P9.1 AN EXTREME SAHARAN DUST OUTBREAK IN SPRING 2004 AND ITS IMPACT ON THE ONSET OF THE WEST AFRICAN MONSOON

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1. THE DUST OUTBREAK

Aeolian dust from the Sahara has profound impacts on the living conditions in and around West Africa (e.g., air traffic, health), in particular during the boreal cool season. In addition, dust particles affect the atmospheric radiation budget and can serve as cloud condensation nuclei.

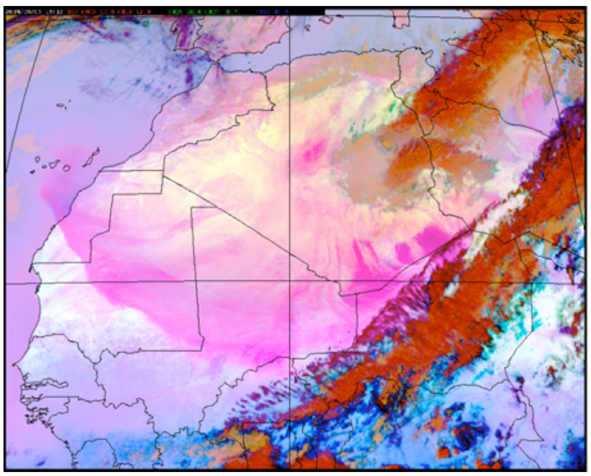

FIG. 1: Meteosat Second Generation image at 1812 UTC 3 March 2004 showing the dust front arching from the Canary Islands across Western Sahara, Mauritania, Mali, Niger, Algeria into Libya. The image was taken from the EUMETSAT webpage (www. eumetsat.int).

The present paper deals with an unusually large-scale, strong, and persistent outbreak of Saharan dust that occurred in early March 2004 and its ramifications for the spring onset of the West African monsoon. For 1812 UTC 3 March Fig. 1 shows an image that was produced by combining three channels from the Meteosat Second Generation satellite in order to identify dust both over land and ocean. The dust appears pink on this image.

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The dust front shown in Fig. 1 originally formed over north-central Algeria around 14 UTC 2 March 2004 and then spread south- and westward over the following days. On 4 March the dust front crossed the west coast of West Africa and two days later it spanned several thousand kilometers from the northern tip of Morocco around West Africa and into the Gulf of Guinea (Fig. 2).

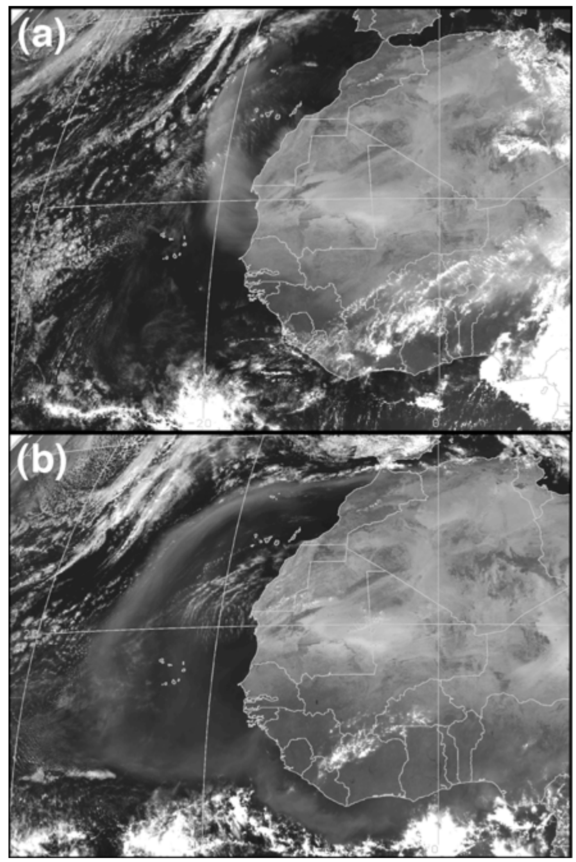

FIG. 2: The spreading of the dust front over the Atlantic Ocean as seen on Meteosat visible satellite images. (a) 12 UTC 4 March 2004 and (b) 12 UTC 6 March 2004. From Knippertz and Fink (2006).

