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Spatial and temporal variability of windborne dust in the Sahel-Sahara zone in relation with synoptic environment

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Windborne dusts have been recognised as climatic indicators in the Sahel region, because of their ability to cause reduction in horizontal visibility. These phenomena have intensified after the exceptionally drought periods in the 1970s over the Sahel region. In this work, we have analysed the spatial and temporal evolution of visibility reduction in the Sahel-Sahara zone between 1957 and 1987. The results showed that windborne dusts were more frequent and severe over the western coast of West Africa. The zone characterised by the maximum variability included largely, the Sahel region (15° to 20°N). Stations in this region were characterised by a progressive reinforcement of suspended windborne dust between 1970 and 1987. Dust emissions in the Sahelian region increased during dry years and were associated with weak monsoon flux, African Easterly Jet (AEJ) reinforcement and weak Tropical Easterly Jet (TEJ).

Key words: Horizontal visibility, windborne dust, synoptic parameters, Sahel-Sahara.

INTRODUCTION

One of the observed weather characteristics in Northern Africa after the exceptionally drought period of the latter half of the 20th century over the Sahel has been the quasi constant presence of suspended desert-dust in the atmosphere. When the desert-aerosol density in the atmosphere is sufficient, it becomes a windborne dust phenomenon. The windborne dust phenomena and sand wind constitute, as the same order as rainfall season, a seasonal climatic event (Bertrand, 1977; Gac et al., 1991; Ozer, 2002). This new climate tendency which was directly linked to the exceptionally drought period and recent changes in Sahelian ecosystems has attracted a lot of scientific interest in an attempt to provide comprehensive explanation of dust phenomena. These kinds of dust production mostly depend on surface

conditions such as humidity, vegetation cover, wind speed, turbulence etc. Dust can be transported through the African continent, toward Europe and America over the Atlantic Ocean.

Desert aerosols are the most important among aerosols in the World. Global mineral aerosol emission is estimated between 1000 and 3000 million tons per year (Ramanathan et al., 2001; Ginoux et al., 2004). Sahelian-Saharan region has been identified as the most important and the most studied emission zone with annual estimate between 1000 and 2000 million tons of aerosols according to Laurent et al. (2008a, b). Nowadays, some portion of desert aerosols emission is from anthropogenic sources (Tegen et al., 2004; Yoshioka et al., 2005). Land use (agriculture, pasturage) induce naked soil previously

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protected from wind erosion, which becomes potential aerosol emission source and also induce desertification in some regions.

During their stay time in the atmosphere, mineral aerosols influence the radiative budget either direct (absorption and/or scattering solar radiation) and indirect (modification of cloud properties and precipitation processes) (Sokolik et al., 2001). However, it has been difficult to quantify the relative complexity and extreme uncertainties of dust effect on the radiative forcing. Aerosol effects on atmospheric temperature depend on their vertical distribution, particle sizes, concentration, location and life time in the atmosphere (Liao and Seinfeld, 1988; Brooks, 1999). Modelling studies using Regional Climate Model (RegCM) have shown that the radiative effects of dust are precipitation reduction, weaker Tropical Easterly Jet (TEJ) and reinforcement of the African Easterly Jet (AEJ) (Konare et al., 2008; Solmon et al., 2012).

The aim of this work is to contribute to the understanding of spatial and temporal distribution of Saharan dust during 1957 to 1961, 1970 to 1974 and 1983 to 1987 periods. Horizontal visibility reduction evolution has been compared to the synoptic environment.

MATERIALS AND METHODS

Gac et al. (1986), Bertrand (1977), Legrand (1990), N'Tchayi (1992), and N'Tchayi et al. (1997) have shown that windborne dusts, because of their frequency, density, and geographic extension are important climatic characteristic in West Africa. They also revealed the advantages of using visibility as an important factor to assess dust presence and desert aerosols concentration in the atmosphere. This is due to the fact that visibility is really a measure of the integrated surface concentration of aerosols and other particles between eye and distant objects. In addition, the aerosol-layer is well mixed due to convection (diurnal) and its thickness is less variable in the sub-Saharan dust sources regions. We used visibility data from ASEENA (Agence pour la Sécurité de la Navigation Aérienne en Afrique et à Madagascar) meteorological stations to assess the long term trends in desert dust emissions. Visibility data from these sites are in kilometres, and indicate how far away a large black object can be seen against the sky at the horizon (Seinfeld and Pandis, 1998; WMO, 1992). Each synoptic station has several (about ten) measurement points spread in all directions. Eight of these measurement points are located about 5 km around the station, which limits potential error occurrence in horizontal visibility estimations. Thus, when it happens that the observer is able to identify a target located at 3 km while the reference point located at 4 km is masked due to dust presence, the recorded visibility will be 3 km. In this example, the recorded value includes error less than 1 km. The data quality has been well discussed in previous studies (Middleton, 1985; Ozer, 2005; Ozer et al., 2007; Mahowald et al., 2007). Data from the periods 1957 to 1961; 1970 to 1974 and 1983 to 1987 have been assessed because most of these stations have reliable records only during this time. Moreover, based on horizontal visibility reduction due to dust presence, some authors have estimated dust concentration over Sahelian synoptic stations by using relationship available in literature (D'Almeida, 1986; Ozer, 2005; Ozer et al., 2007; Mahowald et al., 2007). We used as reference horizontal visibilities as recorded by ASEENA network. Our approach is different from

those of previous studies because we used the horizontal visibility as measured at the station, instead of the number of hours of visibility reduction (N'Tchayi, 1992; N'Tchayi et al., 1997), frequency of dusty days (Ozer, 2002) or dust particles concentration (Ozer, 2005; Ozer et al., 2007; Mahowald et al., 2007). Observations were made following three synoptic times step (0, 3, 6, 9, 12, 15, 18 and 21 UTC). Visibilities closely depended on suspended dusts into the atmosphere, and have been taken as tracer to follow spatial and temporal evolution of windborne dust production (Ozer, 2005; Ozer et al., 2007; Mahowald et al., 2007). For this work, 40 stations located between 9.09°N and 25.14°N and 17.3°W and 20.51°E have been considered. The study has been done on data that spanned from 1957 to 1987. We have also used rainfall from National Oceanic and Atmospheric Administration (NOAA) which was composed of monthly rainfall accumulation across the Africa continent between 20°N to 8°N and 20°W to 10°E. For synoptic environment, we have used monthly zonal and meridional wind data from National Center for Environmental Prediction/ National Center for Atmospheric Research (NCEP/NCAR). These data allowed for the analysis of the monsoon flux intensity in lower layers, and altitude jets: AEJ in middle layers and TEJ in high layers to be undertaken.

