Research Journal of

Environmental Sciences

ISSN 1819-3412

Academic Journals Inc.

www.academicjournals.com

Research Journal of Environmental Sciences 5 (12): 850-866, 2011
ISSN 1819-3412 / DOI: 10.3923/rjes.2011.850.866

Atmospheric Dynamic and Raining Mechanisms in the Congo Basin

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ABSTRACT
The Congo basin located between 10°N and 10°S of latitudes and 8° and 30°E of the longitudes and it is the unique zone in Africa where the Inter-Tropical Convergence Zone (ITCZ) is difficult to locate on the low layer. The Congo basin, like the Amazona, plays an important role in the dynamics especially towards the climatic change which is at the moment a preoccupation of the international community. The presence of the Mayombe (800 m) and Nabemba (1000 m) mountains, do not prevent the penetration in the Congo basin, outside influences; it presents complex climatic or meteorological characteristics. To realize this study, we used NCEP/NCAR Reanalysis data. The Congo basin lies on to both hemispheres; we examined the atmospheric dynamic in the step of seasonal time by making a astronomical seasonal division (DJF, MAM, JJA and SON). The average climatic characteristic situations pointed out in January (DJF season) and in July (JJA season); the extreme positions of the centres of action in these periods justify this dynamics. In surface, we note the presence of a vast barometric marsh during the season DJF. In the low layers the anticyclone of Ste-Hélène plays an important role in the circulation of the air masses.

Keys words: Congo basin, atmospheric dynamic, raining mechanisms

INTRODUCTION
The atmospheric dynamic is well studied today in Inter-Tropical zone. However, it remains rudimentary in the Congo basin. From its geographic position between the 10°N and 10°S latitudes and the 8 and 30°E longitudes, this basin show a pressure or an atmospheric traffic complexity. The Congo basin is the unique zone in Africa where precisely in the Inter Tropical zone, where the Inter-Tropical Convergence Zone (ITCZ) is not easily locatable on the ground. However, it is one of the determining elements to characterize of the seasonal rhythm of the InterTropical world. The works of Hills (1979), Leroux (1980), Janicot and Fontaine (1993), Nicholson (2000) and Nicholson and Grist (2003) for western Africa, of Back and Bretherton (2005) for the American zone were precisely devoted to the ITCZ or the atmospheric dynamic. The scarcity of documents on the atmospheric dynamics in the Congo basin limits the understanding of distributions of the precipitations. This Congo basin, as well as the Amazon, constitutes a zone of high importance in the climatic dynamic (low pressures, detention of the CO_2, refill humidity in the atmosphere, etc.) especially in a current context of global climatic change.

In spite of significant progress in the use of data stemming from measures or from satellites estimations of the last twenty years, the dynamic in the Congo basin is evoked only in the works having an African regional character of Leroux (1975, 1980), Suchel (1988). The landscape around the basin (200-500 m) does not protect it from outside streams; indeed it is limited in the East by the rift valley (3000-4500 m) or the ropemaker of the big lakes, in the South by mountain range (1000 m), to the North by plateaus the South Cameroon, Nabemba Mountain (1000 m), on the West by the mountain range of Mayombe (800 m) and the sector lake Moéro (1600 m). This basin, also called the Congo Washbasin remains widely opened to the penetration of the outside influences and the traffic of streams is freely made there. The Congo basin is under multiple influences, even if they can constitute an obstacle on the scale of the topoclimat with regard to the transfer of the humidity of oceanic origin. The action of the mountain range of Mayombe, for example, is double: when its direction is close to the orthogonal with regard to the trajectory of the stream, it provokes the orographic haste and it besides limits the thickness of the humid coat which penetrates in the continent, the thickness which is function of the height of the inversion within the stream and within the height of the considered relief.

The Congo basin seems to be the seat of convergence between the stream of northeast wind and the stream of oceanic air mass (Atlantic and Indian). From previous works of Leroux (1980), Nicholson (2000), of Okoola and Ambenje (2003), the ITCZ in the Congo basin would take a meridian direction during a long period of the year. This configuration should create an East-west movement of the ITCZ in the Congo basin. In most of the previous works, data of direct observation were used with a less dense network. The advantage in this work lies in the use NCEP/NCAR re-analysis data, in spite of problems that it poses their resolution is better with incomplete and less homogeneous series.

This zone of Africa presents complex climatic or meteorological characteristics: it constitutes a zone where the distribution of rains or rainfalls structures lack spatial coherence in the synoptic scale (Moron, 1994; Bigot *et al.*, 1997). Would his meteorological and climatic complexity be linked to the atmospheric dynamics where juxtapose low pressures, barometrics winds are permanently juxtaposed and ITCZ which would take a meridian direction.

The purpose of this study was to document the actual atmospheric dynamics field season pressure, low level atmospheric circulation and discontinuities. Although some results have been achieved in the Congo basin on the basis for selected seasons.

MATERIALS AND METHODS

We used the National Center for Environment Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis data recently made available during the period of 1979-2000. The NCEP/NCAR database contains reanalysed data of the global observational network of several meteorological variables (pressure levels, geopontential, such a wind). Data are reported on a 2.5°×2.5° grid on 17 levels from 1000 to 10 hPa. For our purpose, we have selected data over the 20°W-30E/30°S-15°N area on 10 pressure levels from 1000 to 200 hPa, namely the geopotential height, zonal and meridional wind.

Here we apply the same technic as the NCEP/NCAR reanalysis zonal mean zonal winds. The time period that is coves is January 1979 December 2000; data before this time period were not used because of problems with the reanalysis in the stratosphere before the incorporation of satellite data in 1979 (Randel *et al.*, 2000; Haigh *et al.*, 2005). All data and indices are monthly and (where appropriate) zonally averaged and the analysis is carried out separately at each point on a grid of 73 latitudes and 17 isobaric levels.