Knippertz and Fink (2006) showed that the dust front was initially related to a density current caused by strong evaporational cooling along a precipitating cloud band that penetrated into the northern Sahara ahead of an upper-level trough. The remnants of this cloud band are evident over eastern Algeria in Fig. 1. At later stages massive

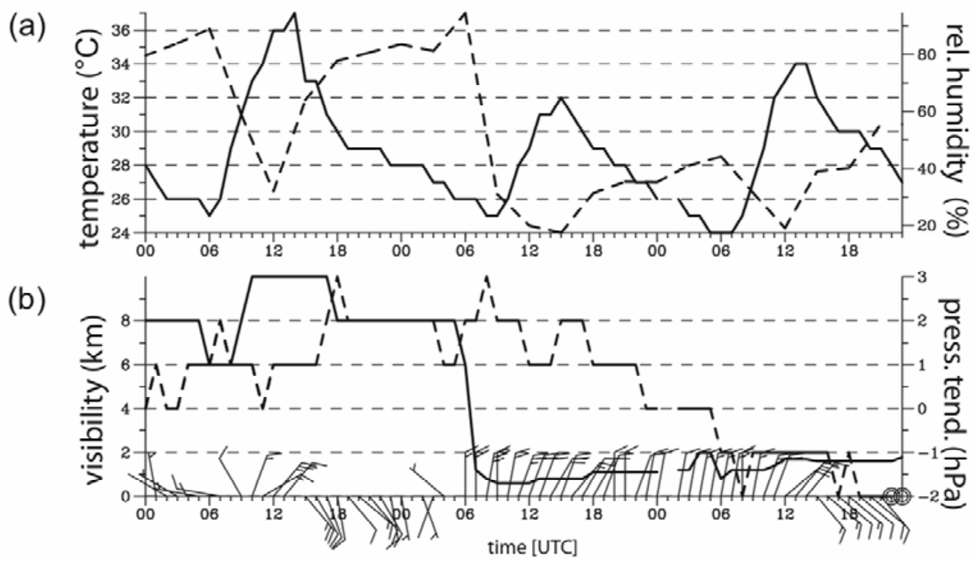

FIG. 3: Observations at Cotonou between 00 UTC 4 March 2004 and 23 UTC 6 March 2004: (a) air temperature (^{o}C, solid line) from hourly METAR reports and relative humidity (%, dashed line) from 3-hourly SYNOP reports, and (b) as in (a) but for METAR 24-hour pressure tendency (dashed) and hourly visibility (solid). Wind barbs: half barb=5 knots, full barb=10 knots. From Knippertz and Fink (2006).

upper-level convergence, sinking, low-level divergence, and an explosive anticyclogenesis over northwest Africa caused strong northerly flow and a quick displacement of the dust to the south and west. The strong pressure gradients over North Africa were further enhanced by the formation of a cyclone ahead of the upper-trough.

Surface observations show that the event was accompanied by unusual sensible weather conditions across large parts of North Africa including cold temperatures and high wind speeds in the Sahara and extreme precipitation in the arid parts of Algeria and Libya (see Knippertz and Fink 2006).

2. HEAT WAVE AT THE GUINEA COAST

Surface observations at various stations in southern West Africa indicate that the day before the arrival of the dust front was characterized by a heat wave along the Guinea Coast. As an example Fig. 3 shows high-resolution observations from Cotonou (Benin) between 00 UTC 4 March and 23 UTC 6 March 2004. On 4 March the maximum temperature at this station reached 37ºC, which exceeds the highest observed value for the 60-year period 1931–90 (Fig. 3a). Analysis data and trajectory calculations indicate anomalous subsidence (not shown). Relative humidity was rather low on that day (Fig. 3a) and synoptic observations reveal below-average cloud cover. Together these factors allow a strong heating of the ground through solar irradiation (Fig. 5).

The wind barbs in Fig. 3b indicate a delayed onset of the cooling southerlies from the Gulf of Guinea on 4 March. This is consistent with a weakening of the continental heat low as indicated by positive pressure tendencies (dashed lines in

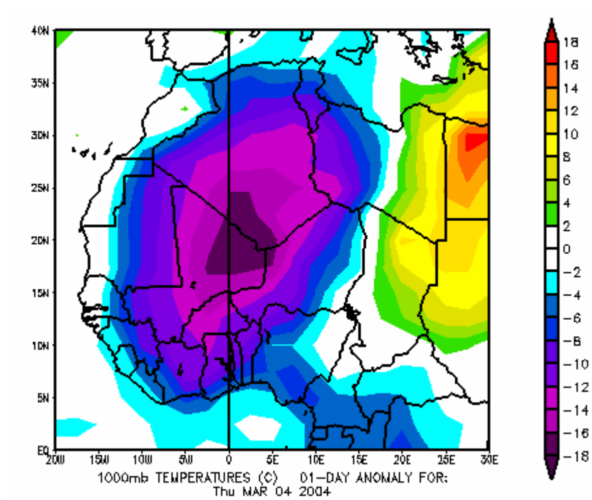

FIG. 4: 1000-hPa temperature anomaly [°C] for 4 March 2004 based on NCEP daily analysis data (taken from www.cdc.noaa.gov/HistData).

