The 'WMO Sand and Dust Warning Advisory and Assessment System' Program

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Abstract — **Large amounts of sand and dust are continually lifted from bare, dry soils and transported through the atmosphere affecting regions hundreds to thousands of kilometers away. For countries in and downwind of arid regions, airborne sand and dust present serious risks to the environment, human health and economy. The World Meteorological Organization (WMO) has taken the lead with international partners to develop and implement a Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS). The program is organized around a Regional Center for Asia and a Regional Centre for Northern Africa, Middle East and Europe. The Regional Centre for Northern Africa, Middle East and Europe, set in Barcelona, is hosted by the Barcelona Supercomputing Center-Centro Nacional de Supercomputación (BSC-CNS) and the Meteorological State Agency from Spain (AEMET). Its first objective is to lead the development and implementation of a comprehensive system for mineral dust observation and forecast in the region, with special emphasis on extreme sand and dust events. The second objective of the Regional Centre is to facilitate user access to information. It manages a web-based portal for user access to value-added observational and forecast products as well as sources of basic information: in particular, the portal provides the National Meteorological and Hydrological Services with the necessary input to issue dust-related early warnings. The third objective is to build capacity of countries to use observations, analysis and forecasts provided by the WMO SDS-WAS programme.**

Keywords — **sand and dust, dust model, web portal, capacity building.**

I. Introducción

Large amounts of sand and dust are released every year from bare, dry soils into the atmosphere and transported downwind to regions located hundreds to thousands of kilometers away. The emission is produced by the combination of two physical processes: saltation - horizontal motion of particles in a turbulent layer and sandblasting - release of particles when the saltators impact the surface [Gomes et al., 1990]. The amount of mobilized dust depends on atmospheric and soil parameters, with wind speed, atmospheric stability, surface roughness, soil texture and moisture, and vegetation among them. The released particles present regionally specific mineralogical, chemical, physical, and optical properties [Schepanski et al., 2009].

Airborne dust represents a significant threat to the environment, property and human health. First, dust storms cause soil loss and damage to crop plants, thereby reducing agricultural productivity [Sivakumar, 2005]. Then, when suspended in the atmosphere, dust particulate plays an important role in different aspects of the climate system, such as radiation budget [Tegen and Fung, 1994], cloud microphysics [Lohmann, 2002] or atmospheric chemistry [Dentener et al, 1996]. It has negative impact on human health, causing respiratory and cardio-vascular problems, eye infections and, in some regions, diseases such as meningitis and valley fever [Griffin and Kellogg, 2004]. In Europe, far from the source regions, a significant fraction of the dust mass consists of particles less than 2.5 μm diameter that can readily penetrate the respiratory system and be deposited in the lungs. Epidemiological studies have shown that high concentrations of such particles are associated with increased death rates and respiratory-related hospital admissions [Pope, 2000]. The impact of mineral dust on the economy is mainly related to reduced visibility, affecting aircraft and road transportation, and polluted air, affecting semiconductor industry or solar power plants.

Finally, when deposited onto soil or ocean surfaces, mineral dust can have beneficial effects on certain ecosystems, such as Central and South American rain forests, which get most of their mineral nutrients from the Sahara, and iron-poor ocean regions, which get this metal and allow increased biomass growth [Prospero, 1996].

II. The WMO SDS-WAS programme

The World Meteorological Organization (WMO) has taken the lead to develop and implement a Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS): (http://www.wmo.int/sdswas). The mission of the WMO SDS-WAS programme 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 institutions. The main objectives are to identify and

improve SDS products through consultation with research, operational and user communities, to provide users with access to forecasts, observations and information, and to build capacity of countries to utilize SDS observations, forecasts and analysis products

The Regional Center for Northern Africa, Middle East and Europe, hosted by Spain, is managed by a consortium that includes the Spanish State Meteorological Agency (AEMET) and the Barcelona Supercomputing Center - Centro Nacional de Supercomputación (BSC-CNS). It develops and maintains a web-based portal (http://sds-was.aemet.es) for user access to value-added observational and forecast products as well as sources of basic information and research materials. The portal provides the National Meteorological and Hydrological Services with the necessary input to issue dust-related warnings.

A. The observational system

A comprehensive observational network is fundamental to any mineral dust forecasting and early warning system for real-time monitoring, validation and verification of numerical prediction models and eventual data assimilation schemes. The main data sources are in-situ measurements from air-quality stations, aerosol optical depth (AOD) and derived products retrieved from ground-based sun-photometer measurements, vertical profiles from lidar systems, and satellite products. The description of the observing system is mostly illustrated with examples from the dust outbreak over Western Europe and Eastern mid-latitude Atlantic recorded in April 2011.

