Warning Advisory System for Sand and Dust Storm in West Africa: Concept Note

Background

Sand and dust storms constitute common meteorological hazards in desert regions and usually occur when strong winds drag large amounts of sand and dust from bare and dry soils into the atmosphere. In the last decade, scientists have realized the impacts of these storms on climate, human health, environment and many other socio-economic sectors, thus, it is essential to study this phenomenon for the development of products to guide preparation, adaptation and mitigation policies.

Airborne dust presents serious risks for human health. Particles larger than 10 μm are not breathable, so that they can only damage external organs – mostly causing skin and eye irritation, conjunctivitis and enhanced susceptibility to ocular infection. However, inhalable particles, those smaller than 10 μm, often get trapped in the nose, mouth and upper respiratory tract, so that they can provoke respiratory disorders such as asthma, tracheitis, pneumonia, allergic rhinitis and sillicosis. Moreover, finer particles may penetrate the lower respiratory tract and enter the bloodstream, where they can affect all internal organs and be responsible for cardiovascular disorders.

Some infectious diseases have also been associated with airborne dust. Meningococcal meningitis, a bacterial infection of the thin tissue layer that surrounds the brain and spinal cord, can result in brain damage and, if untreated, death in 50% of cases. Outbreaks occur worldwide, yet the highest incidence is found in the “meningitis belt”, a part of sub-Saharan Africa extending from Senegal to Ethiopia. These outbreaks have a strong seasonal pattern – many studies have linked environmental conditions, such as low humidity and dusty conditions, to the time and place of infections. Researchers believe that inhalation of dust particles in hot dry weather may damage nose and throat mucosa creating favourable conditions for bacterial infection.

Airborne dust has also many negative impacts on other sectors: safety of the air transport, production of solar energy, agriculture (including reducing crop yields by burying seedlings, causing loss of plant tissue, reducing photosynthetic activity and increasing soil erosion), etc. Indirect dust deposit impacts include filling irrigation canals, covering transportation routes and affecting river and stream water quality.

Being aware of this, the United Nations General Assembly, through its resolution 72/225, invited the Executive Director of the United Nations Environment Programme, to consider initiating an inter-agency process involving relevant entities of the United Nations system, to prepare a global response to sand and dust storms. In response to that, in September 2018, has been agreed to form a Coalition to Combat Sand and Dust Storms (SDS), including UN agencies and other non-UN organizations and research institutes, to strengthen coordinated action on SDS, highlighting the need to address SDS in both source and destination countries. This coalition includes UN Environment Management Group (UN EMG), International Civil Aviation Organization, UN-Habitat, United Nations Economic and Social Commission for Asia and the Pacific, United Nations Economic Commission for Europe, World Meteorological Organization (WMO), World Health Organization, UN Development Programme, World Bank, International Union for Conservation of Nature, UN Food and Agriculture Organization, United Nations Institute for Training and Research and International Telecommunication Union.

The Sahara is the major source on Earth of mineral dust, accounting for about half of the dust particles emitted globally into the atmosphere. Especially in winter and spring, a large amount of such particles are transported southwards by trade winds, known as Harmattan, affecting mainly the Sahel, but sometimes also regions bordering the Gulf of Guinea.

In 2007, owing the societal needs for monitoring and forecasting dust events, and for assessing and mitigating their negative impacts, WMO launched the Sand and Dust Storm - Warning Advisory and Assessment System (SDS-WAS) with the mission 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.

In 2013, in view of the demand of many National Meteorological and Hydrological Services (NMHSs) and the good results obtained by the SDS-WAS, which prove the feasibility and the need to begin developing operational services beyond the scope of R&D, the WMO Executive Council designated the consortium formed by the State Meteorological Agency of Spain (AEMET) and the Barcelona Supercomputing Center – Centro Nacional de Supercomputación (BSC-CNS) to create in Barcelona the first Regional Specialized Meteorological Center with activity specialization on Atmospheric Sand and Dust Forecast (RSMC-ASDF). The Center began operating in February 2014 with the name of Barcelona Dust Forecast Center[1]. It generates and distributes dust predictions for Northern Africa (north of equator), Middle East and Europe.