In this study the examination of the atmospheric dynamic is set at the seasonal time interval. We, used, the astronomical seasonal division, given that the basin an extension on both sides of the equator: the first season is DJF (the Southern summer or boreal winter), the second season is MAM (the Southern autumn or the boreal spring), the third is JJA (austral winter or the boreal summer) and finally the last season is SON (the Southern spring or the boreal autumn).

RESULTS

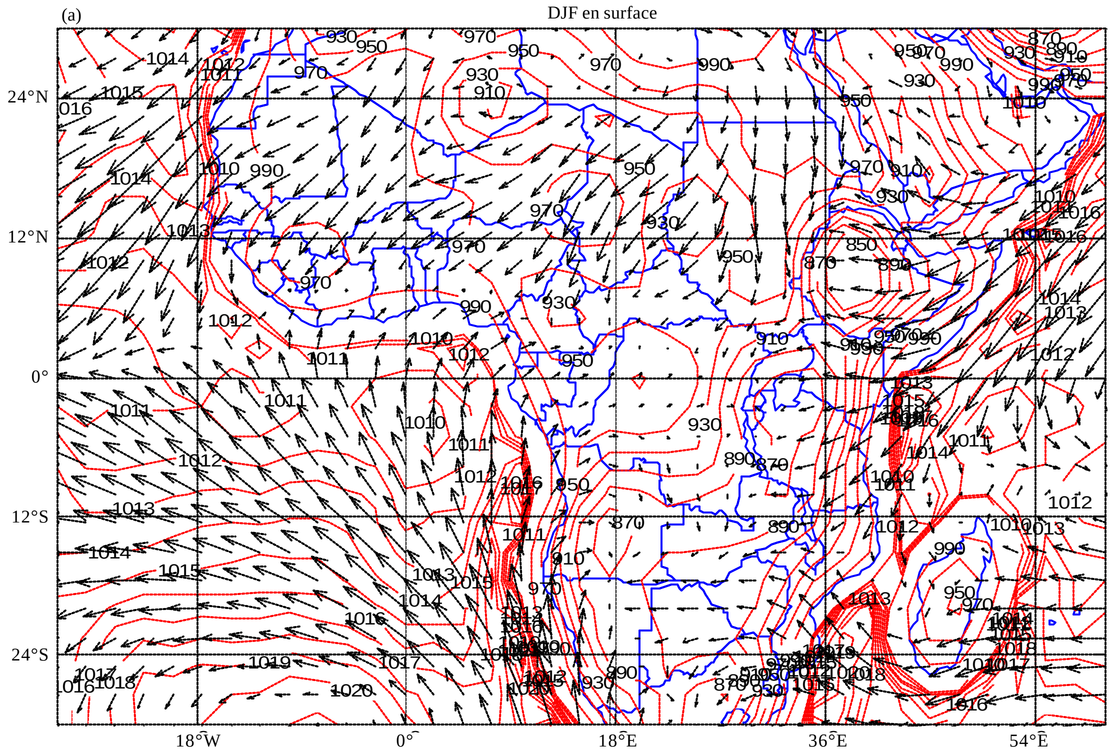
Field season pressure: The most characteristic average climatic situations in the Congo basin are those of January (DJF season) and of July (JJA season) which better report the evolution of the field of pressure. Indeed they present, the extreme positions of the centres of action responsible for the atmospheric dynamic. MAM and SON present conditions of transition towards a season of intense activity or low atmospheric activity.

The baromotric situation in surface or in 1000 hPa (Fig. 1a) during the DJF season, is characterized by the low pressures. This forms a vast barometric lightly marked, centred on the Congo basin and continues through the South to Angola. We note a scale of the anticyclone of Sainte-Hélène and the anticyclone of the Indian Ocean strongly moved east. In 850 hPa or 1500 m, the barometric configuration is practically identical to that of the surface (Fig. 1b). The pit of the low pressures moves southward surmounts Angola. The anticyclones are going to get closer to the equator in 700 hPa at a height of 3000 m approximately (Fig.1c). The relative low pressures, move at the same time towards the equator (Fig. 1c). In 500 hPa (5500 m) a high pressure appears in Namibia (Fig. 1d). In the superior layers 200 hPa (Fig. 1e) where the low pressures disappear, a vast anticyclonic area prevails which is move to the South of the equator.

For this DJF season, at various levels of the troposphere, low pressures, weakly dug, stretch on the South of the basin. It results from that it that Africa has an important on the surface of the axis of the low pressures, gap which is reduced eases with the height.

During the MAM season, the atmospheric dynamic in surface (1000 hPa is under the dominating influence of the anticyclone of Sainte Hélène which has weakened and moved to the South (Fig. 2a). The low pressures of the Congo basin and that of Angola are individualized. The crossing place of the north wind and of the wind South or the Atlantic Ocean wind going astray (stemming e Sainte Hélène) is situated in the North of Central African Republic. In 850 hPa (Fig. 2b) the Congo basin remains a low pressure zone and the other one a pit of low pressures which surmounts Angola. The dominant winds are those from the east in the South of the Congo basin which take a meridian direction inside the basin. The cartography of pressure is practically identical the surface but the anticyclones get closer to the equator. A high pressure zone in the low layers 700 hPa (Fig. 2c) appears on South Africa. It surely represents an extension of the anticyclone of the Indian Ocean which fuses with the Sainte-Hélène anticyclone. The zone of low pressure of the Congo basin is moved towards the south. This configuration disappears at 500 hPa (Fig. 2d) where the low pressures are more delocated to the South and high pressures disappear. In the high layers at 200 hPa (Fig. 2e) where the low pressures disappear exist a vast anticyclonic area delocated to in the South of the equator.

The Sainte-Hélène anticyclone reaches its large-scale maximum and forms a continuous anticyclonic strip in surface during the JJA season (Fig. 3a). The low pressures decrease their influence. The Sainte-Hélène influence is maximum in the entire region. At 850 hPa (Fig. 3b) the barometric configuration remains identical to the surface. The Sainte-Hélène anticyclone gets closer to the equator and the low pressures almost disappear. In the low layers 700 hPa (Fig. 3c) and 500 hPa (Fig. 3d) the southern anticyclones weaken considerably with the height whereas the low pressures still remain. The superior layers (Fig. 3e) are characterized by the low pressures.



