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Research Article

The 6-9-Day Wave and the Spatial Distribution of Air Temperature in Northern Africa in Summer: Inter - Annual Variability

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Abstract

The composite method is used to analyse 6-9 day waves and air temperature over North Africa during the summer of 1981-1990. Based on the daily outputs of the NCEP/NCAR reanalysis, the results of this study demonstrate that a large peak in the 6-9 days band (at 7.2 days) in the power spectra of the zonal wind component at 700 hPa during summer 1981 has been found. The waves were clearly visible in the filtered (around 7.2 days) and even in the unfiltered series of the zonal wind component. The structure of the 6-9 day waves shows two opposing circulation vortices on both sides of latitude 12.5N, with the maximum (minimum) temperature anomaly appearing around 15N - 25N above the equator. In addition, these vortices are associated with anomalies in the meridional component of the northerly (southerly) wind, which are respectively connected to the maximum (minimum) temperature anomalies. The spatial configuration of the waves also shows strong temperature modulations associated with the disturbed meridional component of the wind, mainly north of 20°N, and for summers when these waves are very active, there is an opposition of signs between the temperature anomalies to the north-east and to the north-west in the areas of the Libyan and Azores highs. Due to the strong influences of the Libyan and Azores highs, a distribution of opposite surface level pressure (SLP) values is also observed. On the contrary, when these waves were not active, this opposition of signs in the composite of the air temperature anomalies did not exist and the isopleths tended to be paralleled to the parallels of latitude, and the filtered SLP anomalies had the same sing in the two anticyclones areas. Thus, the appearance and/or activity of the 6 to 9 day waves could be linked to the existence of a phase opposition between these two anticyclones. This study reinforces our understanding of the involvement of atmospheric dynamic and thermodynamic processes in the variation and evolution of waves in North Africa.

Keywords

Atmospheric Waves, Air Temperature Anomalies, Cyclonic, Anticyclonic Vortices

1. Introduction

The easterly waves commonly called African waves with 3-5-days period have been one of the main topics for many studies in northern Africa. Duvel [1], Lenouo et al. [2], Lenouo and Mkankam [3], Créat et al. [4], Enyew and Mekonnen [5] and many others, have studied these westward propagating waves and found that they appear clearly at 700

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and 850 hPa with a wavelength of 2000-3000 km and a phase velocity around 8 m s^{-1}.

Another type of westward propagating waves with a period of 6-9 days, a wavelength of about 5000-6000 km and a phase velocity around 7°longitude per day, had been identified in this region at the same levels. De Felice et al. [6] have shown that lower and middle troposphere waves with that same period moved westward during summer in northern Africa. Viltard et al. [7] showed that these waves are very different from the African waves. Several studies, Diedhiou et al. [8], Viltard et al. [9] established a link between these waves pattern and rainfall in West Africa. Oubuih et al. [10] and Diedhiou et al. [11], applied a composite method to the NCEP/NCAR (National Center for Environmental Prediction / National Center for Atmospheric Research) reanalyses, and noted that the air temperature was also affected by these waves. But the composite method used (this method is described in [6, 1]) did not show the spatial distribution of air temperature in both latitude and longitude directions. All the works done on the 6-9-day waves mentioned the intermittency of these phenomena. But none of these different studies investigated the inter-annual variability. For example, since they are intermittent, differences on their influences on the temperature distribution may probably occur between years where they are very active than other years.

This paper studies the spatial distribution in latitude and longitude, of temperature in northern Africa in connection with the 6-9-day waves, for several summers (1 June to 30 September). The NCEP/NCAR reanalyses have been used for the period 1981–1990. This dataset consists of a reanalysis of global observational network of meteorological variables (wind, air temperature, geopotential height, humidity on pressure levels, and surface and flux variables) with a “frozen” state–of–the–art analysis and forecast system of the NCEP at a triangular spectral truncation of T62 ([12]). Data are reported on a 2.5°x 2.5°grid every 6 hours (00.00, 06.00, 12.00 and 18.00 UTC), in 17 pressure levels from 1000 to 10 hPa, which are good resolutions for the study of the 6-9-day waves. We also used the NCEP/NCAR daily sea level pressure (SLP) for the 10 summers.

In the next section, we determine and describe the wave structure and the associated air temperature anomalies during summer 1981 where the 6-9-day phenomena were very active ([6, 13, 14]). In section 3, we determine the spatial pattern on the wind field and the distribution of air temperature anomalies; we investigate the inter-annual variability of the air temperature in connection with these waves, throughout the period 1981-1990.

2. The 6-9-Day Wave Structure and Temperature Modulation

2.1. Spectral Analysis and Evidence of the 6-9-Day Wave

To determine the parameter, the level and the latitude where the 6-9-day waves had large amplitudes, Monkam [15] and De Felice et al. [6] computed the ratios of the root-mean-square (rms) of the series filtered around that period by the rms of the unfiltered series for each parameter at each grid point and level, for summers wouldn’t it be for 1981-82 and 1985-87. They found the largest ratio on the zonal wind component, at the level 700 hPa and the latitude 12.5°N, during summer 1981.