RESULTS

Horizontal visibility evolution and sources localization

Horizontal visibility disturbance phenomena are two types: lithometeors (dust) and hydrometeors (rain, fog). There are markers in the datasets that specifically indicate dust events or rain events. In the absence of dust, horizontal visibilities recorded in the dry tropical regions were around 15 km and more. Otherwise, in most of the times, events causing reduction in visibility occurred for several days. During these events, dust densities and their corresponding visibilities varied slowly.

Recorded horizontal visibilities at 9, 12 and 15 UTC were considered and their mean values were processed in this work. This choice has been done based on previous studies which showed that diurnal emission cycle of horizontal visibilities in stations such as Niamey, Zinder, Gao, Tombouctou and Bilma showed that the occurrence of dust events has a maximum during the day between 9 and 15 UTC and a minimum during the night between 21 and 3 UTC (Ozer, 2001). Chaboureau et al. (2007) works have also observed a diurnal cycle pronounced with a peak at 15 UTC. This was in agreement with recent studies (Todd et al., 2007; Knippertz, 2008), implying a determinant role of the Low Level Jets (LLJs) and diurnal convection variation in the Atmospheric Boundary Layer (ABL), in the diurnal dust emission cycle. Diurnal cycle seemed true during the dry season in north Africa, where the major parts of the continent were under the influence of the Harmattan wind flow from the North-East, but it was not the same during monsoon period where half of the southern part of north Africa was governed by monsoon flow, which during night times behaved as density current and induce intense desert aerosols rising over Sahel in the Inter-Tropical Front (ITF) (Bou Karam, 2008). For example, to remove

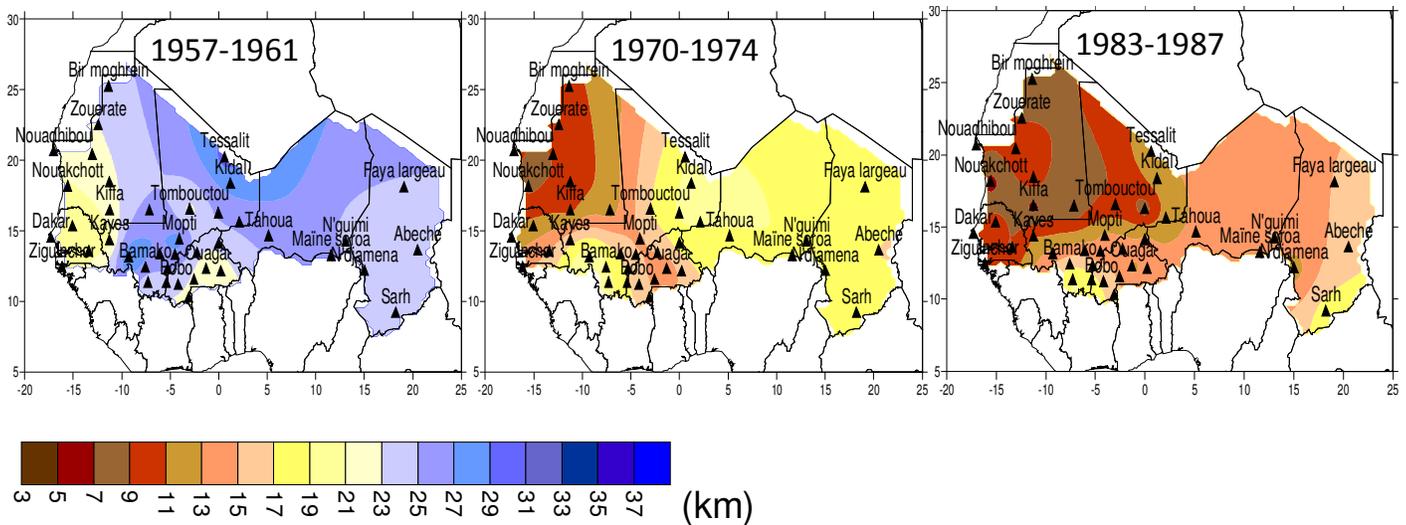


Figure 1. Comparison of the evolutions of the mean horizontal visibility for the periods 1957 to 1961, 1970 to 1974 and 1983 to 1987.

nebulosity due to lower and middle cloud, it was sufficient to consider a zone above the Inter-Tropical Convergence Zone (ITCZ) ground trace. However, horizontal visibility representation by windborne dust was not absolute because of dust plume top which was not always at the same altitude. Sometimes it happened that due to dust plume vertical structure, horizontal visibility can be higher than 10 km while the transmittance was bad (Bertrand, 1977). This previous phenomenon can happen at oceanic air and continental air mass separation (ITCZ). Oceanic air mass driven by the monsoon flux, which was denser due to strong temperature, went deeper under dust plume which was propagating toward the altitude. Furthermore, due to their dependence on wind speed and the exposed ground surface, the desert aerosol emissions are sporadic. If the exposed surfaces extent aridity was controlled by wind deflation, wind was the engine. Furthermore, these emissions are phenomena where frequencies and intensities are strongly linked to wind regime variations. Therefore this indicated that mineral aerosol emissions present strong diurnal, annual, inter-annual and decadal cycles.

Decadal and inter-annual variability

Figure 1 represents the variability of windborne dust during 1957 to 1961, 1970 to 1974 and 1983 to 1987. It showed that on the long term perspectives, reduction in horizontal visibility in all the West African stations was marked by a significant increase between 1957 to 1961 and 1983 to 1987. Reduction in visibility, less than 10 km showed the presence of dust in the atmosphere. If this reduction had been less than 5 km, it would have meant that the suspended dusts density in the atmosphere was important. During the period of 1957 to 1961, horizontal

visibility was generally above 20 km. Also, between the periods of 1970 to 1974, reduction in horizontal visibility was observed for stations in Mauritania and northern Senegal (horizontal visibility was less than 10 km). While in between 1983 to 1987, the presence of dust extension was observed at stations in Mali as well as those in Mauritania and Senegal.