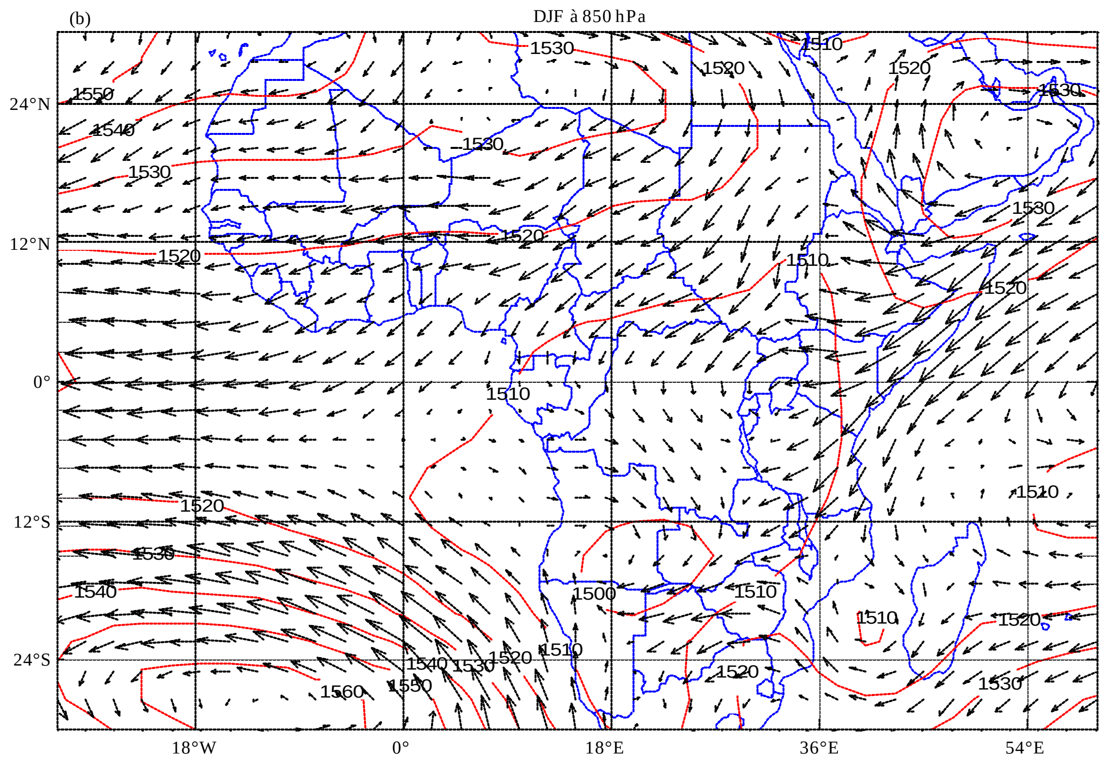
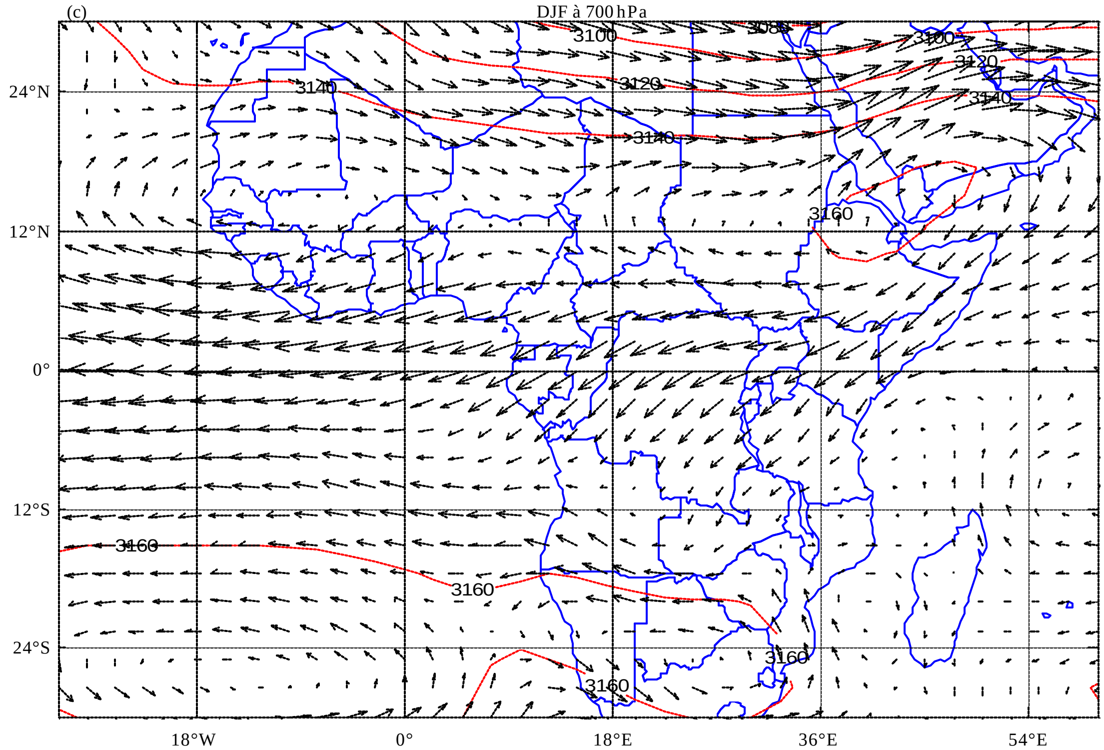