In this work, we computed the power spectra of zonal and meridional wind components and air temperature at each grid point, for summers 1981 to 1990, and we found that, on the whole, the peaks in the 6-9 days band were most prominent during summer 1981 mainly for the zonal wind component at 700 hPa. This is in agreement with the results of the above authors. Figure 1 displays the mean power spectra of the zonal wind component computed along the 12.5°N latitudinal circle, between 20°W and 0°E for the whole summer of 1981, at 700 hPa level. The largest peak (significant at 90% confidence level) is at the 7.2 days period.

We filtered the signal with a band pass filter centered at 7.2 days. Figure 2 displays the filtered and unfiltered zonal wind component at 700 hPa level for the grid point 12.5°N, 10°W. The 6-9-day waves appear clearly even in the unfiltered data. Between 17 June and 5 September, there are 11 dates of maximum (for 10 waves) at 17, 25, 34, 41, 48, 54, 61, 68, 75, 83, 91, where the filtered zonal wind component is greater than 1.5 m.s^{-1}. The difference between two successive dates is equal to 6, 7, 8 or 9 days, belonging to the 6-9 days band. Many other grid points at 12.5°N had similar results (not shown). In general, between 17 June and 5 September, there are about 8-10 regular and rather large waves in the band of latitudes 5°N-20°N.

2.2. Wave Structure and Temperature Modulation

The composite method has been used to determine the wave structure and the associated temperature modulation. Monkam ([14, 15]) and De Felice et al. ([6]) described this method in some details. It is closed to the method used by Reed and Recker ([16]) and by Burpee ([17]). From the spectral analysis and numerical filtering seen above, we choose the filtered zonal wind component, at the level 700 hPa and the latitude 12.5°N, where the 6-9-day wave had large or rather very large amplitude as the reference parameter, level and latitude (see Figures 1 and 2), respectively. In this way we compose the wave, dividing it into eight categories in the time interval 17 June to 5 September. Category 1 dates are associated with maximum westerly wind and category 5 dates with maximum easterly wind. The dates of categories 2, 3 and 4 are at a quarter, half and three quarters, respectively, of the interval between category 1 and the following category 5. The dates of categories 6, 7 and 8 are at a quarter, half and three quarters, respectively, of the interval between category 5 and category 1 of the following wave. After estimating the value of each parameter for each category for all the waves of the time interval 17 June to 5 September, the mean values are computed for each grid point over all the waves of this time interval. So, as there are about 10 waves of 6-9 days period in this time interval, at each grid point a mean time–composite wave is obtained where the value at each category is a mean of 10 values. Then a mean composite wave is computed at each latitude over the grid points of the latitude. With 10 waves in the time interval and 18 grid points at each latitude between 20°W and 22.5°E, each composite value is a mean of 10 × 18 = 180 values. We applied this composite method to the data series of wind components and temperature anomalies obtained at each grid point by subtracting the mean of summer. So, the filtered zonal wind component at the level 700 hPa and the latitude 12.5°N, was used only to determine the dates of categories.

Figure 3 displays the wave structure and the associated of the air temperature modulation at 700 hPa level during the summer of 1981. The maximum wind vector anomaly is 4.0 m s^{-1}. The zonal wind component was strongly affected by the 6-9-day wave towards the band of latitudes 10°N-13°N. There are two vortices of opposite circulations north and south of 12.5°N. In the north, an anticyclonic (cyclonic) vortex on categories 4-6 (8-2), is centred at 17.5°N. The composite air temperature anomalies are rather small (0.4 to 0.6°C). This is typical of the tropical troposphere. Oubuih et al. ([10]) found similar values. The maximum (minimum) air temperature anomaly of about 0 to 0.6°C (–0.4°C to –0.3°C) appears at 16°N –26°N, associated with northerly (southerly) wind anomaly, towards the core of the anticyclonic (cyclonic) vortex. The meridional air temperature gradient is weak at the reference latitude 12.5°N close to the ITCZ (inter tropical convergence zone) mean position where the zonal wind anomaly is maximum. This air temperature anomaly pattern is very different to the mean field on which, in general, the isolines are parallel to the parallels of latitude and the air temperatures increase from south to north, in summer.

So, figure 3 illustrates that the air temperature is affected by the 6-9-day waves. We propose, in the next section, to study the spatial variation and identify the zones of impact of these 6-9-day waves on the spatial distribution of this variable in the studied area.

3. The 6-9-Day Wave Spatial Pattern and Spatial Distribution of Temperature

3.1. Spatial Pattern and Air Temperature Anomaly in the Summer of 1981

To study the variability of the 6-9-day waves and examine their effects on the spatial distribution of air temperature, we used another composite method close to the previous one, but showing both latitudinal and longitudinal mean variations of parameters. For this purpose, we filtered the daily June-September 700 hPa zonal wind component time series of each grid point of the reference latitude 12.5°N with the band pass filter centered at 7.2 days. Then, for each of the filtered series (each grid point or reference point of the latitude 12.5°N), we selected the days (or dates) where the filtered 700 hPa zonal wind component is maximum with an amplitude equal or greater than 0.5 m s^{-1}. We computed for each grid point of the studied area, the mean of a given parameter or its anomaly (the zonal and meridional wind components, the air temperature, between others) over all the dates selected at each reference point. Finally, we computed the mean over all the reference points of the reference latitude. By selecting such a threshold of 0.5 m s^{-1}, a large number of cases and the composite fields obtained are very stable. For example in 1981 at the reference latitude 12.5°N and level 700 hPa (Figure 4), we found 247 cases for the 18 grid points from 20°W to 22.5°E.