Figure 2 shows that the inter-annual variability of windborne dust emissions was strongly pronounced in all stations. The results revealed quasi missed dust during 1957 to 1961. However, from 1983 to 1987, all the zones were covered with dust except stations in Niger and Chad, where dust prevalence decreased. Generally, spatial configuration of active zones and their dust plumes remained relatively unchanged from year to year during each period. This indicated that sources were well established and likely represented the conditions affecting dust production in the long term. An important mean-progression was observed from 1983, with a reduction in visibility of less than 10 km around 15° N and 20° N. The most significant reductions in visibility were recorded at stations including: Nouakchott, Kiffa, Nema and Gao.

Concerning Sahelian sources, we observed a discontinuity that was well defined over periods of 1957 to 1961 (absence of windborne dusts could be observed), 1970 to 1974 (windborne dusts located over western Mauritania) and 1983 to 1987 (increase of the phenomenon with an extension to the eastern Sahel). Contrast between 1983 to 1987 period and the two (1957 to 1961 and 1970 to 1974) other periods were obvious. Sources were more active during 1983 to 1987. In all, we observed that stations in the Sahelian zone were characterised by progressive reinforcement of suspended windborne dusts into the atmosphere between 1970 and 1987.

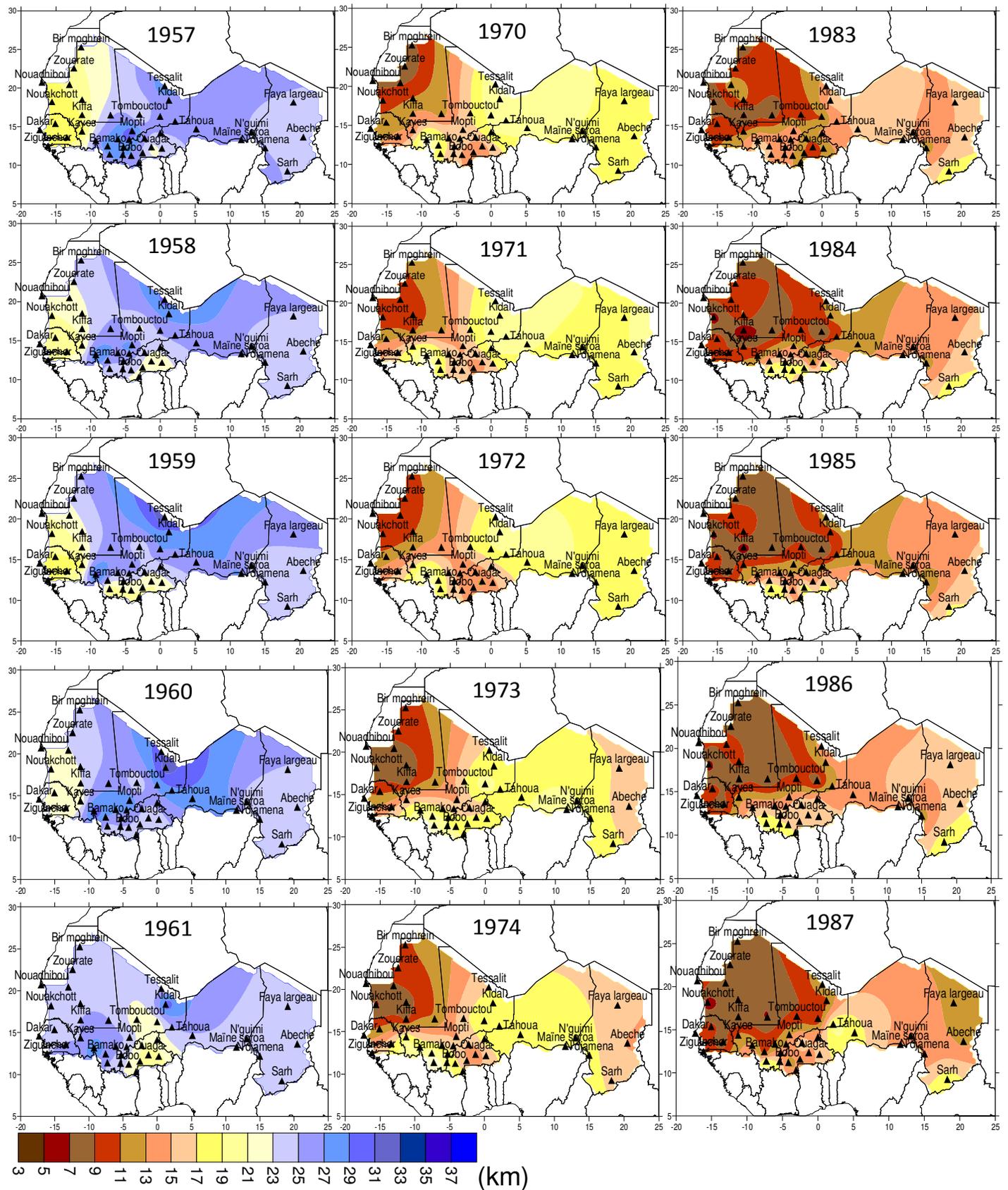


Figure 2. Evolution of the mean inter annual horizontal visibility during 1957 to 1961 (left), 1970 to 1974 (middle) and 1983 to 1987 (right) periods.

