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Climatology of Saharan dust transport events at mt. Cimone gaw global station, Italy (2165 m a.s.l.)

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Abstract

The occurrence of mineral dust transport from North Africa towards the Mediterranean basin and the Europe was studied on a 11-y period (2002-2012) thanks to the continuous observations carried out at the "Italian Climate Observatory – Ottavio Vittori" (2165 m a.s.l., 44°11'N, 10°42'E), a WMO/GAW global station sited at Mt. Cimone, the highest peak of Italian northern Apennines. Due to its position, Mt. Cimone (CMN) represents a strategic station where investigating the impact of mineral dust from northern Africa to the atmospheric composition of the Mediterranean basin and southern Europe. The identification of the Dust Transport Events (DTEs) is based on the coupling of the measured in situ coarse (1 µm ≤ Dp≤ 10 µm) aerosol number concentration with the analysis of back-trajectory simulations tracing air mass origin from North Africa. 474 DTEs were identified, which accounts for 15.7 % of the investigated period (August 2002 – November 2012). A clear seasonal cycle is evident for DTE occurrence with the highest frequency in spring, and the highest aerosol loading in summer.

The analysis of FLEXTRA 10-d back-trajectories allowed to obtain information about transport patterns and source regions of mineral dust: for CMN, the most active source region appeared to be represented by the western North Africa, with a secondary contribution from central North Africa, the latter especially important during spring.

Keywords: Mineral dust; coarse aerosol; climatology; Mediterranean basin; Italy.

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1. Introduction

Mineral dust aerosol is ubiquitous in the atmosphere and globally constitutes the greatest sources of particulate matter, with Africa responsible for approximately half of its global emissions (Huneeus et al., 2011). The mobilized aerosol can be transported over large distances by the synoptic circulation, with effects (both direct and indirect) on the atmosphere radiative balance that depends on the altered solar radiation scattering and absorption. However, African emissions are not steady but have a strong inter-annual and intra-seasonal variability (Ridley et al., 2014), thus their climatic impact can vary largely. Therefore, the need exists to have ”long-term” continuous databases to get a clearer overview of the impact of mineral dust on different atmospheric processes. The Italian Climate Observatory “O. Vittori” (ICO-OV) represents one of the first high elevation stations that are affected by the northward transport of mineral dust from Africa: here, the measurements of aerosol particle number size distribution started in August 2002. This 11-y data-set represents a valuable base of information to study the impact of dust transport on the atmospheric composition in the Mediterranean and Southern Europe free troposphere, two hot-spot regions for regional climate and air-quality changes.

2. Measurement site and instrumental set-up

ICO-OV is the only WMO/GAW global station over the Italian territory, which is located at the summit of Mt. Cimone (CMN, 44°12' N, 10°42' E, 2165 m a.s.l.), the highest peak of the northern Apennines. The atmospheric measurements carried out at ICO-OV are considered representative for the baseline conditions of the Mediterranean free troposphere (Bonasoni et al., 2000; Fischer et al., 2003).

The aerosol number concentration and size distribution (0.3-10 μm in 15 bins) are continuously observed by mean of an optical particle counter (OPC 1.108 GRIMM) since August 2002 to November 2012, allowing to determine the coarse particle number concentration (N_{1-10}) According to the manufacturer, the accuracy of the OPC in particle counting is ± 2% over the entire measurement size range. As deduced by Putaud et al. (2004), a random uncertainty in particle sizing of ± 20% can be associated to a similar OPC during desert dust advection.

The identification of the days characterized by the transport of mineral dust from North Africa (Dust Transport Events, DTEs) is the result of the analysis of the N_{1-10} variability coupled with the analysis of 10-d 3-D back-trajectories calculated by the FLEXTRA model (Stohl et al., 1995). Trajectory calculations, with a horizontal resolution of 1°× 1°, are based on meteorological analysis fields produced by the numerical weather prediction model of the European Centre for Medium Range Weather Forecasts (ECMWF), with a T106 spatial resolution and 60 vertical levels. For each day, 4 back-trajectories were calculated at 00, 06, 12 and 18 UTC for the ICO-OV location, with the air mass position (geographic location and altitude) recorded every 3 h backward in time.