When analyzing the spatial composite pattern of wind vector anomalies and stream lines (Figure 4a) and the associated field of the air temperature anomalies (Figure 4b) at 700 hPa for summer 1981. Maximum wind vector anomaly of 3.4 m s^{-1} is observed. There is a large modulation of the zonal wind component west of the Greenwich meridian, with circulations of opposite signs on either side of the African Easterly Jet (AEJ) location at 10°N –15°N, clearly visible on the stream lines (Figure 4a). Two cyclonic vortices appear in the ITCZ band in which Monkam ([14]) mentioned a strong rainfall modulation by the 6 –9-day waves. West of the Greenwich meridian, there are two vortices of opposite circulation on either side of latitude 17.5°N. Diedhiou et al. ([8]) indicated that this latitude 17.5°N, is the latitude of the mean track of these 6-9-day waves.

The air temperature anomaly (see Figure 4b) is negative south of 12.5°N, around the ITCZ mean position. There are two zones of minimum: one of about-0.3°C at 12.5°N-25°N, 10°W-0°, towards Mauritania and Mali, probably in connection with the West Africa monsoon. The other one at 20°N-30°N, 15°E-22.5°E, in Libya, in the north-east part of the studied area, which could be related to the Libyan anticyclone. A maximum of about 0.4°C appears at 25°N-30°N, 20°W-0°, towards Algeria and Morocco, in the north–west part of the area, probably associated with the Azores anticyclone. There is a close link between the air temperature anomalies and the wave spatial pattern on the wind field, mainly north of 20°N: this maximum anomaly in the north-west is associated with the anticyclonic vortex and the minimum in the north-east is located in the northern branches of a cyclonic vortex observed in figure 4a. In the 850 to 500 hPa (not shown) layer, the main tendencies of 700 hPa are reproduced.

The westward propagation of the 6-9-day wave and the air temperature modulation are also clearly visible on the Hovmöller diagrams of the filtered zonal wind component and temperature (example: Figure 5 obtained at the level 700 hPa and the latitude 12.5°N). Figure 5a shows alternatively positive and negative zonal wind component (moving westward).

They are very regular and large with amplitudes of about 4 m s^{-1}. This westward propagation is also obvious on Figure 5b showing alternatively positive and negative air temperatures, whit a maximum anomaly is around 0.8 °C. Whereas, the mean phase velocity is of about 6-7 °longitude per day.

To confirm the results above, we used the Wallace et al's ([18]) method that aims to determine the kinematics properties of undulatory perturbations by means of coefficients of correlation. Diedhiou et al. ([8]) applied this method on the wind fields to study the easterly waves over West Africa and tropical Atlantic. From these works, we filtered (in the 6-9-day band) the June-September time series of the air temperature at 17.5 °N/0 °E ([8] used this grid point to apply the method). Following the Wallace et al's ([18]) method, we computed the correlations between this filtered grid point series and the overall grid points time series of unfiltered temperature with -1, 0 and +1 day lags. Figure 6 displays the fields of correlations at 700 hPa level during summer 1981 (a correlation of 0.2 is significant at 95% confidence level). It is observed a westward propagation of the maximum correlation indicated on the Figure 6 by «M», from 17.5 °N/5 °E (correlation = 0.55) at t-1 to 17.5 °N-20 °N/5 °W (0.50) at t + 1. This gives a local (relative to the grid point 17.5 °N/0 °E) velocity of about 5 °longitude per day or 6.5 m s^{-1}. The local wavelength is deduced from the distance between the longitudes of the two nearest negative extremes of correlations east and west of the maximum at the same latitude, at t=0. So, at 16 °N–17.5 °N, these minima indicated by «m», are towards 17.5 °E–20 °E and 25 °W-27.5 °W and the maximum («M») is at 0 °E. Hence, the local wavelength is around 45 °longitude or 5000 km. Finally, the air temperature modulation by the 6-9-day waves is obvious with the Wallace et al's ([18]) method. The westward propagation is clearly shown and the kinematics characteristics found are the same as those usually attributable to these waves ([14, 15, 6, 13, 19, 8]).

3.2. Inter-Annual Variability of the Air Temperature in Connection with the 6-9-Day Wave

To examine the inter-annual variability, we established the spatial composite patterns of the air temperature anomalies for summers 1982-90, as in 1981. But to save space we computed two mean patterns: one for the summers where these waves were active and the other one when they were weak. For this purpose, we computed the mean power spectra of the zonal wind component along the 12.5 °N latitudinal circle, between 20 °W and 22.5 °E (18 grid points), at 700 hPa level for each summer. Then, from the mean power spectra, we determined the percentage of variance in the 6-9-day band-period for each summer. There are about 7 harmonics in this band-period. So, we computed the sum of spectral energy fractions of the 7 harmonics. From 1981 to 1990, we found 13.5, 4.9, 7.3, 9.7, 8.1, 7.4, 5.2, 10.9, 15.0 and 6.1%, respectively. We selected the years (1982, 1983, 1986, 1987 and 1990) having weak percentages of variance (<7.5% for example). Figure 7a displays the mean composite pattern over the 5 years. The air temperature anomaly is negative south of 7°N and west of the Greenwich meridian and positive from 7°N to 30°N in the major part of the studied area. The general tendency is very different to summer 1981. There is no contrast of anomalies between the north-east and the north-west parts of the studied area. On the whole, the isolines tend to be parallel to the parallels of the latitude. Figure 7b displays the mean composite pattern of 4 summers (1981, 1984, 1988 and 1989) having large percentages of variance (>9.5% for example). The anomalies are negative east of 5°E from 0 °N up to about 26 °N, and between 15°N and 26°N there is a minimum contrasting with a maximum in the north-west within the zone of Azores anticyclone, as in Figure 4b corresponding to summer 1981.