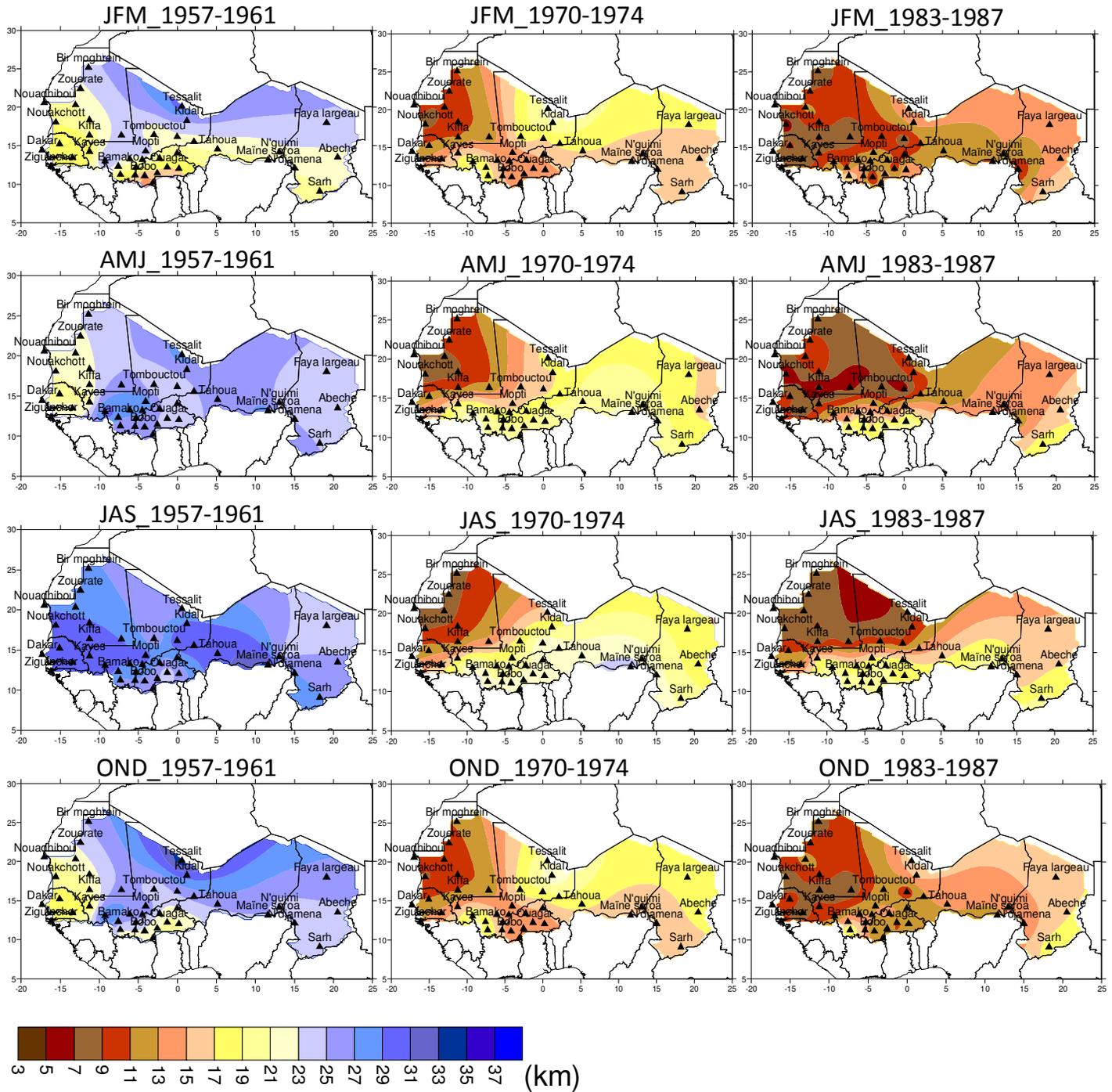


Figure 3. Evolution of seasonal mean horizontal visibility during the periods of 1957 to 1961 (left), 1970 to 1974 (middle) and 1983 to 1987 (right).

Seasonal and diurnal variability

Seasonal cycle

Figure 3 presents the evolution of the seasonal horizontal visibility. The Sahel was covered by windborne dusts in the lower layers during JFM (January, February and

March) over the entire region from 1970. During 1970 to 1974 and 1983 to 1987, dust plumes moved northwards, reaching the highest northern location in JAS (July, August and September). They moved down toward the southern part in OND (October, November and December). In JAS, the reductions in the horizontal visibility of less than 5 km were almost non-existent in

stations below 15° N. During AMJ (April, May and June), severe reduction in visibility was observed in the central Sahel (16° to 18° N). And during 1983 to 1987, the western Sahel part was mostly covered by thick dust plume (visibility was less than 10 km) independent of the season. These seasonal variations in the locations with maximum reduction in horizontal visibility can be explained by the movement of the ITCZ, which marked the separation of Harmattan flow (that transported dusts from North to South) and the monsoon flow.

Diurnal cycle

Figure 4 shows the evolution of the monthly mean synoptic visibility during February 1985 between 0 to 6, 9 to 15 and 18 to 21 UTC at six selected stations (Nouakchott, Kayes, Tombouctou, Bobo Dioulasso, Maïnesoroa and Nguimi), with a dense windborne dust situation (visibility less than 3 km). At the daily time scale, horizontal visibilities were variable as indicated by Figure 4. However, strong horizontal visibility reduction seemed clearly differentiated by a good continuity (several days). Windborne dust (strong reduction of visibility) was located at the beginning of the month, between 15th and 20th February and at the end of the month. Moreover, for the same station, horizontal visibility evolution was similar for each of these 3 daily time steps.

Spatial evolution of horizontal visibility

Windborne dust emissions were sporadic and spatially heterogeneous as it has been seen previously. Therefore, it was necessary to study them on different time and space scales. Some locations such as the wide arid and semi-arid zones can be major sources. So, it seemed appropriate to divide the study zone into small zones in order to investigate each of them with respect to their dust emission variability. This allowed identifying regions where maximum dusts emission was produced and whether it was as a result of transportation from the Sahara to the Sahel during these last years. We have divided the study area located between 9° N and 26° N into three zones, namely: Sudan-Sahel zone (9° to 15° N), Sahel zone (15° to 20° N) and Sahel-Sahara zone (2° to 26° N). For each zone, we have processed different mean-visibilitys (monthly mean, decadal monthly mean, annual mean and seasonal mean).

Figure 5 represents the evolution of the annual mean visibilitys in each of the three zones. The behaviour of windborne dusts was generally similar for each zone although the phenomenon magnitude was different. We observed a clear discontinuity between the 3 periods, 1957 to 1961 was characterised by the absence of windborne dusts, 1970 to 1974 characterised by weak reduction in visibility and 1983 to 1987 was characterised by strong reduction in visibility. Analysis revealed an increase in the reduction of visibility (less than 10 km)

due to windborne dusts from 1983 to 1987, within the Sahelian and Sahel-Sahara zones (Figure 5). The evolution of the horizontal visibility in the two regions showed more reduction in visibility over the entire Sahel. This was related to a progressive reinforcement of dusts emissions between 1970 and 1987. Nevertheless, the reinforcement was more pronounced over the Sahelian zone than the Sahel-Sahara zone. This suggested a maximum meridional production located between 15° to 20° N. The strong dusty levels in the Sahel could not only be due to the transportation and accumulation of particles in a stagnation zone by circulation slowing down around the inter-tropical convergence front, but also due to local emissions.