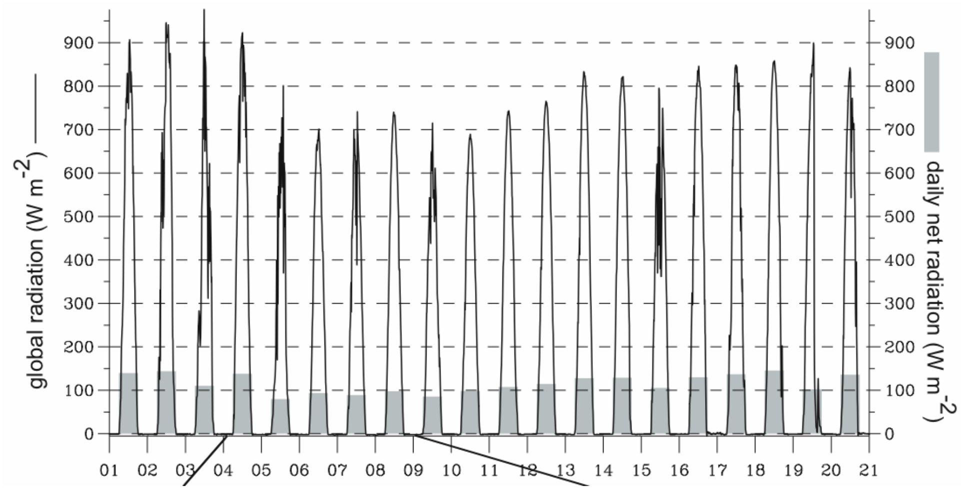

FIG. 5: 10-minute total down-welling shortwave radiation (lines) and 24-hour (06–06 UTC) net full-spectrum radiation (gray bars) at Cotonou for 1–21 March 2004. From Knippertz and Fink (2006)

Fig. 3b). As shown by Knippertz and Fink (2006) southward advection of evaporationally cooled and dusty air behind the dust front seen in Figs. 1 and 2 is directly related to the weakening of the heat low. The continental scale cool anomaly resulting from this process is shown in Fig. 4 with the help of NCEP analysis data. The maximum close to the border between Mali and Algeria reaches almost 18°C. Note that the values are calculated from an average over the 00 and 12 UTC analysis, which obscures the daytime warm anomalies along the Guinea Coast. Figure 4 does, however, point to the fact that the heat wave might be a relatively local phenomenon that is closely tight to the suppressed sea-breeze circulation on 4 March.

Early on 5 March 2004 the dust front passed Cotonou (see also Fig. 2). This period was characterized by relatively low temperatures (the maximum on this day is only 32°C), and a pronounced drop in relative humidity to 20% and in visibility to below 1 km (Fig. 3). Strong northerly winds of up to 25 kt prevailed until the afternoon of 6 March, when the sea breeze slowly recovered.

3. IMPACTS ON THE MONSOON ONSET

The dust outbreak had a distinct impact on the onset of the African monsoon in the spring of 2004. As shown in Fig. 2 the strong Harmattan winds and the massive cooling of the continent was associated with an unseasonable southward displacement of the Intertropical Convergence Zone (ITCZ). Over the following two weeks the cold air over the North African continent and the large dust loadings hindered the re-establishment of the African heat low, resulting in an unusually late and prolonged Harmattan episode. Radiation observations from Cotonou show that it took in fact about two weeks until the total down-welling shortwave radiation and the 24-hour net radiation reached the large values observed before the dust outbreak (Fig. 5).

The suppressed heat low and the equatorward shift of the ITCZ position were associated with a delayed onset of the African monsoon and widespread dry anomalies along the Guinea Coast in March 2004 (not shown).

4. CONCLUSIONS

The case study presented here deals with an extreme example of an influence of an upper-level extratropical trough on meteorological conditions in tropical West Africa. It demonstrates a disturbance of the heat low dynamics for a period exceeding the time of the actual synoptic event with impacts on the entire West African monsoon system. The radiative effects of Saharan dust are likely to play a non-negligible role in this process. Future studies should investigate if comparable situations (even though probably less extreme) can be detected in other spring seasons and if this could potentially contribute to an improvement of monsoon onset predictions along the Guinea Coast. Such predictions are of large economic value to the societies in West Africa.

5. REFERENCES

Knippertz, P. and Fink, A. H., 2006: Synoptic and dynamic aspects of an extreme springtime Saharan dust outbreak. *Quart. J. Roy. Meteorol. Soc*., in press.