Finally, the air temperature modulation depends on the wave activities in each summer. For the years where the 6-9-days waves were not very active, the anomalies were positive north of a latitude around 10°N and negative in the south, from east to west of the studied area. On the contrary, when the waves were very active, the anomalies were negative (positive) east (west), in the band of latitudes 20°N-26°N; then there was a contrast anomalies between the areas of Libyan (east) and Azores (west) anticyclones (see Figures 4b and Figure 7b).

3.3. Figures

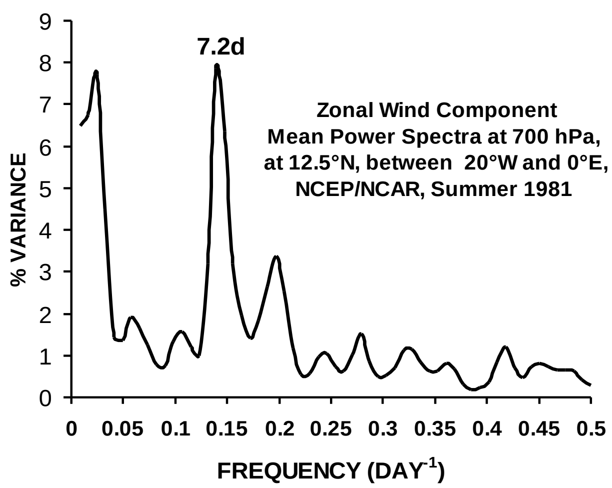


Figure 1. *Zonal wind mean power spectra at 12.5 °N, between 20 °W and 0 °E, 700 hPa, summer 1981, with 90% confidence interval.*

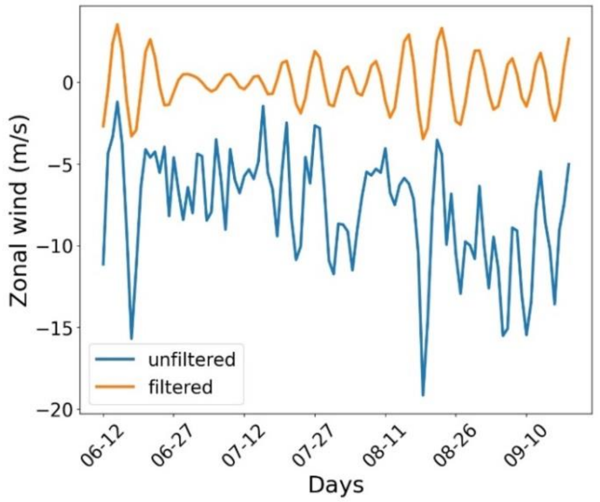


Figure 2. zonal wind component (positive eastward) at 700 hPa level at the grid point (12.5°N, 10°W) during summer 1981. Thin line: unfiltered data of the NCEP/NCAR model; thick line: filtered by a band-pass filter around 7.2 days from day 12 (12 June) to day 111 (19 September).

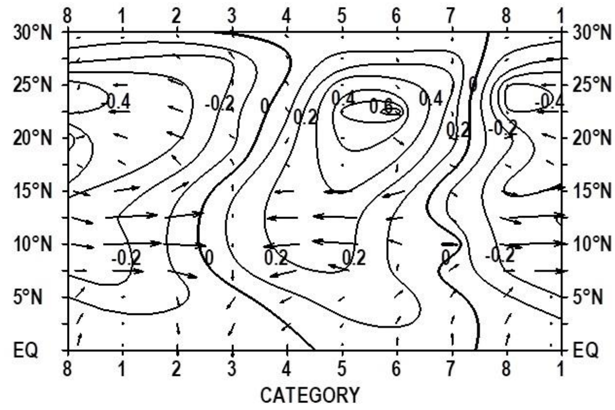
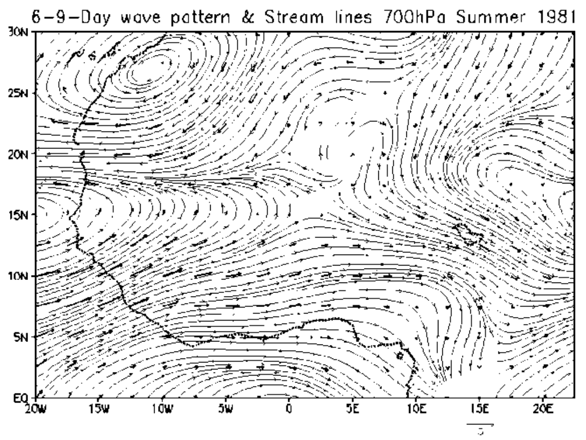


Figure 3. The 6-9-day composite wave for wind vector and air temperature anomalies at 700 hPa level during summer 1981. The composites were computed using the category dates determined from the filtered zonal wind component at the reference level 700 hPa and latitude 12.5°N. The maximum wind vector is 4.0 m s^{-1}. The iso-lines of air temperature anomalies are in °C; the maximum (minimum) value is around 0.6°C (– 0.4°C).