Early Warning Systems (EWS) are well recognized as critical life-saving tools for floods, droughts, storms, bush-fires, and other hazards. The recorded economic losses linked to extreme hydro-meteorological events have increased nearly 50 times over the past five decades, but the global loss of life has decreased significantly, by a factor of about 10, thus saving millions of lives over this period. This has been attributed to better monitoring and forecasting of hydro-meteorological hazards and more effective emergency preparedness.

Since October 2018, AEMET and the BSC-CNS, in collaboration with the Burkina Faso National Meteorological Agency (ANAM), operate a Warning Advisory System (WAS) for sand and dust storm for the thirteen regions in which Burkina Faso is administratively divided (Terradellas et al., 2018). The warning advisory products are released by the WMO SDS-WAS Regional Center for Northern Africa, Middle East and Europe and distributed on its website[2] and through email.

1 https://dust.aemet.es

2 https://sds-was.aemet.es/

Figure 1: Map of West Africa

West Africa, as the westernmost region of Africa, it has been defined as including 16 countries: Benin, Burkina Faso, Cape Verde, The Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo, but for the purpose of this document Chad, Cameroon and Central African Republic are also included (Figure 1). West Africa (from now on including Chad, Cameroon and Central African Republic) covers an area of about 7,000,000 square kilometres and its population is estimated at about 450 million people (Source: Worldometers from latest United Nations estimates).

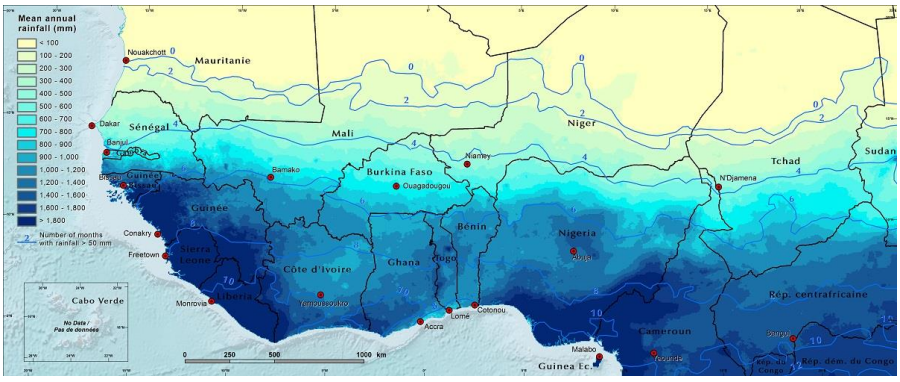

Figure 2: Mean annual rainfal 1981-2014 with number of months of 50 mm or more of rainfall (Cotillon and Tappan, 2016)

It is known that the Sahara Desert produces about half of the global dust emission (Tanaka and Chiba, 2006), which is estimated in the range of 1,000-3,000 Tg/year (Engelstaedter et al., 2006). In winter, the areas of most frequent dust emission are located in the Bodélé Depression, in Western Chad, and in the western foothills of the Aïr Mountains, in Niger. Then, the northeast trade winds (Harmattan), which are very common here during this season, transport the dust to lower latitudes, reaching the coast of the Gulf of Guinea. In spring and summer, dust emission is much more frequent and dust events more intense, but they do not reach such low latitudes. The main sources are again the Aïr Mountains basin, the Adrar Plateau in Mauritania and the endorheic basins, sometimes splashed with salt flats, of central and southern Algeria (Schepanski et al., 2007; Laurent et al., 2008).