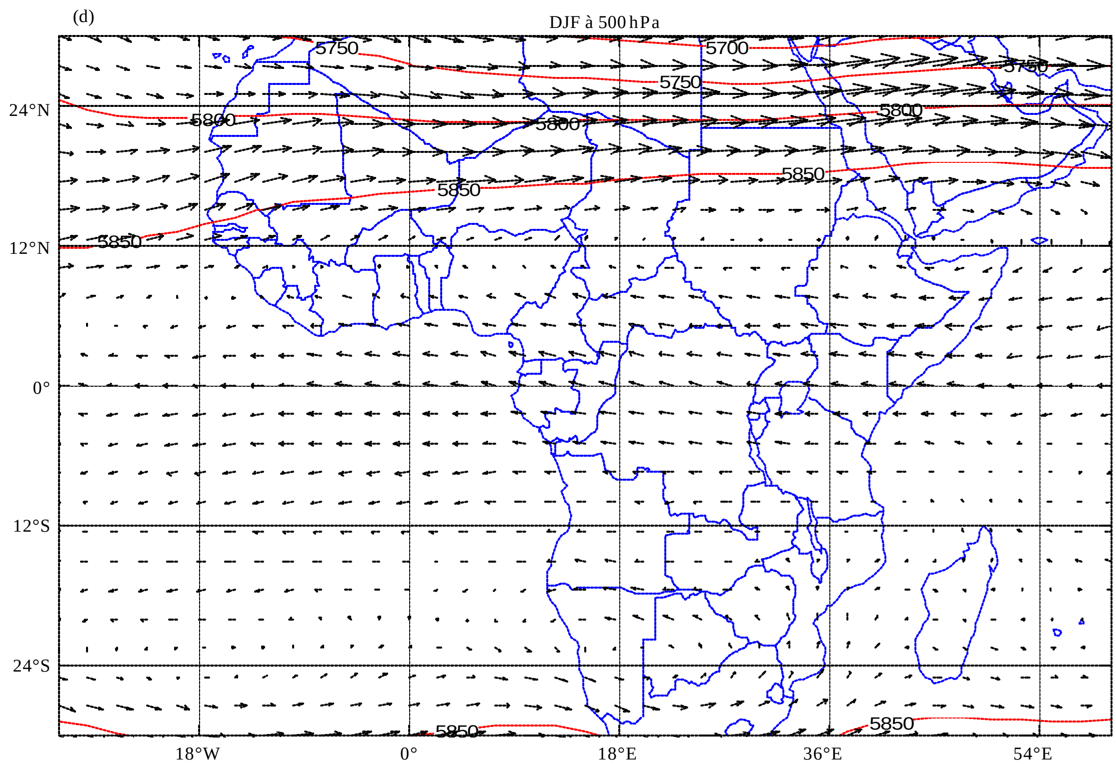