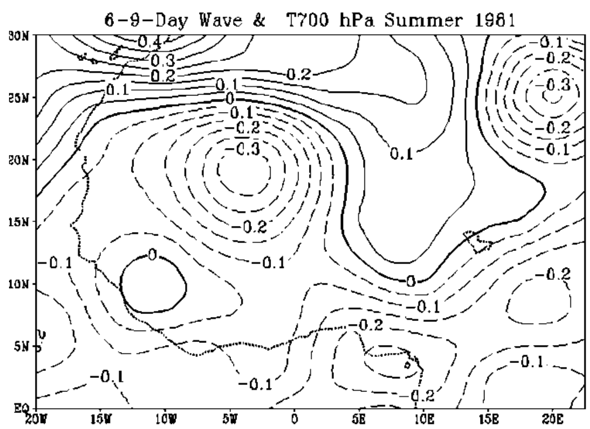


Figure 4. Spatial pattern of the 6-9-day wave and the associated distribution of air temperature at 700 hPa in summer 1981. The composites were computed by selecting the dates where the filtered 700 hPa zonal wind is maximum and equal or greater than 0.5 m s^{-1} at 18 reference points of the reference latitude 12.5°N from 20°W to 22.5°E. The mean of anomalies of a parameter is computed at each grid point over the dates selected for each reference point; finally the mean is computed over all the reference points (see text for more explanations). a) Wind vector anomalies with stream lines: Vmax = 3.4 m.s^{-1}; b) Air temperature anomalies: Unit: °C.

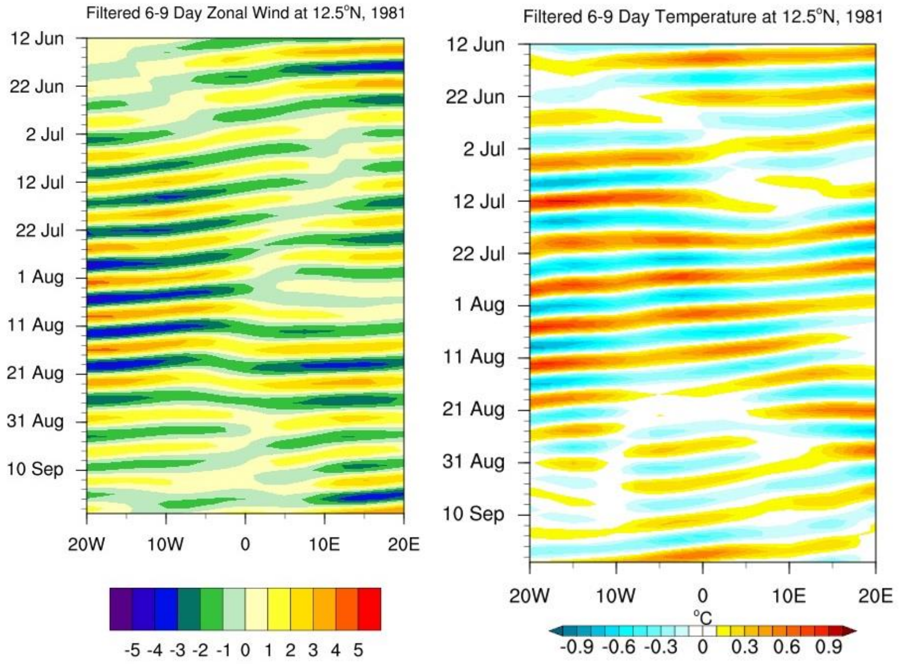


Figure 5. *Hovmöller diagrams of the 6-9-day filtered zonal wind component (a) and air temperature (b) at 12.5°N, 700 hPa, for summer 1981; for the sake of clearness only the positive isolignes have been drawn, contour interval is 2 m s^{-1} for the zonal wind component and 0.4°C for the air temperature.*