Country	First-level administrative divisions
Benin	12 departments
Burkina Faso	**13 regions**
Cabo Verde	**2 historical (not administrative) regions**
Chad	**23 regions**
Cameroon	10 semi-autonomous regions
The Gambia	5 regions + 1 city
Ghana	10 regions
Guinea	7 regions
Guinea Bissau	8 regions + 1 autonomous sector
Ivory Coast	14 districts
Liberia	15 counties
Mali	**10 regions + 1 capital district**
Mauritania	**13 regions**
Niger	**7 regions + 1 capital district**
Nigeria	36 states + 1 federal capital territory
Central African Republic	16 administrative prefectures
Senegal	**14 regions**
Sierra Leone	4 provinces + 1 Western Area
Togo	5 regions

Table 1: First level administrative divisions of West African countries (including Chad, Cameroon and Cameroon and Central African Republic)
Cabo Verde, Senegal, Mauritania, Mali, Niger and Chad**: countries to implement the dust WAS along with **Burkina Faso in this first phase of the project

Since all the countries of the region, with greater or lesser frequency and intensity, are affected by the dust hazard, and the Burkina Faso system has been received positively, it is proposed to implement a Warning Advisory System (WAS) for airborne dust at the first-level administrative subdivisions of the West African countries (Table 1). In those cases in which the extension of the administrative entities is very small in relation to the model resolution, they will be grouped in larger clusters. The core of the system would be a universally understood product based on colour-coded maps

The objective is to daily release two maps for each country with the status of the dust warning advices for today and for tomorrow in each region (or alternative administrative division). This clear, concise information would help plan any activity vulnerable to airborne dust or activate services and procedures aimed at mitigating the hazards lurking agriculture, public health or any other vulnerable sector. Thus, each region in West Africa will be colour-coded on the map to represent one out of four warning advisory levels: red to indicate that an extremely high concentration of airborne dust is expected, down through orange and yellow to green, indicating that dusty weather is not expected.

Design and implementation of a Warning Advisory System (WAS) for airborne dust

The warning advisory levels will be based on the multi-model median forecast produced by the SDS-WAS Regional Center for Northern Africa, Middle East and Europe[3] that is described in Terradellas et al. (2018). The warning advisory level for each region will be set according to the highest concentration value expected for the given day at any model grid-point within the region.

Then, the warning advisory thresholds will be set following a percentile-based approach, so that they may be higher for the northern regions more prone to high dust concentrations, than for the southern ones, where heavy dust events are not so frequent. This approach is common in existing EWSs, such as Meteoalarm[4], implemented by Europe's NMHSs to provide advice for outstanding weather.

In order to set those thresholds for each region, time series of daily maximum concentration (considering all the grid points within the region and tri-hourly forecasts) predicted by the SDS-WAS multi-model median during 2013-2020 will be built at first. Once all the series are ready, their values will be ranked and the percentiles defining the warning thresholds will be computed. Unless for any reason it is decided to adopt a different threshold for a specific region or area, the 80th percentile will be the threshold for high concentration (yellow colour), the 90th percentile for very high concentration (orange) and the 97.5th percentile for extremely high concentration (red).

In the phase of operation, once the SDS-WAS multi-model median is available, the warning advisory levels for the 204 administrative divisions and for D + 1 and D + 2 will be computed. Afterwards, two maps will be generated for each country. In them, each region will be coloured according to the corresponding warning advisory level. Those maps will be posted on the SDS-WAS Regional Center's website and sent by email to predefined distribution lists.

The WAS will comprise:

1. Analysis of the forecasts issued by the SDS-WAS median since 2016 to 2020 for the different regions of West Africa aimed at establishing the warning advisory thresholds. Although, as a general rule, thresholds will be set at the 80, 90 and 97.5 percentiles, the peculiarities of the statistical distribution of dust events or the specific needs of a NMHS may suggest using different values for a given region or country. Once this phase is completed, a document describing the entire process and including the proposed threshold values will be delivered. Also, if appropriate, the document could include alternative values whose implementation could be studied during the next phase.