Fig. 1(a-e): Continued





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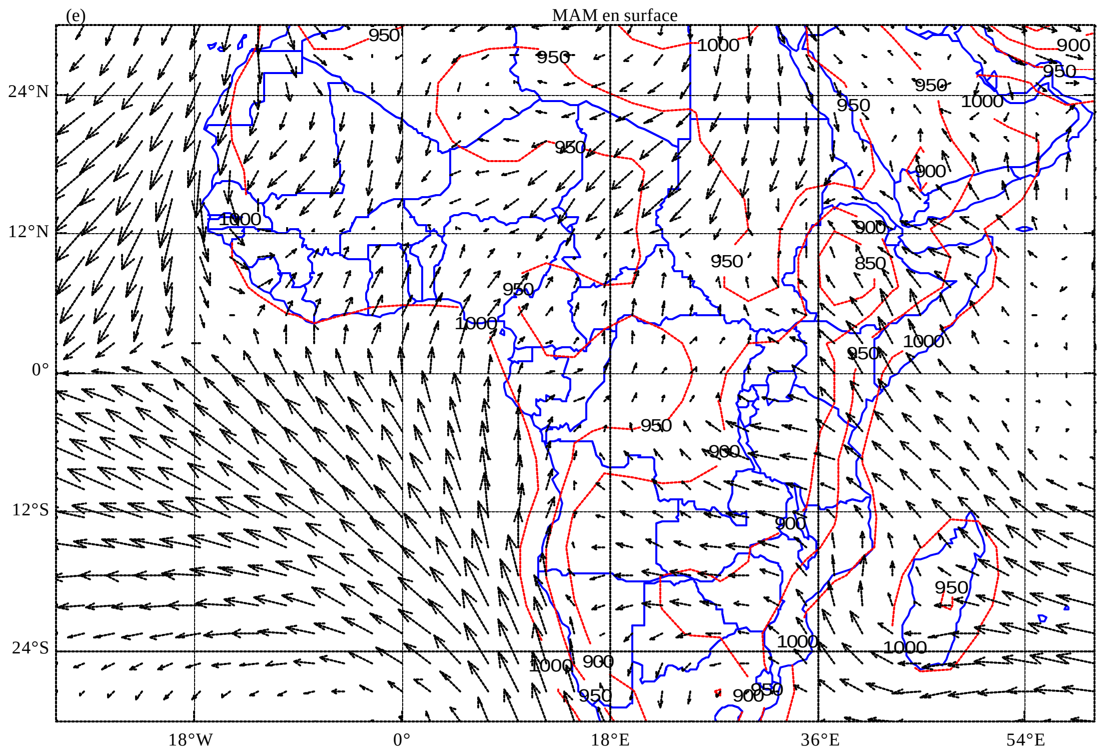
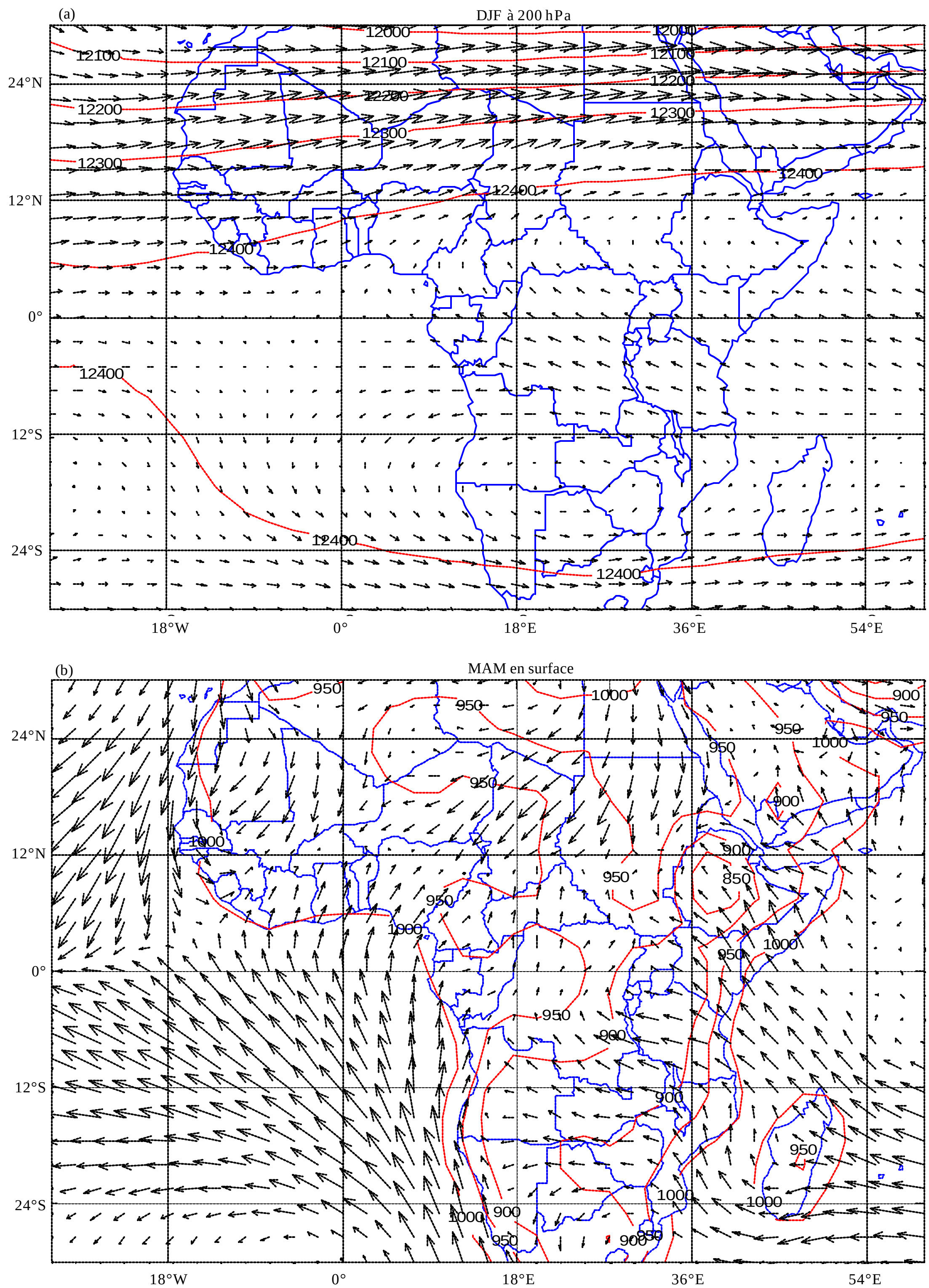


Fig. 1(a-e): DJF season: (a) Sea-level pressure (isobars) and the Field average surface wind flow (black arrows) and Average geopotential height (m) and wind (m sec^{-1}) at (b) 850 hPa; (c)700 hPa; (d) 500 hPa and (e) 200 hPa

During this SON season in surface (Fig. 4a) the individual isobaric reappear such as the depression of the Congolese basin, of Angola which remains much more dig than the MAM season. In 850 hPa (Fig. 4b) the Congo basin depression and of Angola grow together with a very important barometric inside the Congo basin. In the low layers 700 hPa (Fig. 4c) and 500 hPa (Fig. 4d), the Ste-Hélène anticyclone decrease considerably with the height whereas the low pressures extend over South Africa. At the level of the high layers (Fig. 4e), we note an intensification of the anticyclone.

Low level atmospheric circulation: The study of the circulation in the Congo basin is limited, within this study, to the low layers notably the surface circulation. From Fig. 1a, 2a, 3a and 4a we can deduct that the air mass which interest the Congo basin largely comes from the anticyclone of Sainte-Hélène. It is this that Leroux (1975) defines as a diverted trade wind in the East or which Suchel (1988) calls a pseudo-monsoon. It is a trade wind deviated from the fact that it is a stream which stays in the same hemisphere which saw it born. The importance of the inversion and the power of the subsidence determine the stability (or the instability) of the air mass. It is also called pseudo-monsoon because of its change of direction and a part of itself the stream crosses in a not significant way the equator before integrates into the traffic of the Congo basin where it relatively brings enough rains. However, the monsoon in the neighbourhood of the equator remains stable