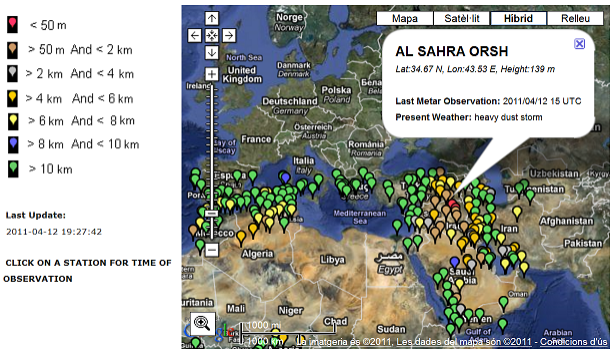

Fig. 1 Low visibility observed during the dust event of April 12, 2011 in the Middle East

In-situ measurements of particulate matter concentration are common in Europe, but very scarce, intermittent and rarely near-real-time available close of the main source regions. Indirect, qualitative, real-time information can be found in weather reports produced in synoptic stations and airfields. The program's web portal displays visibility and present weather from a large number of stations in South Europe, Northern Africa and Middle East. Figure 1 shows visibility reduction in Middle East stations during the dust outbreak of April 12, 2011. This event is shown instead of the mentioned outbreak over Western Europe, where dust travelled in an elevated layer and did not substantially reduce the horizontal visibility near ground.

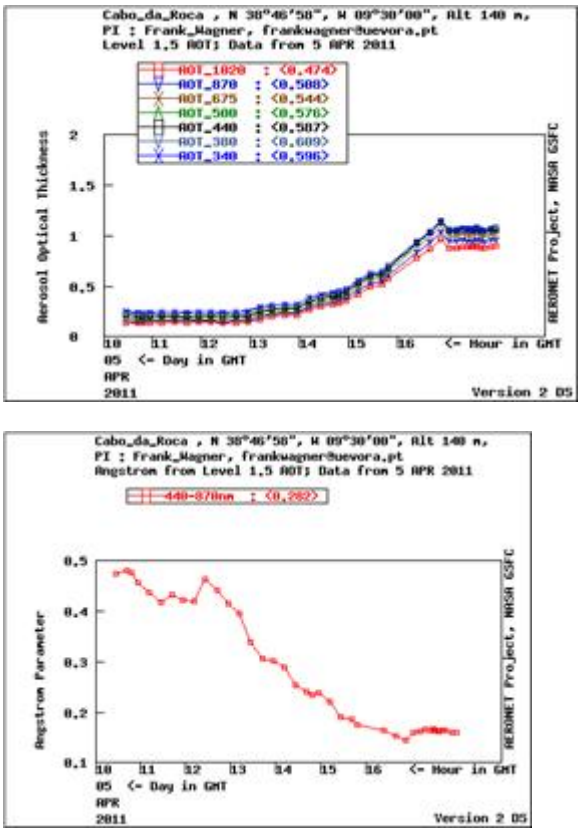

Fig. 2 Aerosol optical depth (up) and 440-870 Angström exponent (down) recorded on April 5, 2011 at the Cabo da Roca station (Portugal), managed by the University of Evora.

Ground-based aerosol remote sensing does not provide global coverage; however, its numerous spectral measurements of solar radiation are well suited to reliably and continuously derive aerosol optical properties. AERONET (AErosol RObotic NETwork) is a federation of ground-based remote sensing aerosol networks that provides observations of spectral AOD and inversion products in geographically diverse aerosol regimes. Aerosol speciation can

be done from the spectral variations of the AOD [Gobbi et al., 2007]. Figure 2.shows a progressive increase of AOD and decrease of 440-870 nm-Angström exponent (AE) indicating the dust outbreak in Cabo da Roca, Portugal, on April 5, 2011.

Active remote sensing using lidar systems allows vertically-resolved observation of dust layers (depths, layer base and top heights, mixing state, optical properties). Moreover, advanced devices such as multiwavelength Raman-polarization lidars can be employed so that aging and mixing of the dust during long-range transport can be studied in large detail based on measured time series of backscatter and extinction-related Angström exponents, depolarization ratio, and lidar ratio in the dust layers. Figure 3 shows an elevated dust layer observed in Granada, south Spain, on April 7, 2011. The European Aerosol Research Lidar Network (EARLINET) and the Micro Pulse Lidar Network cover the European territory with sites that are typically 500-1000 km apart from neighbor stations, but none of these devices have been deployed close to the dust sources. This shortcoming could be resolved in the future by the new generation of ceilometers, more robust, fully automated and less expensive than current lidars. They can provide vertical profiles of backscattering.