Horizontal visibility reduction and precipitations

Figure 6 illustrates simultaneously, the evolution of horizontal visibility and annual rainfall levels in the Sahel for each of the three periods (1957 to 1961, 1970 to 1974 and 1983 to 1987). It showed that the Sudano-Sahelian zone had a regime (monsoon regime) characterised by one peak during JAS, with a maximum in August linked to the ITZC boreal position. Annual accumulation maximum were concentrated only in three months during the monsoon period in contrast to the long dry period from November to March. Moreover, the length of the rain season did not significantly change from one period to another. We rather observed an increment in precipitation and horizontal visibility, followed by a decrement, at least during June, July, August and September. In addition, we observed a decrease in rainfall amount (from June to September) associated with a reduction in horizontal visibility from 1957 to 1961 and 1983 to 1987. We calculated the correlation coefficient between rainfall amount and horizontal visibility, and obtained values of 0.72, 0.73 and 0.67 respectively for 1957 to 1961, 1970 to 1974 and 1983 to 1987 respectively. This implied a possible close link between the occurrences of rainfall and windborne dusts on the long term. The southward isohyets movement (not shown) and precipitation decrement during JAS affected the dry Sahelian zone, leading to low vegetation cover and also the appearance in the southern zones of new areas that favoured dust production.

Synoptic environment evolution

We have considered here, the evolution of the monsoon flow vis-à-vis the AEJ and TEJ (Figure 7). The wet periods (1957 to 1961) compared to the dry periods (1970 to 1974 and 1983 to 1987), revealed a decrease in the monsoon flow intensity from the wet to dry periods. Strong wind cores, more than 10 m/s during the wet period were reduced to 6 m/s during the dry period. The reduction in the monsoon intensity continued far into the

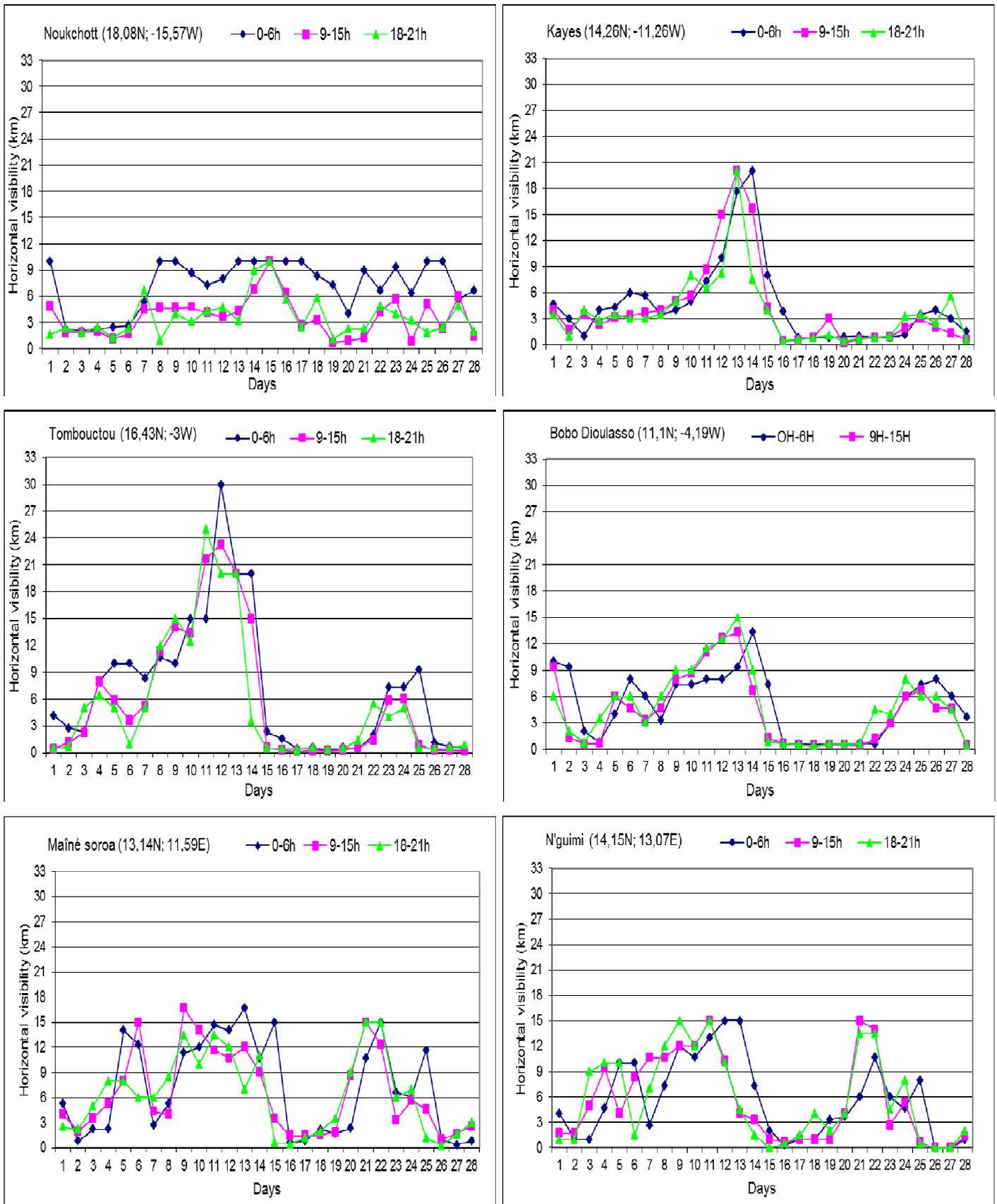


Figure 4. Evolution of horizontal visibility for February 1985, measured between 0 to 6, 9 to 15 and 18 to 21 UTC.