2. Design and implementation of the map generation in the model's operative chain and visualization on the SDS-WAS website. This phase will overlap as much as possible with the previous one. Once completed this phase, a document describing the entire system will be delivered.

3. Daily publication of the warning advisory maps on the SDS-WAS website. Every day, the maps with the warning levels in the different regions for today and tomorrow will be available. Warning advisory maps released the previous days will also be available on the website in order to facilitate evaluation of the WAS performance.

Validation of the system

To assess the performance of the whole system, it is essential the users feedback, especially in which concerns to the thresholds, and to have observational data to validate the model outputs. Furthermore

3 https://sds-was.aemet.es/forecast-products/dust-forecasts/ensemble-forecast

4 http://www.meteoalarm.eu/

PM measurements will allow us to offer a more realistic quantitative forecast of the dust surface concentration in a region with a lack of in-situ measurements.

Therefore, it is proposed to install a low-cost and no maintenance PM counter and provide a hand-held manual sunphotometer for each country in order to complement dust concentration data. The data from the sunphotometers will be recorded and transmitted by internet (*an application will be provided for this purpose)* at fixed hours (6, 12, 18 UTC) and it will required a meteorologist/technician to take the measurements. The PM counters will need Internet connection to send data every 10 min.

The following technical requirements for the instruments are needed:

Hand-held manual photometer:

- a meteorologist/technician to measure AOD manually 3 times a day (at agreed time)
- send data through internet to a server (application provided)

PM counter:

- Suitable installation site
- 45 cm diameter and 2 m high mast
- 220 V power/current
- Ethernet cable, router and network configuration: IP, subnet mask, DNS, gateway

This device does not have any maintenance. It would be necessary to check if data are been sending and the counter is functioning properly.
In order to provide an uninterrupted supply of electricity and consequently lost of measurements the PM sensor must be connected to a UPS.

It should be taken into account that it might not be possible to install PM sensors for reasons of security, location, local cooperation, etc.

Besides, a preliminary qualitative evaluation of the WAS performance will be carry out using SYNOPS and METARS reports, AERONET AOD measurements and other observational data if available.

Technical reports about the WAS evaluation and calibration of the instruments will be provided.

Training and workshops

Two kinds of on-line workshops will be organized aimed at Meteorological Services staff of the countries:

- on-line workshop on installation, management and operation of instrumentation.
- on-line workshop on interpretation of the WAS and its implementation in the daily work routine.

Partners

AEMET

The State Meteorological Agency of Spain (AEMET) aims at the development, implementation and delivery of state's weather services and at supporting the performance of other public policies and private activities, contributing to the safety of persons and property, and to the welfare and sustainable development of Spanish society. The Agency has the status of meteorological authority of the state, as well as aeronautical meteorological authority.

Traditionally, the National Meteorological Agency of Spain (AEMET) has also had a strong vocation for international development cooperation, even long before its Statute pointed it out among its competences. AEMET cooperation programs are participatory, proactive, aligned with the needs identified by their partners and by the World Meteorological Organization (WMO) and are regionally oriented. They focus mainly on Latin America, West Africa and the Greater Mediterranean Region, creating networks for development and focusing on capacity development.

BSC-CNS

The Barcelona Supercomputing Center – Centro Nacional de Supercomputacion (BSC-CNS), created in 2005, is the leading supercomputing centre in Spain. It is specialized in High-Performance Computing and its mission is twofold: to offer supercomputing facilities and services to Spanish and European scientists and to provide knowledge and technology to be transferred to society. The BSC hosts the MareNostrum Supercomputer, a Tier-0 PRACE system currently ranked as the #3 most powerful supercomputer in Europe (#13 in the world)

The Earth Sciences Department of the BSC-CNS was established with the objective of carrying out research in Earth system modelling and focuses its activity on emissions, air quality, mineral dust and global and regional climate modelling and prediction.