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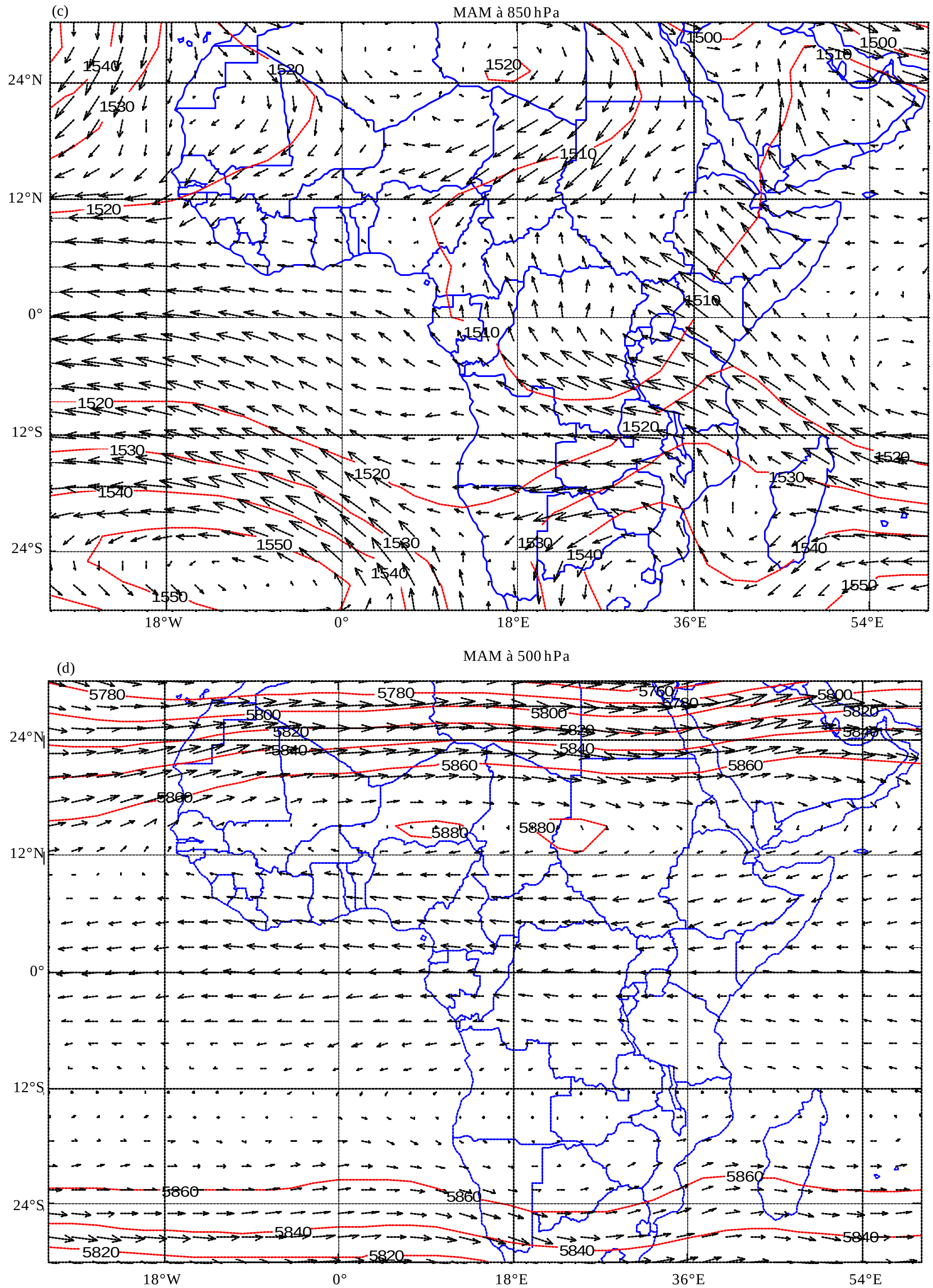

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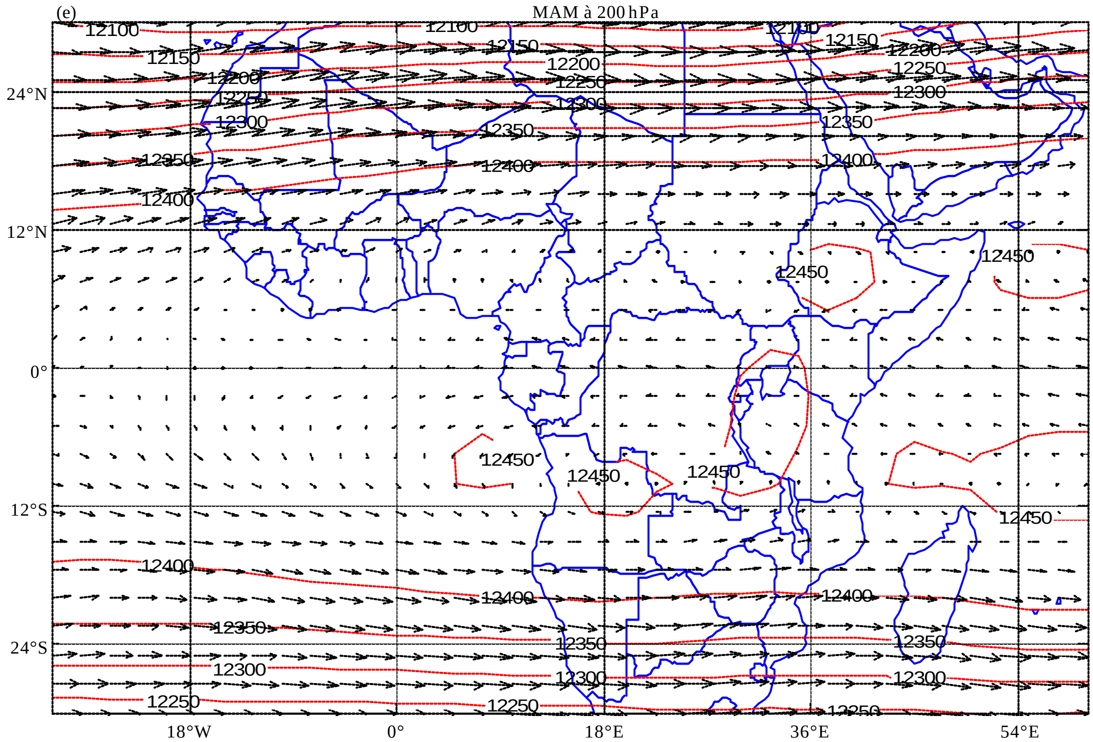