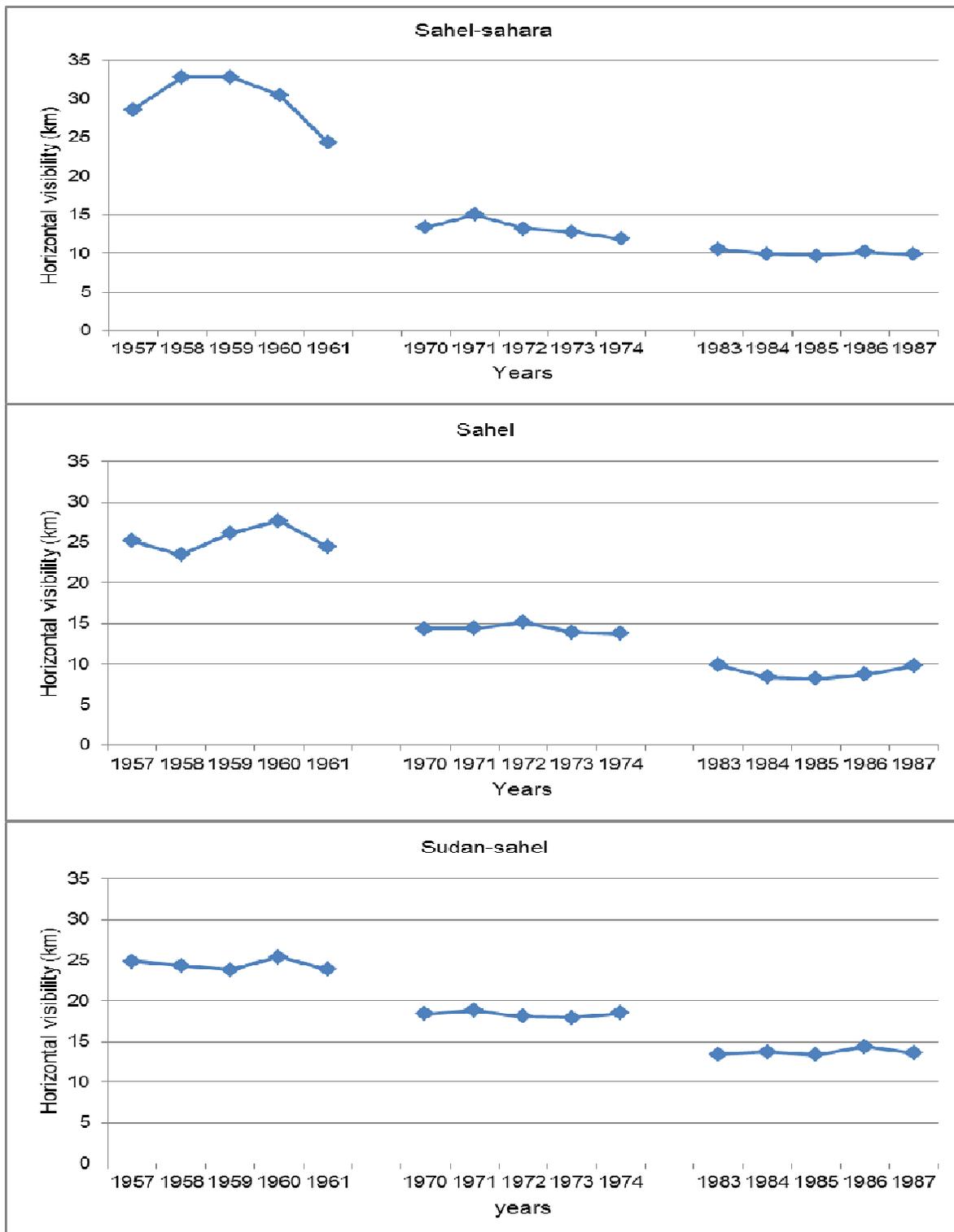


Figure 5. Evolution of mean horizontal visibility in the Sahel-Sahara (top), the Sahel (middle) and the Sudan-Sahel (bottom) regions.

continent and became less intense from the wet to dry periods. This explained the movement downwards the southern latitude of the isohyets between the wet and dry

periods. Due to dry effects, this downward movement had induced reduction in the vegetation cover, conducive for dust emissions (N'Tchayi, 1992).

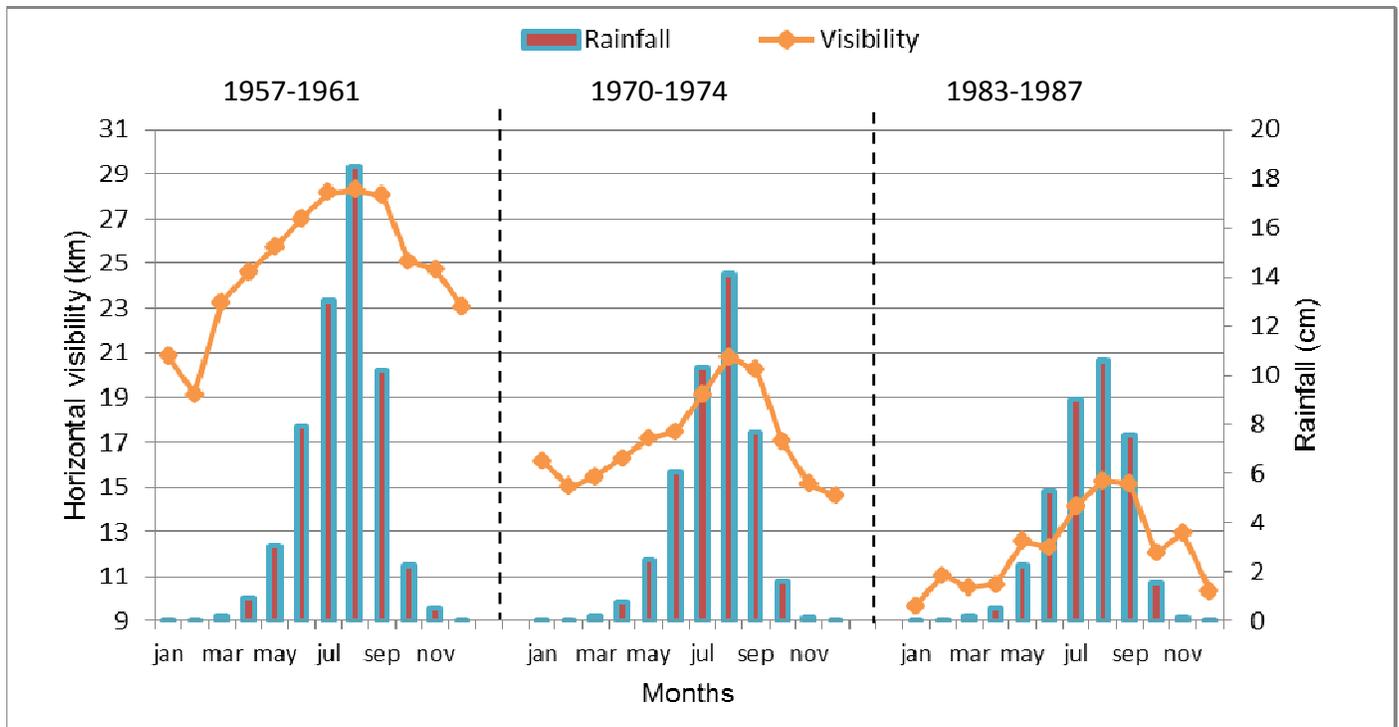


Figure 6. Evolution of horizontal visibility and rainfall for the periods, 1957 to 1961 (left), 1970 to 1974 (middle) and 1983 to 1987 (right).