Since 2010 Spain hosts the Northern Africa-Middle East-Europe Regional Node of the Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS NA-ME-E Regional Centre), jointly managed by AEMET and the BSC-CNS. In 2014 the Barcelona Dust Forecast Centre (BDFC) has been established and is managed jointly by AEMET and BSC, being the first WMO regional meteorological specialized centre for atmospheric sand and dust forecast, providing operationally products to assist NMHSs in making their forecasts and warnings.

WMO/CREWS

The Climate Risk and Early Warning Systems (CREWS) Initiative aims to provide additional financing to Least Developed Countries (LDCs) and Small Islands Developing States (SIDS) that are most vulnerable to the impact of climate and weather extreme events to reduce vulnerability and strengthen resilience and adaptive capacity.
At the Third UN World Conference on Disaster Risk Reduction in March 2015, the Government of France announced a new initiative to mobilize the international community to support early warning systems in the most vulnerable LDCs and SIDS countries. The Government of France, in collaboration with the World Meteorological Organization, the UN Office for Disaster Risk Reduction and the World Bank/Global Facility for Disaster Risk and Recovery, announced the launch of the CREWS Initiative in Paris in December 2015 as part of the COP21 Solutions Agenda.
African countries participating in this phase: **Burkina Faso, Mali, Niger and Chad**

MAC-CLIMA/INTERREG

The objectives of the MAC-CLIMA project is to promote the progressive creation of an institutional, scientific and social network among the countries of the cooperation area to work, in a coordinated manner, for the adaptation and mitigation of climate change.

The cooperation area is made up of the outermost regions of Madeira, Açores and the Canary Islands and the third geographically close countries that have accepted to participate in the Program: **Cape Verde, Senegal and Mauritania**.

In a framework of progressive increase of the Saharan desert, the mineral dust source for SDS, during the last centuries, the implementation of an SDS warning advisory system to help the countries of the cooperation area to cope with SDS impacts is aligned with the objectives of MAC-CLIMA project.

WEST AFRICA NMHS (including Chad, Cameroon and Cameroon and Central African Republic)

Country	NMHS
Benin	Agence Nationale de la Meteorologie
Burkina Faso	Agence Nationale de la Météorologie du Burkina Faso
Cape Verde	Cabo Verde National Institute for Meteorology and Geophysics
Chad	Direction Generale de la Meteorologie Nationale
Cameroon	Direction de la Météorologie Nationale
The Gambia	Department of Water Resources
Ghana	Ghana Meteorological agency
Guinea	Directorate of Meteorology
Guinea Bissau	National Institute of Meteorology of Guinea-Bissau
Ivory Coast	Société d'Exploitation et de Développement Aéroportuaire, Aéronautique et Météorologique
Liberia	Liberia Meteorological Service
Mali	Agence Nationale de la Meteorologie
Mauritania	Office National de la Météorologie
Niger	Direction de la Meteorologie Nationale
Nigeria	Nigerian Meteorological Agency
Central African Republic	Direction de la Météorologie
Senegal	Meteorological Branch
Sierra Leone	Sierra Leone Meteorological Agency
Togo	General Direction of Meteorological National Office

Table 2: NMHSs involved in the present initiative

The system will be jointly developed, implemented, operated and maintained by the State Meteorological Agency of Spain (AEMET) and the Barcelona Supercomputing Center (BSC), in close coordination with the NMHSs of the involved countries (Table 2). The warning advisory products will be released by the WMO SDS-WAS Regional Center for Northern Africa, Middle East and Europe. It will be sought that the African Centre of Meteorological Applications for Development (ACMAD) also has an active participation. In fact, ACMAD is already collaborating with AEMET and the BSC in the framework of SDS-WAS.

References

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5 https://sds-was.aemet.es/materials/technical-reports/SDSWASNAMEE2018001.pdf