Intense Saharan Dust Outbreak over the Iberian Peninsula in springtime 2021: Monitoring and Characterization of Transported Dust Particles

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Introduction

Dust particles play an important role in the frame of Earth's radiative budget and climate forcing, also affected by their interaction with clouds by acting as cloud condensation nuclei (CCN) and ice nucleating particles (INP). The retrieval of their vertically-resolved optical and microphysical properties is crucial to evaluate the aerosol radiative impact in the atmosphere (i.e., Córdoba-Jabonero et al., 2021).

In spring 2021 an intense Saharan dust outbreak reached the Iberian Peninsula (IP), lasting from 26 March until 5 April. It was monitored at six lidar stations, belonging to either MPLNET or ACTRIS/EARLINET networks, covering thus almost all the IP extension. Polarized Micro-Pulse Lidar measurements were carried out at El Arenosillo/Huelva (ARN, Spain; 37.1ºN, 6.7ºW, 40 m a.s.l.), Torrejón de Ardoz (TRJ, Spain; 40.5º N, 3.5º W, 568 m a.s.l, which is not within MPLNET yet), and Barcelona (BCN, Spain; 41.4ºN, 2.1ºE, 125 m a.s.l.); and multi-wavelength Raman lidars measurements were performed at Granada (GRA, Spain; 37.1ºN, 3.6ºW, 680 m a.s.l.), Évora (EVO, Portugal; 38.6ºN, 7.9º W, 293 m a.s.l.), and Madrid (MAD, Spain; 40.5ºN, 3.7ºW, 680 m a.s.l.).

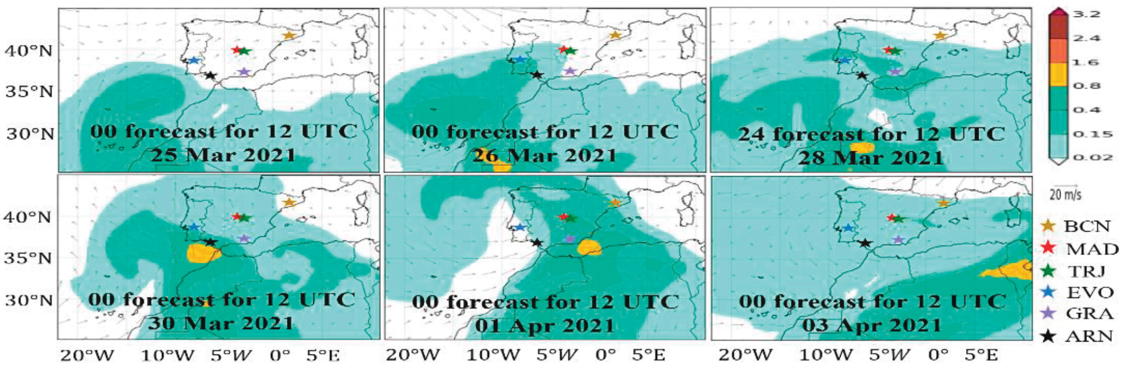

Figure 1. BSC-DREAM8b forecast images. Dust optical depth at 550 nm and 700 hPa wind field for the Saharan dust outbreak (25 March to 3 April 2021) over the IP. The six lidar stations are marked by coloured stars (see the legend).

Both particle backscatter coefficient (β_P) and particle linear depolarization ratio (δ_P) profiles at 532 nm are retrieved for all the stations under cloud-free conditions. The optical properties (backscatter and extinction coefficients at 532 nm) for both the fine (Df) and coarse (Dc) dust components are separately derived by applying the POLIPHON (POlarisation LIdar PHOtometer Networking; Mamouri and Ansmann, 2014) approach, using a lidar ratio (LR) of 55 sr and 50 sr for dust and non-dust particles, respectively. Additionally, the mass concentration profiles, the mass extinction efficiency and the height of the centre-of-mass for both fine and coarse-modes are also calculated for the overall period. Results are compared along with the evolution of the dust intrusion as it crosses the IP.