In the middle troposphere, AEJ was located around 15° N with speed more than 10 m/s at its core during the dry period and 6 m/s during wet period. AEJ remained stationary during the three periods (with mean location around 12° N). Strong wind cores were located around 12° W and 10° E during the wet period. However, during dry period AEJ core was extended over Atlantic Ocean until 15° E. AEJ reinforced during the dry period (10 m/s) but its intensity during the wet period did not exceed 8 m/s. TEJ was located around 5° N with wind speed at 18 m/s and 16 m/s respectively during the wet and dry periods. TEJ located around 5° N in the wet period did not change in the dry period, but rather its magnitude decrease from during the wet to dry transition.

DISCUSSION

This work focused on horizontal visibility data from ASECNA meteorological stations. It used visibilities as an indicator of windborne dusts variability. Previous works have shown that visibility is one of the major indicators of the evolution of the windborne dusts phenomenon. We have used horizontal visibility data to study spatial, seasonal and inter-annual variation of windborne dusts and their maximum emission locations.

The results showed that windborne dusts were more frequent and more severe on western coast of the Sahel, in the regions located between Mauritania and Mali, western Mauritania and upper part of Niger. The

maximum variability zone included largely Sahel (15° to 20° N). Stations in this region were characterised by suspended windborne dusts progressive reinforcement between 1970 and 1987, suggesting a new geographical distribution of dusts emission zones. Laurent et al. (2008) from modelling studies have shown that between 1996 and 2001, inter-annual variability emissions from sources in East Africa reached 60%, while emissions from sources in West Africa were regular from year to year with about 20% variation. This variation in emissions from sources in West Africa (Mauritania, Mali and Algeria) has been studied by Barkan et al. (2004) over 1979 to 1992 through TOMS (Total Ozone Mapping Spectrometer) AI (Aerosol Index). They showed that sources represented a discontinuity during 1983 to 1992 when ascending dusts were important. Their results corroborate those obtained by our study using horizontal visibility records from ASECNA synoptic stations. Moulin and Chiapello (2004) also showed that inter-annual changes in dust emissions over semi-arid regions such as the Sahel, could fundamentally be due to the combination of three factors that included: change in mean wind intensity (dynamic impact), change in dust particles washing (wet deposition) and change in soil characteristics as humidity, or vegetation cover (dry impact). They assumed that dry conditions in the Sahel beginning from 1980 may have deeply modified soil characteristics and created increase in dust emissions and transport over decadal scale. From Brooks (1999), it has been shown that inter-annual

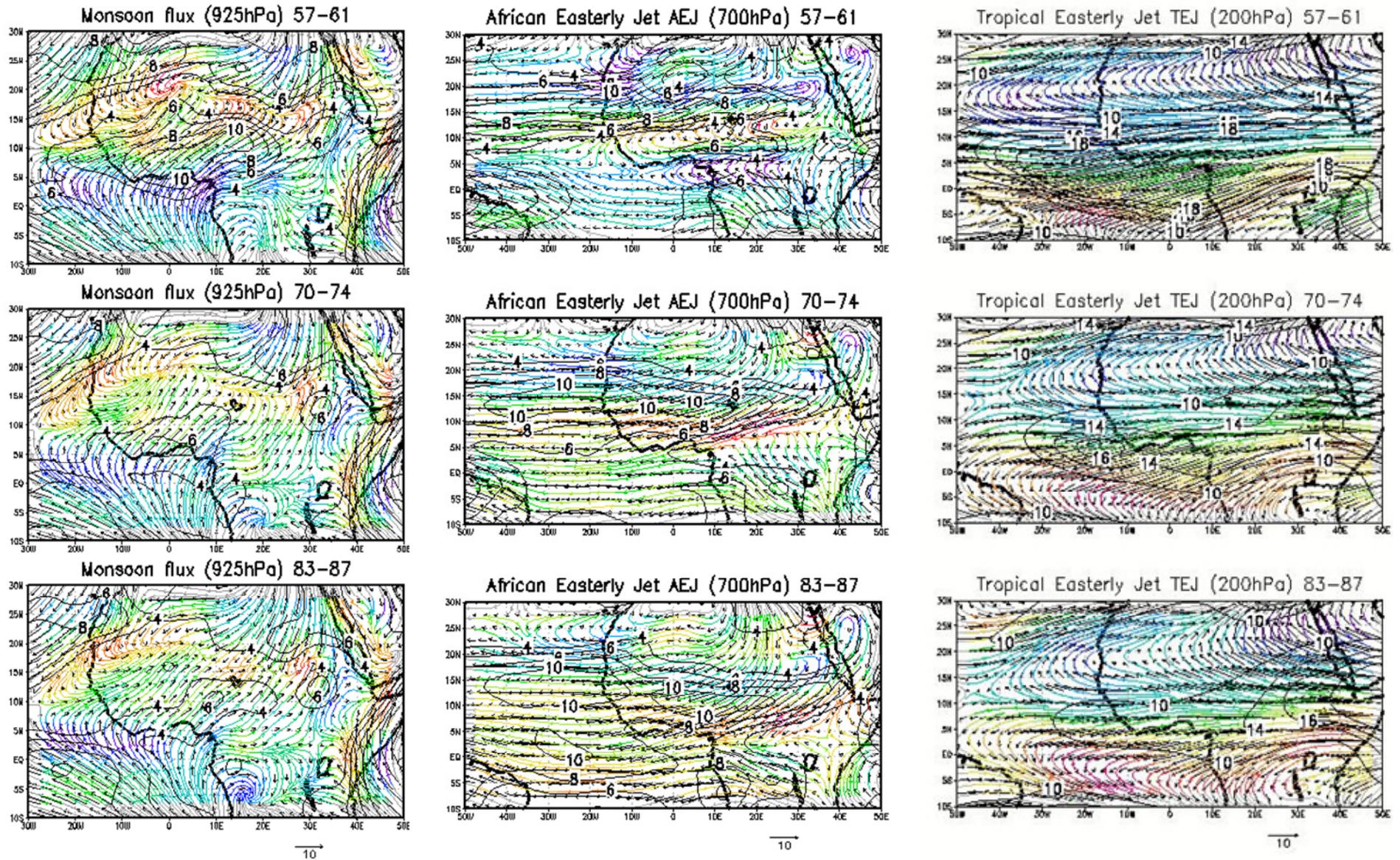


Figure 7. Mean field and wind module 925, 700 and 200 hPa respectively showing the evolution of the monsoon flow (left), AEJ (middle) and TEJ (right) during 1957 to 1961, 1970 to 1974 and 1983 to 1987 periods respectively from top to bottom. Unit is m/s for wind modulus.