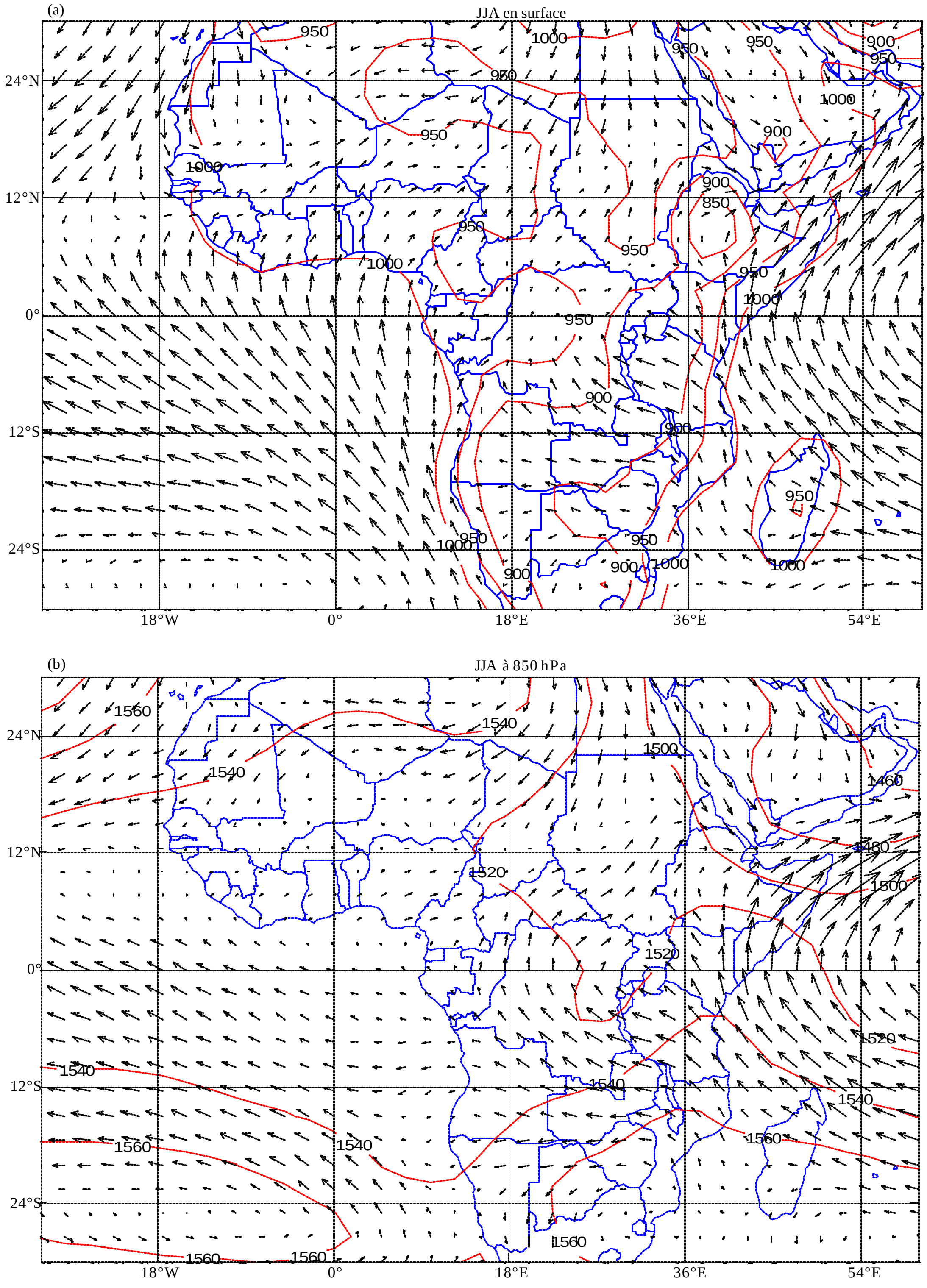
Fig. 2(a-e): MAM season: (a) Sea-level pressure (isobars) and the Field average surface wind flow (black arrows) and Average geopotential height (m) and wind (m sec^{-1}) at (b) 850 hPa; (c) 700 hPa; (d) 500 hPa and (e) 200 hPa

and becomes unstable only when it sufficiently goes away from it, acquires the characters of a monsoon from the moment it is diverted with regard to the usual trajectory of the trade wind. This stream can be qualified as pseudo-monsoon in the heart of the basin and as a trade wind diverted at first. Only its change of direction does not confer instability, it remains stable because of the subsidence.

From the South Sainte-Hélène wind meets the Indian Ocean winds which penetrates in southern Africa by drying out gradually in the West direction. At 850 hPa, during the DJF season, the Congo basin is dominated by the winds of the northeast which take a NW-SE direction inside the basin. These winds weaken off towards the coast of Congo-Angola.

Whereas in JJA season, the maritime trade wind stemming from Sainte-Hélène is rejected towards the Congo basin and is well strengthened. At 850 hPa the Congo basin is invaded by a warm and dry stream, coming from the Indian Ocean. This season corresponding to the most northerly position of the broadcasting anticyclone, the characters of stability of the monsoon are strongly moved northward and affect all basin.

Discontinuities: The most important discontinuity in the Congo basin would be the InterTropical Convergence Zone, defined by Fontaine *et al.* (1998) as a zone of low inter tropical pressures which show an important activity of deep organized convection (cumulus with strong vertical development). It undergoes an annual migration according to the seasons, by following the visible