Basically, a DTE was identified when a statistically significant increase of the N_{1-10} daily value was associated with 10-d old air mass originated from northern Africa. To identify the N_{1-10} increase, the so-called “Kolmogrov-Zurbenko” filter was applied, i.e. a three-time repeated running mean over a period of 20 d was calculated. A day is considered as possibly affected by dust transport when the daily High Frequency value (HF, difference between the daily average and the Kolmogrov-Zurbenko average) is significantly higher (at the 95% confidence limit) than the average HF value over the period 2002-2012, and thus could be related with transport of mineral dust from Sahara. This result must be corroborated by the presence of air masses that originated (or passed) over North Africa, as deduced by the FLEXTRA model. In case of ambiguous identification, further information was gained by the inspection of other model outputs (i.e., NAAPS - Navy Aerosol Analysis and Prediction System, see http://www.nrlmry.navy.mil/a) or satellite data (i.e., TOMS/OMI UV Aerosol Index, MODIS AOD).

3. Results

3.1 DTEs climatology and seasonal cycle

Over the investigation period, 474 DTEs were identified, corresponding to 15.7 % of the days in which OPC measurements were available. This value appears to be in good agreement with the dust outbreak frequency obtained by Pey et al. (2013) for southern-east France and northern Italy (17-18 %). On average, the contribution of the observed mineral dust transport to the coarse aerosol number concentration caused a significant increase of N_{1-10} which increased from 0.110 ± 0.001 cm^{-3} (average mean value during not-DTE conditions ± 95 % Confidence Limit) to 0.664 ± 0.083 cm^{-3} during the DTEs (Fig.1).

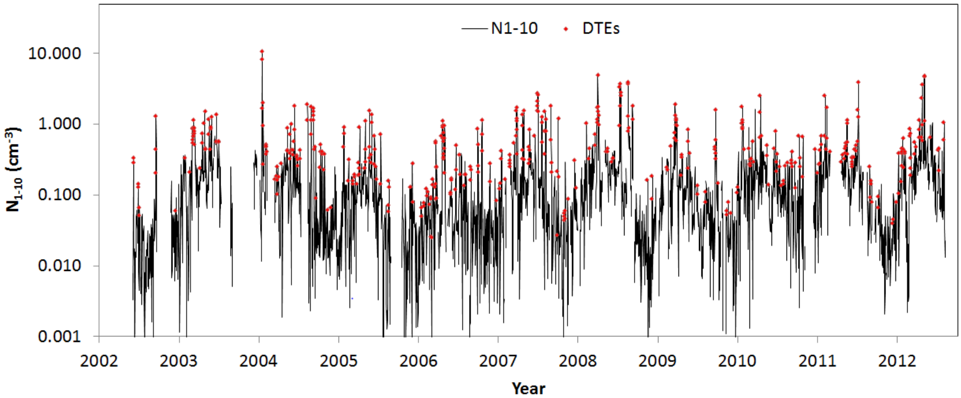

Fig. 1. Time series of the mean daily N_{1-10} observed at ICO-OV (period: August 2002 – November 2012). The red dots denoted the observations affected by DTEs.

Fig. 1, reports the time series of daily N_{1-10} at ICO-OV together with the identified DTEs (red dots). Overall, the N_{1-10} at ICO-OV is characterized by a seasonal cycle with spring-summer maxima and winter minima, likely to be affected by the occurrence of DTEs. In fact at ICO-OV a clear predominance of DTEs occurrence is evident from March to August, with a frequency peak on May when, on average, dust outbreaks affected 26.4 % of the days. A secondary peak in the DTE frequency is evident on Autumn (16.6% on November), indicating that also this season is usually impacted by significant amount of mineral dust emitted from northern Africa. The seasonality of DTEs at ICO-OV fits well with the peak in the dust outbreak activity depicted by Collaud Coen et al. (2004) for the central Mediterranean basin. The occurrence of dust outbreaks is reflected by the variability of the monthly N_{1-10} average values, with the highest 10-y average monthly values (± 95 % Confidence Limit) on May (0.71 ± 0.36 cm^{-3}), June (0.79 ± 0.37 cm^{-3}) and September (0.89 ± 0.67 cm^{-3}).

No statistically significant long-term trends (at the 95% confidence level) were detected for the observed DTEs frequency, nor for their "intensity" (expressed as N_{1-10}), both for yearly or seasonal aggregation.

Interestingly, based on the OPC measurements, also the finer fraction of aerosol particles ($N_{0.3-1}$, .e. the integrated number concentration of aerosol particles with optical diameter between 0.3 and 1 μm) showed a statistically significant (at the 95% confidence level) increase during DTEs (+25%), possibly indicating advection of fine aerosol particle in the dust plumes or mixing with polluted aerosol along the transport towards ICO-OV.