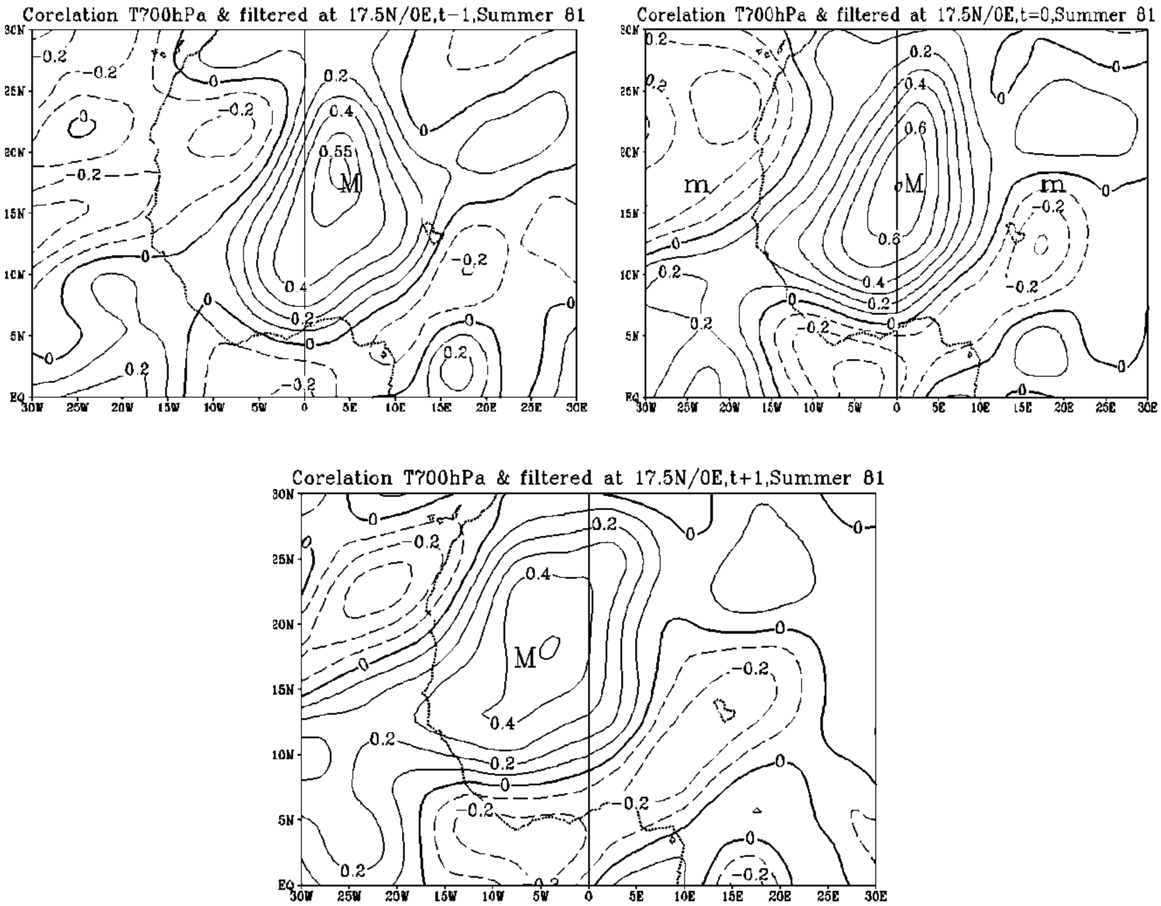


Figure 6. *Correlations between this filtered air temperature series at the grid point 17.5°N/5°E and the overall grid points time series of unfiltered air temperature with –1, 0 and +1 day lags, at 700 series at the grid point 17.5°N/5°E and the overall grid points time series of unfiltered air temperature with –1, 0 and +1 day lags, at 700 hPa level for summer 1981.*

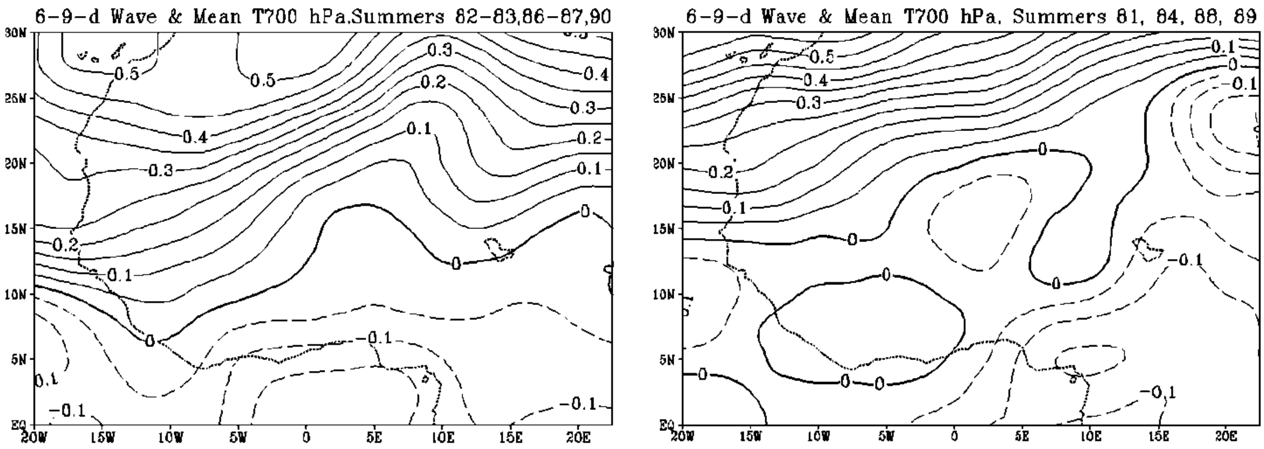


Figure 7. *Zonal a) The mean composite variability of air temperature anomalies at 700 hPa for the 6-9-day waves for summers 1982-83, 86-87, 90. The composites were computed each year by selecting the dates where the filtered 700 hPa zonal wind is maximum and equal or greater than 0.5 m s^{-1} at 18 reference points of the reference latitude 12.5 °N from 20 °W to 22.5 °E. The mean of air temperature anomalies is computed at each grid point over the dates selected for each reference point. Then the mean is computed over all the reference points. Finally the mean composite pattern is computed over the 5 summers Unit: °C; b) same as figure 7a, but for summers 1981, 84, 88, 89.*