variability seemed linked to extended dry periods which sustained the whole Sahelian zone since 1968. Furthermore, climatic analysis of dusty indicators suggested that the variability in the emissions of desert aerosols from North Africa was linked to meteorological changes through large scale where drought was one of the effects (Prospero and Nees, 1986; Moulin et al., 1997; Brooks and Legrand, 2000; Chiapello et al., 2005). For Ozer (2002), the northern Sahelian zone above 16° N was one of the largest mineral dust production regions following the high frequencies observed for deflation events. He assumed that the effects of drought were responsible for the new geographical distribution of wind erosion processes, decreasing soil humidity and vegetation cover.

From JFM to JAS, the evolution of the horizontal visibility showed that dust plumes were moved toward the north, reaching their northern locations in JAS. During OND, dust plumes were descended toward southern part. At the daily time scale, the evolution of the horizontal visibility was similar for each of the 3 daily time steps (0 to 6, 9 to 15 and 18 to 21 UTC). However, strong horizontal visibility reduction seemed clearly differentiated by a good continuity during several days. Seasonal emission of the dusts cycle in North Africa has also been studied by Prospero et al. (2002), Kaufman et al. (2005) and Evan et al. (2006). Their studies have shown that dust emissions over North Africa had a marked seasonal cycle with a maximum during boreal summer in JJA (June, July and August) and with a minimum during boreal winter DJF (December, January and February). Shannon (2009) suggested a maximum emission in Sahara during summer and minimum emission in Sahel during winter. This author explained these seasonal changes with the seasonal variability of wind speed and precipitations as a result of the North-South movement of the ITCZ.

The diurnal cycle of the emission of desert aerosols in northern Africa is still not well documented due to lack of sufficient frequent diurnal observations necessary for such studies. Most of the satellites observations dedicated to aerosol studies provided one or two measurement per day. Only synoptic data (visibility types or frequent dust events) constitute adapted measurements to diurnal emissions cycle studies (Bou Karam, 2008). However, this type of measurement is not adapted to spatial coverage. Also emissions representativeness largely depends on the station localisation compared with dust sources. In addition, during the monsoon season, density currents, coming from organised convective systems and propagating through Africa during several days, induce important dust rising over the Sahel during daily time as well as night time (Flamant et al., 2007).

Our results showed that an increase in precipitation and horizontal visibility was followed by a decrement, at least during June, July, August and September. We also observed a decrease in monthly rainfall amount

associated with the reduction in horizontal visibility from 1957 to 1961 and 1983 to 1987. We obtained correlation coefficients between rainfall amount and horizontal visibility of 0.72, 0.73 and 0.67 respectively for 1957 to 1961, 1970 to 1974 and 1983 to 1987. This implied a possible occurrence of a close link between rainfall and windborne dusts in the long term. The impact of dust on precipitations has also been shown although this is still not well understood. Climate models made improvement in their simulations when dust particles were considered (Fouquart et al., 1987; Tashima and Hartmann, 1999). Some previous works (Brooks, 1999; Prospero and Lamb, 2003; Chiapello et al., 2005; Evan et al., 2006) have been done on mineral dust inter-annual variability and correlation between Sahelian dry periods and dust concentrations in the atmosphere. These works found a negative correlation between mineral dust and rainfall over the Sahel, at different levels.

On the other hand, N'Tchayi (1992) showed that it was not possible to find a relationship between rainfall and desert aerosol production in the Sahelian desert regions where rainfall was almost absent but important desert dust amount emanate from. In these regions, aerosol production depends essentially on wind and the presence of fine particles that can be mobilised by wind. However, on annual scale, an increment in windborne dust frequencies was observed due to the dry period. Conversely, when rainfall amount was regular or had been exceeded, we obtained a moderate mineral aerosol production. N'Tchayi et al. (1994, 1997) revealed a continuous increment in annual dust rising events during dry periods. Other works have also shown that increment in aerosol amount in the atmosphere was connected to precipitation decrement in North Africa. Ozer (2001) has shown that the frequency of dust events in West Africa during dry seasons (January to April), increased by a factor of 10 between 1951 and 1997. In addition, Prospero and Nees (1986) also observed that mineral aerosols concentrations transported over Atlantic Ocean to Barbados had increased by a factor of 4. These increments in dust emissions were attributed to new source emergence linked to vegetation cover reduction (Tucker et al., 1991) and/or assigned to zone under climatic or anthropogenic perturbations (Tegen and Fung, 1995).

Windborne dusts emission magnitude in Sahelian zone during dry years (1970 to 1974 and 1983 to 1987) was associated with the weakness of the monsoon flow, AEJ reinforcement and weakness of the TEJ. Grist and Nicholson (2001) found that dry years in the Sahel were characterised by weak monsoon flow, a reinforcement of the AEJ in the south and weak TEJ, suggesting that considering dust in modelling results in a reduction in precipitation over the Sahelian region.

Conclusion

In this study, we used horizontal visibility data to explain

the spatial, seasonal and inter-annual variation of windborne dusts and their maximum emission locations. Moreover, reduction in horizontal visibility has been compared on the synoptic environment. The results revealed that windborne dusts were more frequent and intense on the western coast of the Sahel, in the regions located between Mauritania and Mali, western Mauritania and upper part of Niger. The maximum variability zone included largely Sahel (15°N to 20°N). This results are consistent with the conclusion of previous studies using the reduction in hourly number of visibilities (N'Tchayi, 1992; N'Tchayi et al., 1997), frequency of dusty days (Ozer, 2002), concentration of dust particles (Ozer, 2005; Ozer et al., 2007; Mahowald et al., 2007) or model simulations (Laurent et al., 2008). We showed that the magnitude of windborne dust emitted over the Sahelian zone during the dry years (1970 to 1974 and 1983 to 1987) was associated with a weak monsoon flow, AEJ reinforcement and weak TEJ. This work reveals the possibility to use horizontal visibility measurements obtained directly from meteorological stations, without other conversion to assess spatial and temporal variability of dust.

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