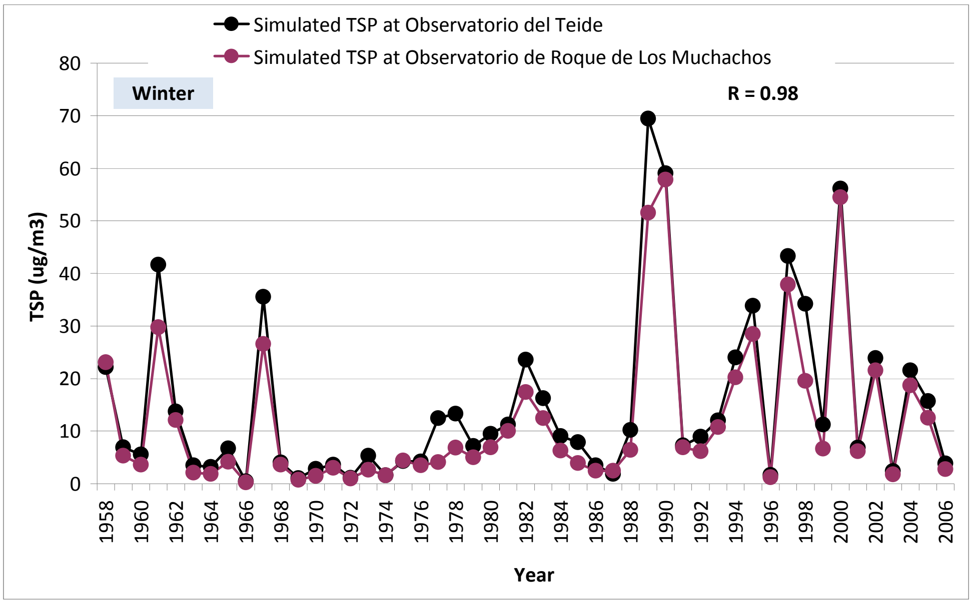

Figure 6; Annual averages of simulated TSP at OT and ORM for winter time (December-February) for the period 1958-2006.

In winter time, normally from January to March, African air masses can reach the Canary Islands, but they are confined to lower levels, within the marine boundary layer (Alonso-Pérez et al., 2007), and do not affect directly the OT and the ORM, or they do sporadically and not every year. As it can be observed in Figure 6 some peaks in monthly TSP means are recorded and grouped in short time periods. These peaks seem to be associated with changes in meteorological patterns at synoptic scale, and particularly with positive phases of the North Atlantic Oscillation (NAO) index (Pérez et al., 2007).

3. Conclusions

In-situ Total Suspended Particles (TSP), PM10 data, and Aerosol Optical Depth (AOD) observations performed at the Izaña Atmospheric Observatory (IZO), next to the Observatorio del Teide (OT), demonstrate that the site IZO-OT is characterized by extremely clean air and pristine skies. IZO-OT is sometimes affected by dust loaded African air mass intrusions in summer time (July-September). Since African air masses impact only in summer when nights are short, the annual percentage of nocturnal observing period affected by dust-loaded air mass episodes is very low. AOD in the night period is even lower than values presented in this report due to the katabatic flow that normally is well established during the night. The fact that under dust-loaded air mass intrusions, middle clouds are observed between 5 and 6 km altitude, minimizes the negative impact of these intrusions on astronomical observations performed at OT and ORM.

Long term simulations (1958-2006) of TSP for TO and for “Observatorio Roque los Muchachos” (ORM) show that no positive trends have been detected since 1958, in agreement with in-situ observations of TSP (since 1987) and AOD (since 1992). These results confirm no trend in the inter-annual variation of dust-loaded air mass intrusions over the TO and RMO. Model simulations estimate a lower incidence of African air masses over ORM compared to OT as it is expected by the geographical location of both observatories.

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