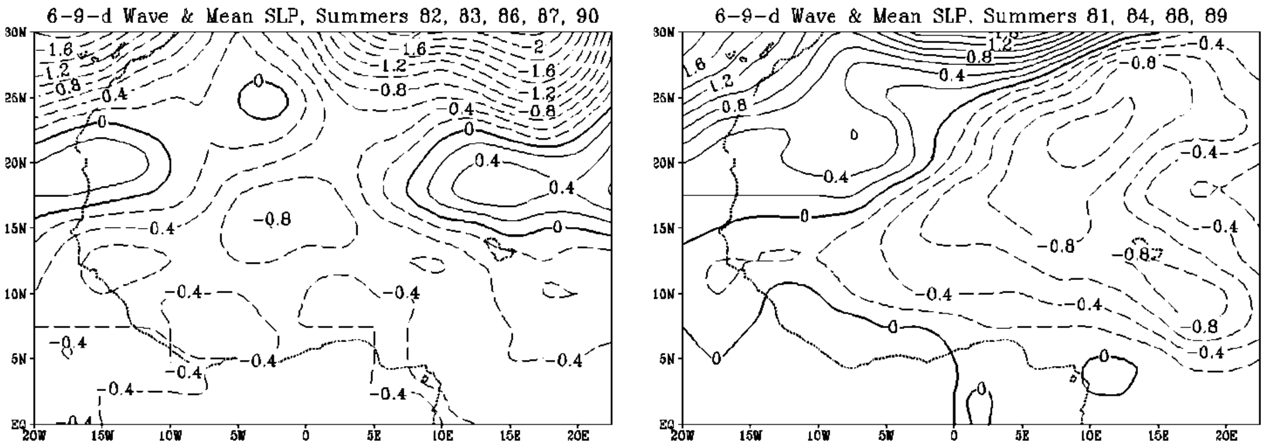


Figure 8. *Mean Sea Level Pressure (SLP) filtered by a band-pass filter around 7.2 days. Unit: Pa: a) summers 1982-83, 86-87, 90; b) summers 1981, 84, 88-89.*

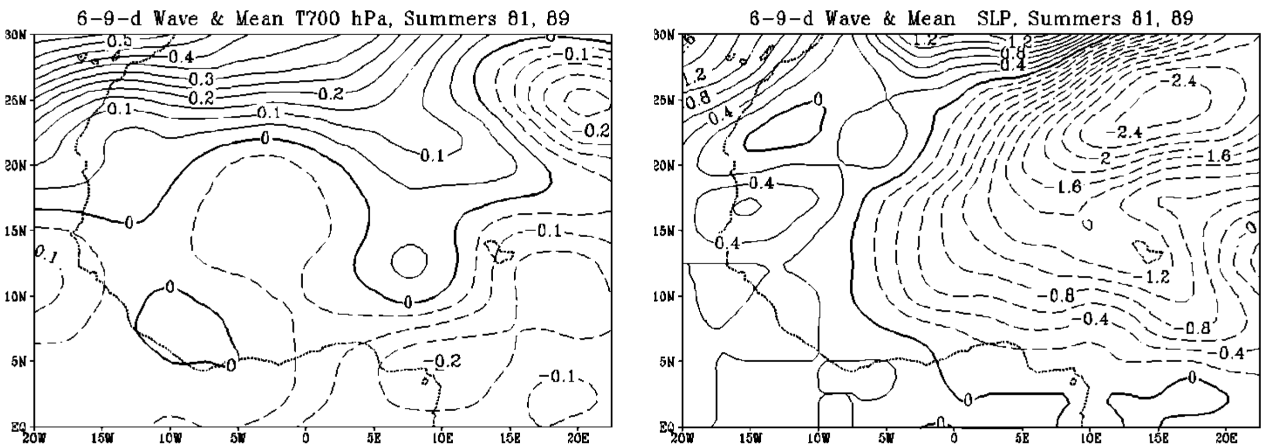


Figure 9. *a) Mean composite of air temperature anomalies as figure 7 but for summers 1981 and 89; b) mean filtered SLP as figure 8 but for summers 1981 and 89.*

4. Discussion

In the composite 6-9-day wave structure, between 10 °N and 20 °N, the air temperature anomaly is maximum on categories 6-1 where the meridional wind component is directed towards the ITCZ, and minimum on categories 2-4 where the meridional wind anomaly diverges from the ITCZ. The agreement between meridional wind component and temperature anomalies implies that: when the wind blows from the ITCZ, it brings cool air; and when the wind blows toward the ITCZ, it brings warm air. This agreement between temperature of air and meridional wind component anomalies is a support to the effects of the 6-9-day waves. Indeed, since the composited values were not filtered, if the wave did not affect air temperature, its anomaly isopleths would be almost parallel to parallels of latitude. The pattern of this anomaly (Figure 3) is consistent with the effects of the 6-9-day waves: the maximum (minimum) of the air temperature anomaly appears at 18°N-25°N, where the northerly (southerly) meridional wind component anomaly is maximum; Diedhiou et al. ([8]) noted that the latitude 17.5°N corresponds to the latitude of the mean track of these 6-9-day waves.

The spatial variability patterns display a large meridional extension of negative air temperature anomalies associated with the African monsoon. Towards 25°N-30°N, the anomalies have opposite signs east and west of the area, within the Libyan and Azores anticyclones zones (Figure 4 a, b). A strong modulation of the air temperature, in connection with the 6-9-day wave activities was found during summer 1981. This configuration also appears clearly on the mean pattern for summers 1981, 1984, 1988 and 1989 (Figure 7b) where large percentages of variance were found in 6–9 days band-period on the power spectra of the zonal wind component. On the contrary, the temperature modulation was weak on the mean pattern for summers 1982-83, 86-87 and 90 where the 6-9-day waves were weak (see Figure 7a). In this figure, the isoanomaly tend to be paralleled to the parallels of latitude. So, as the waves were not active, their effects on the air temperature were rather weak. In the south of the studied area, the zone of negative isoanomaly, generally related to the African monsoon, had a weak meridional extension. In the north, there was no contrast between air temperature anomalies in the Azores and Libyan anticyclones zones.