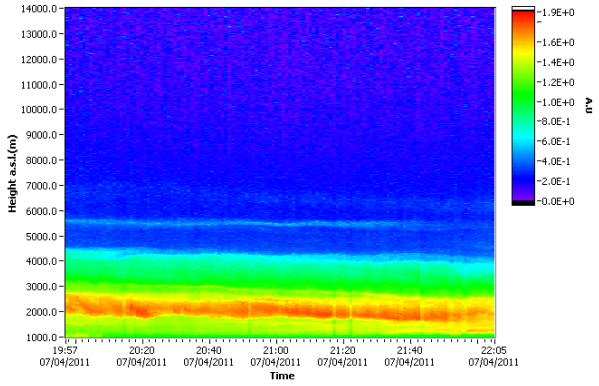

Fig. 3 532 nm corrected backscatter signal on 7 April 2011 in Granada (source: Universidad de Granada)

The SEVIRI instrument onboard the MSG satellites allows generation of RGB products that offer a qualitative detection of dust clouds with good spatial and time resolution and excellent and permanent coverage of the SDS-WAS RC geographical domain. Figure 4 shows the dust cloud (pink color) on April 7, 2011 at 00:00. Furthermore, efforts of different teams aimed to develop a quantitative product for the estimation of the aerosol total-column optical depth yield promising results.

Products derived from instruments such as MODIS (Figure 5), SeaWifs, OMI, AVHRR or CALIPSO onboard polar satellites and, therefore, with a lower time resolution and without permanent coverage, may help to estimate horizontal and vertical distribution, species differentiation, size distribution and optical properties of aerosols.

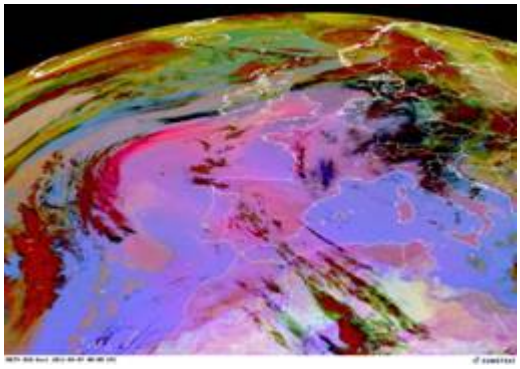

Fig. 4 EUMETSAT MSG RGB-dust picture of 7 April 2011 00:00

Fig. 5 MODIS true color image of 7 April 18:00

A weak point of the observational system is the lack of information from the dust source regions. For this reason, an objective of the WMO SDS-WAS programme is the development of observational capacity of countries in which such source regions are located. The 'Sand and Dust Storm Early Warning System in the Magreb Region' is a project funded by the Spanish Agency for International Coopera-

tion for Development' and managed by AEMET that will reinforce the ground-based observations of atmospheric aerosols in Northern Africa. The main goal of the project is to establish a network of sun photometers for detecting and monitoring sand and dust storms. Two of the instruments are already in operation, in Tamanrasset, Algeria, and in Cairo, Egypt. The project also includes a technical seminar, to be held at the Izaña GAW station, in the Canary Islands, to explain the scientific and technical goals, as well as operational and instrumental details of the project.