3.2 DTEs source regions

With the aim of investigating the source regions of the mineral dust observed at ICO-OV, the paths and the origin of the 10-d FLEXTRA back-trajectories were investigated (Fig. 2).

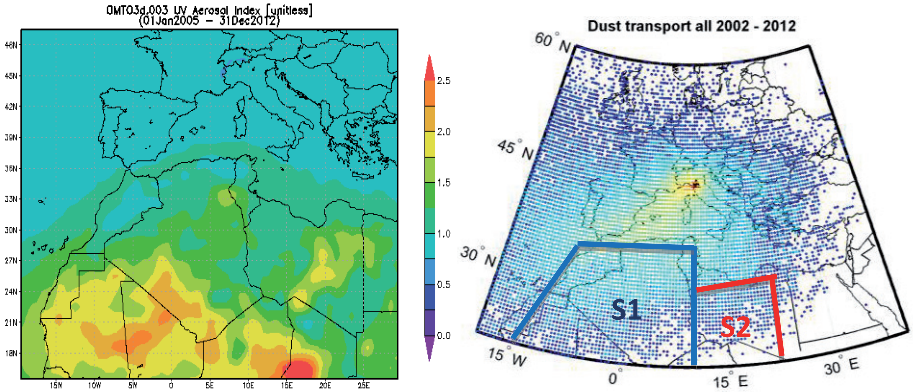

Fig. 2. Left: mean average OMI UV Aerosol Index over the period January 2005 – December 2012 over North Africa and Mediterranean basin (courtesy by NASA). Right: numbers of trajectory segments (hourly time steps) during DTEs over a grid with 0.1°×0.1° horizontal resolution. Source region: western North Africa (S1), central North Africa (S2)

To obtain a general picture of the air-mass flows characterising the mineral dust transport, the field concentrations of the segments of back-trajectories ending at ICO-OV for the 474 DTEs were calculated. To reveal the transport paths for ''peripheral'' regions far from the measurement site, a logarithmic scale was adopted (Fig. 2, right). This elaboration clearly shows that the main transport pattern is related to south-westerly circulation from western North Africa, even if significant variability was observed as a function of the different seasons. During summer this circulation is favoured by the presence of an anticyclone over the Mediterranean basin which, even in association with low pressure trough over west of the Iberian peninsula, promote favourable conditions for mineral dust injected over northern Africa. During the remaining seasons, air-mass transport from the northern Africa is likely to occur also thanks to the presence of low pressure areas over the western/central Mediterranean basin able to induce southerly or south-easterly dust advection from central northern Africa.

Two "macro-regions" were identified as main sources of dustin northern Africa, as depicted (Fig. 2, left) by the satellite measurements of the UV Aerosol Index provided by the ozone monitoring instrument (OMI) on board the NASA Aura satellite (Duncan et al., 2003). In particular, region S1 includes Morocco, Mauritania, Algeria and Tunisia, while region S2 mostly includes Libya. By mean of the FLEXTRA back-trajectories each DTE was tagged to these "macro-regions", thus calculating their average 10-y monthly contribution to the DTE occurrence (Fig. 3). This analysis leaded to the conclusion that region S1 represents the most active source region for the occurrence of DTE at ICO-OV (accounting for 64% of the total DTEs), with a clear predominance during spring season (March and April). An important contribution was also detected for region S2 (31%), while the remaining 5% DTEs were tagged to mineral dust transport from eastern North Africa (Egypt). Concerning the region S2, the highest number of tagged DTEs were observed in spring (May) – summer (June – July), even if the relative contribution is maximised in June and October, when region S2 accounted for 40% of detected DTEs.

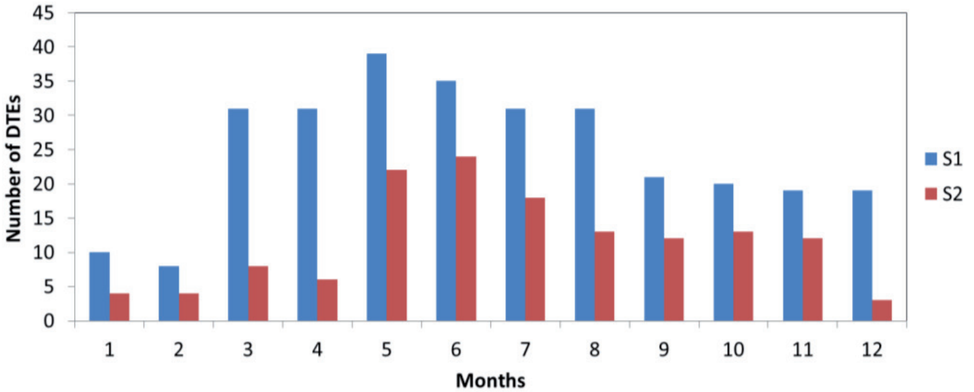

Fig. 3. Total monthly number of DTEs at CMN as a function of the source "macro-regions" S1 (western North Africa) and S2 (central "North Africa").