These results confirm the intermittency of the 6-9-day waves. De Felice et al. ([13]) found a large peak in the 6-9 days band on the power spectrum of the zonal wind component in Dakar at 700 hPa level during summer 1960, whereas there was no large peak in this band for the summers of 1958, 1959, 1961, 1962 and 1963. The authors suggested that the intermittency of the 6-9-day waves might be linked to the zonal wind meridional profile. Monkam ([14]) computed the mean meridional profiles of the zonal wind component for summers 1981 to 1986, between 30°N and the equator for the longitudes 20°W to 22.5°E (18 grid points) and found the same overall tendency for the six years. The profiles shown by the author for 1981 and 1982 were almost identical, whereas the waves were very active in 1981 and weak in 1982. So, the occurrence or the intermittency of the 6-9-day waves would not depend only on the zonal wind profile.

Diedhiou et al. ([20]) computed the meridional cross sections, at 10°W and 10°E from 10°S to 30°N, of the mean variance for the filtered 6-9-day series of the air temperature in August-September 1979 to 1995, and found a maximum between 25°N and 30°N in the layer 1000-700 hPa. In the present work, we found a contrast on the mean composite of the air temperature anomalies at 700 hPa, between the Azores and Libyan anticyclones zones, during the summers where the 6-9-day waves were active (Figure 7b). The two anticyclones action centres are around the band of latitude 20°N-30°N, towards the two meridians 10°W and 10°E. The results of these two studies suggest the influence of the two anticyclones on the development of the 6-9-day waves. To examine this suggestion, we analysed the sea level pressure (SLP) data series by filtering around 7.2 days, the SLP anomalies for summers 1981 to 1990. Figure 8a displays the mean field for 1982, 1983, 1986, 1987 and 1990 when the waves were weak and figure 8b that of 1981, 1984, 1988 and 1989 when they were active, as was done for the composite of temperature anomalies (Figures 7a and 7b). In figure 8a, the SLP are negative between 25 °N and 30 °N from east to west and in the major part of the studied area. On the contrary, figure 8b shows two zones with opposite SLP north of 15 °N: one east of 10 °E in the Libyan anticyclone area with negative values and the other one west of 10 °W in the Azores anticyclone zone with positive values. So, figures. 8a and 8b are in agreement with figures 7a and 7b, respectively. Thus, the 6-9-day waves would be active when there is an opposition of phase between these two anticyclones. We computed the mean composite of the air temperature anomalies (Figure 9a) and the mean filtered SLP (Figure 9b) for summers 1981 and 1989 having the greatest percentages of variance (>13%). For these two summers where the 6-9-day waves were very active, the opposition of sings in the Libyan and the Azores anticyclones areas, were more marked on temperature (Figure 9a) and SLP (Figure 9b).

5. Conclusions

In this work, we have investigated the 6-9-day waves and of the air temperature modulation in northern Africa in summer. We found a large peak in the 6-9 days band (at 7.2 days) in the power spectra of the zonal wind component at 700 hPa during summer 1981. The waves were clearly visible in the filtered (around 7.2 days) and even in the unfiltered series of the zonal wind component. The wave structure obtained using a composite method, displays two vortices of opposite circulation on either sides of the latitude 12.5°N. The of air temperature modulation is clearly visible in this structure. Its maximum (minimum) anomaly appears towards 15°N-25°N associated with northerly (southerly) meridional wind component anomalies.

The westward propagation with a velocity of about 5-7° longitude per day and a wavelength around 5000 km, has been shown by means of the Hovmöller diagrams of filtered series of the air temperature and zonal wind component; and also with the fields of correlations between a filtered grid point series of air temperature and the overall grid points time series of unfiltered temperature for the time sequence day-1/day, 0/day, day+1/day.

The spatial variability has shown that, in general, the of air temperature anomalies are negative south of the area, probably in connection with the African monsoon. From the study of the inter-annual variability, it was noted that the distribution of their anomalies depends on the waves activities. For the summers where the 6-9-day waves were very active, the air temperature anomalies had opposite signs in the north-east and north-west parts of the studied area, within the zones of influence of Libyan and Azores anticyclones, and the filtered SLP anomalies had opposite signs towards these anticyclones action centres. On the contrary, when these waves were not active this opposition of signs in the composite of the air temperature anomalies did not exist and the isopleths tended to be paralleled to the parallels of latitude, and the filtered SLP anomalies had the same sing in the two anticyclones areas. So, the occurrence or/and the activities of the 6-9-day waves, could be linked to the existence of the opposition of phase between these two anticyclones. However, further investigations would be necessary to take into account the effect of the African monsoon in the south of the area.

Abbreviations

SLP Sea Level Pressure

Author Contributions

Zephirin Yepdo-Djomou: Conceptualization, Resources, Data curation, Methodology

David Monkam: Formal Analysis, Investigation

Conflicts of Interest

The authors declare no conflicts of interest.

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