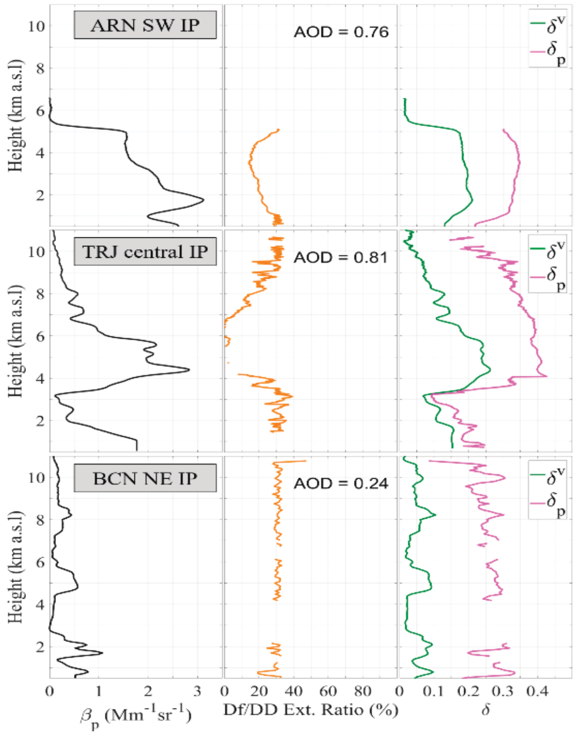

Figure 2. Vertical optical properties on 31 March at 04 UTC, as retrieved at (top) ARN, (middle) TRJ and (bottom) BCN: total β_p (black), Df/DD extinction ratio (orange), and δ^V (green) and δ_p (magenta). AERONET AOD values at 500 nm.

Results and discussion

The dust transport is analysed by combining BSC-DREAM8b and HYSPLIT modelling. Figure 1 illustrates a brief overview of the dust intrusion. The dust plume reached the South-west (SW) IP (ARN, EVO) on 26 March; a few hours later, arrived at the central IP (MAD, TRJ) and South-east (SE) IP (GRA). Finally, on 28 March, it arrived at North-east (NE) IP (BCN). The dust occurrence was below 6 km height at the southern stations, increasing the altitude as it moved northwards in the IP, reaching around 9 km height over BCN. This intense dust outbreak reached the highest incidence between 27 and 31 March, when AERONET aerosol optical depth (AOD) at 500 nm was higher than 1 at several times over the southern and central IP. The overall dust event was specially affected by the presence of clouds at altitudes just above or coincident with the dust layer, preventing the optical retrieval and generating gaps in the datasets.

In order to illustrate the dust progression from SW to NE IP, Figure 2 shows the vertical profiles of β_p, δ_p, and the volume linear depolarization ratio (δ^V) together with the Df-to-total dust (DD) extinction ratio for ARN (SW), TRJ (central) and BCN (NE) on 31 March at 04:00 UTC. β_p profiles show a vertical increase of the dust plume together with a decrease of the β_p values (and then also of dust extinction) along with the dust movement from ARN (SW IP) to BCN (NE IP). In addition, δ_p is slightly higher at ARN and TRJ with values greater than 0.3 (values of 0.4 are even found, which are rarely observed for dust, but they are within the error uncertainty in the δ_p retrieval), representing a dominance (even complete at particular layers) of coarse dust particles, whereas in BCN, δ_p is around or lower than 0.3 (fine dust contribution enhancement). Df/DD extinction ratio is height-varying at ARN and TRJ (0-35%), being almost constant (~ 30%) at BCN.

Challenges

The extreme incidence and duration of the dust outbreak provide a relevant study of dust ageing, finding a decrease of coarse dust particles during the transport of the dust plume along the Iberian Peninsula. The changes occurred in the dust optical properties due to ageing processes are expected to affect the radiative forcing. For a future work, we are interested in analysing the short-wave and long-wave radiative impact as induced by this extreme dust outbreak, as the first is modulated by the fine dust particles, and the second by the coarse dust ones. In addition, due to the high cloud coverage during this dust event, it is also specially challenging to study the cloud nucleation impact of dust by acting as CCN and/or INP. These results can be of interest for the next ESA EarthCARE validation mission.

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