4. Conclusions

The present work provides a preliminary investigation of 10-y mineral dust transport from North Africa to southern Europe/central Mediterranean basin by mean of the continuous observations carried out at the Mt. Cimone WMO/GAW global station in Italy.

The coupling of the in-situ aerosol size distribution measurements at ICO-OV with the 3-D back-trajectories computed by the FLEXTRA model, provided a simple but robust tool for detecting DTEs at this high-altitude measurement site, well representative of the background conditions of the Mediterranean troposphere.

The identified DTEs are responsible for the significant changes in aerosol atmospheric properties, with a N_{1-10} increase of about 600% during DTEs. This increase is also surprisingly associated with a fine fraction rise (+25%), possibly indicating advection of fine aerosol particle in the dust plumes or mixing with polluted aerosol along the transport towards ICO-OV.

The analysis of the monthly DTE occurrence showed high values during spring-summer (in agreement with previous investigation). It was clearly pointed out also important contributions during the autumn which emerges as a season strongly affected by this kind of events.

Our preliminary analyses revealed that the emission basins located in the western northern Africa represents the most important source regions of mineral dust at ICO-OV, but a significant fraction of DTEs can be related with dust transport for central northern Africa.

Further work will be deserved to refine the identification of dust source regions, to investigate inter-annual variability of DTEs and to assess the impact to atmospheric composition properties (i.e. ozone mixing ratios and aerosol optical properties).

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References

Bonasoni P., Stohl A., Cristofanelli P., Calzolari F., Colombo T., Evangelisti F. (2000). Background ozone variations at Mt. Cimone Station. Atmospheric Environment 34, 5183–5189.

Collaud Coen M., Weingartner E., Schaub D., Hueglin C., Corrigan C., Henning S., Schwikowski M., Baltensperger U. (2004). Saharan dust events at the Jungfraujoch: detection by wavelength dependence of the single scattering albedo and first climatology analysis. Atmospheric Chemistry and Physics 4, 2465–2480.

Duncan B.N. et al. (2003). Interannual and seasonal variability of biomass burning emissions constrained by satellite observations. Journal of Geophysical Research, 108 (D2), 4040.

Fischer H., Kormann R., Klüpfel T., Gurk C., Königstedt R., Parchatka U., Mühle J., Rhee T.S., Brenninkmeijer C.A.M., Bonasoni P., Stohl A. (2003). Ozone production and trace gas correlations during the June 2000 MINATROC intensive measurement campaign at Mt. Cimone. Atmospheric Chemistry and Physics 3, 725–738.

Huneeus N., Schulz M., Balkanski Y., Griesfeller J., Prospero J., Kinne S., Bauer S., Boucher O., Chin M., Dentener F., Diehl T., Easter R., Fillmore D., Ghan S., Ginoux P., Grini A., Horowitz L., Koch D., Krol M. C., Landing W., Liu X., Mahowald N., Miller R., Morcrette J.-J., Myhre G., Penner J., Perlwitz J., Stier P., Takemura T., Zender C.S. (2011). Global dust model intercomparison in AeroCom phase I. Atmospheric Chemistry and Physics 11, 7781–7816.

Pey J., Querol X., Alastuey A., Forastiere F., Stafoggia M. (2013). African dust outbreaks over the Mediterranean Basin during 2001–2011: PM10 concentrations, phenomenology and trends, and its relation with synoptic and mesoscale meteorology. Atmospheric Chemistry and Physics 13, 1395–1410.

Ridley D.A., Heald C.L., Prospero J.M. (2014). What controls the recent changes in African mineral dust aerosol across the Atlantic? Atmospheric Chemistry and Physics 14, 5735–5747.

Stohl A., Wotawa G., Seibert P., Kromp-Kolb H. (1995). Interpolation errors in wind field as a function of spatial and temporal resolution and their impact on different types of kinematic trajectories. Journal of Applied Meteorology 34, 2149– 2165.