B. Dust forecasting models

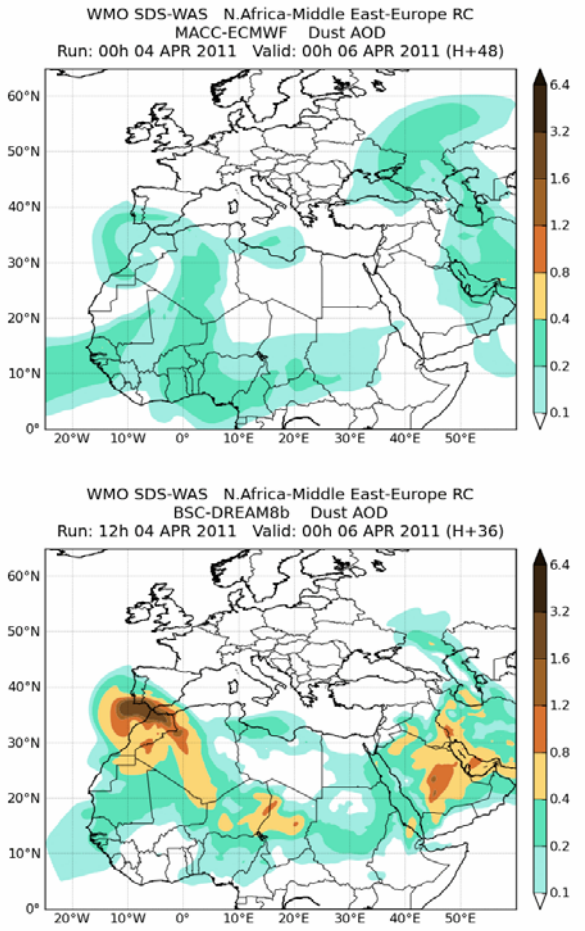

Fig. 6 Dust AOD forecast for 00:00 April 6, 2011 by the BSC-DREAM8b and MACC-ECMWF models run on April 4, 2011.

Operational and research, global and limited-area, the web portal contains links to different model systems used to simulate the production, transport and deposition of atmospheric mineral dust: BSC-DREAM8b, MACC-ECMWF, INCA-LMDzt, MOCAGE, CHIMERE, SKIRON, TAU/DREAM-8b and NAAPS.

The exchange of forecast model products is recognized as a core part of the Implementation Plan of the SDS-WAS programme and the basis for joint near real-time verification activities. At present, outputs from BSC-DREAM8b, MACC-ECMWF and INCA-LMDzt are centralized at the Regional Center and drawn for the reference area using a common color palette. Figure 6 shows dust AOD forecast by BSC-DREAM8b and MACC-ECMWF for 00:00 April 6, 2011. Both models correctly predict the dust outbreak, although with different intensity.

10-day and monthly-averaged values of dust-related variables computed from model outputs are routinely produced and distributed (Figure 7). These products were initially designed in support of the Health and Climate unit of the African Centre of Meteorological Applications for Development (ACMAD).

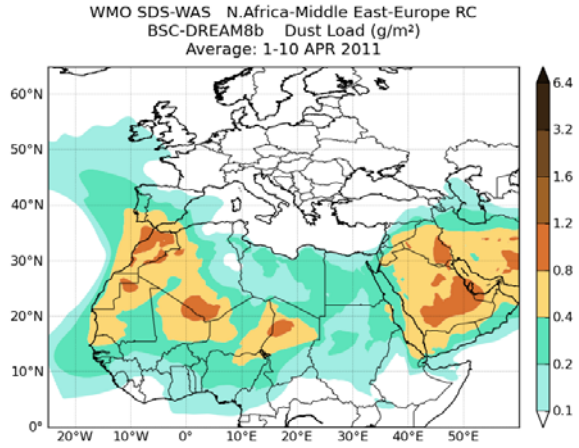

Fig. 7 Averaged dust load (μg.m^{-3}) for 1-10 April 2011 computed from BSC-DREAM8b outputs.

Future plans include, first, resample model outputs to common grid-points in order to generate median multi-model products, and then, to set a common validation and verification scheme for the different models.

C. Product dissemination

The web portal constitutes the basic tool for distributing dust-related products among the sand and dust community. It contains real-time and archived observational and forecasting products, as well as pieces of information, which may be relevant to research and operational institutions (i. e. case studies or information on dust-related meetings and

conferences) as well as to the end users (i. e. training materials and events)

Nevertheless, Internet connections in Africa are scarce and low quality. To overcome this problem, the WMO SDS-WAS Regional Center negotiates with EUMETSAT the inclusion of dust-related products in the EUMETCast transmissions for Africa. EUMETCast is a broadcast system for environmental data that uses commercial television satellites. The products to be disseminated would be dust model outputs, eventual multi-model composite forecasts and observational products, especially the EUMETSAT RGB-dust product.

D. Capacity building activities

AEMET, BSC-CNS, EUMETSAT and WMO jointly organized and funded a training course for African and Middle-Eastern meteorologists: 'Training Course on Satellite Meteorology and Atmospheric Sand and Dust'. It was held between 8 and 19 November 2010 at the BSC-CNS, in Barcelona. It consisted of a 'Training Week on Satellite Meteorology' and a 'Training Week on WMO SDS-WAS products'. The last one was a hands-on event, specifically designed to train meteorologists in the use of dust-related observational and forecasting products.

A similar training course is expected to take place in Antalya, Turkey, in November 2011 in cooperation with the Turkish State Meteorological Service.

III. References

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