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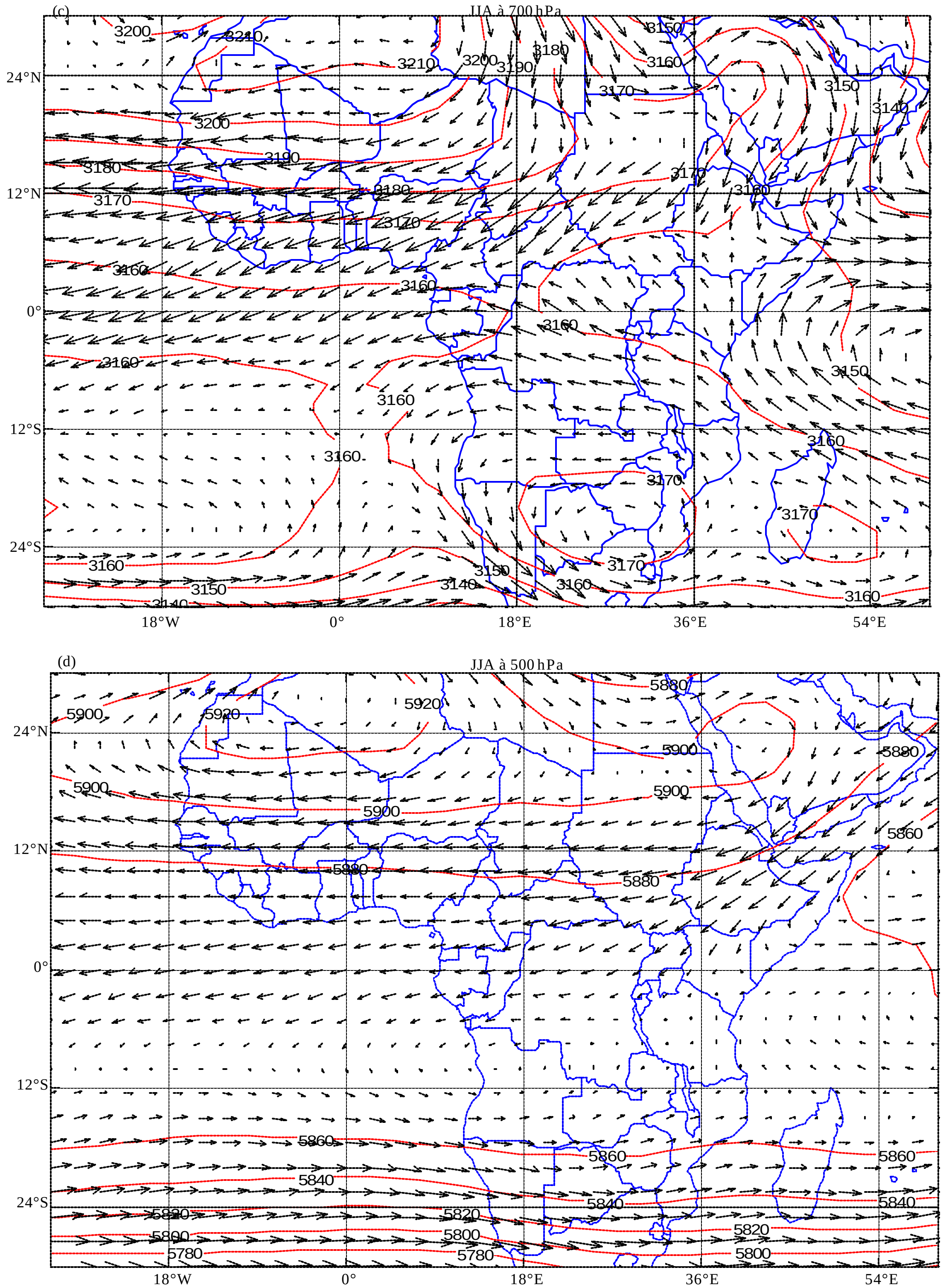

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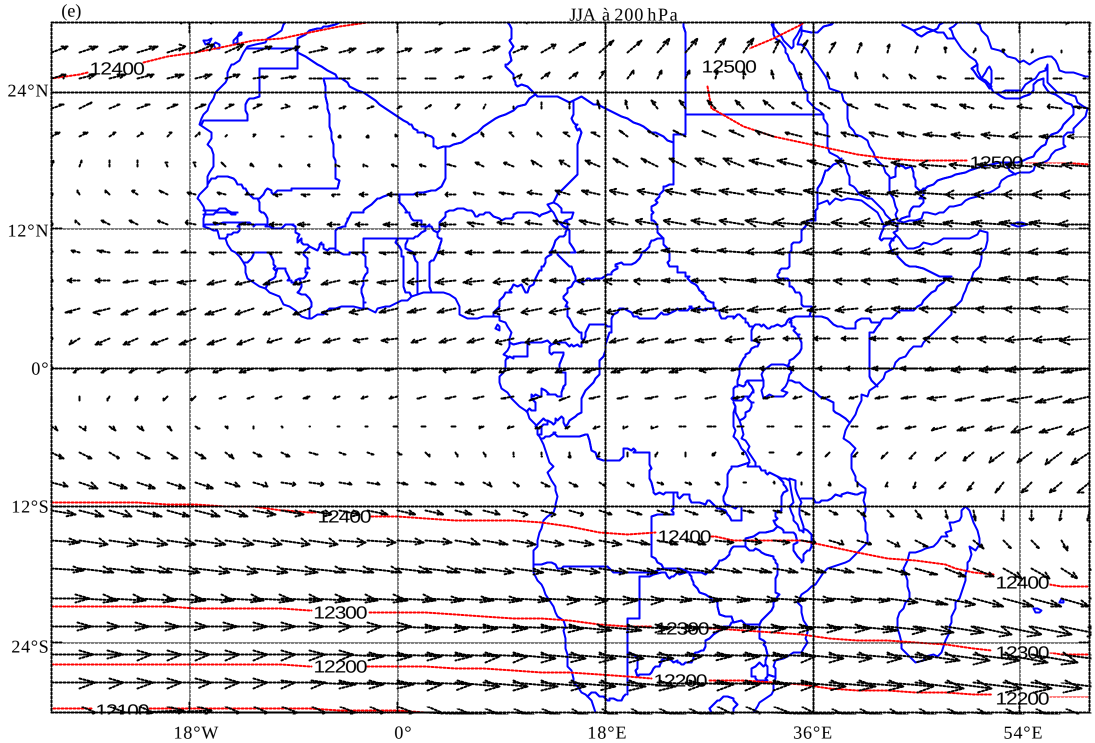
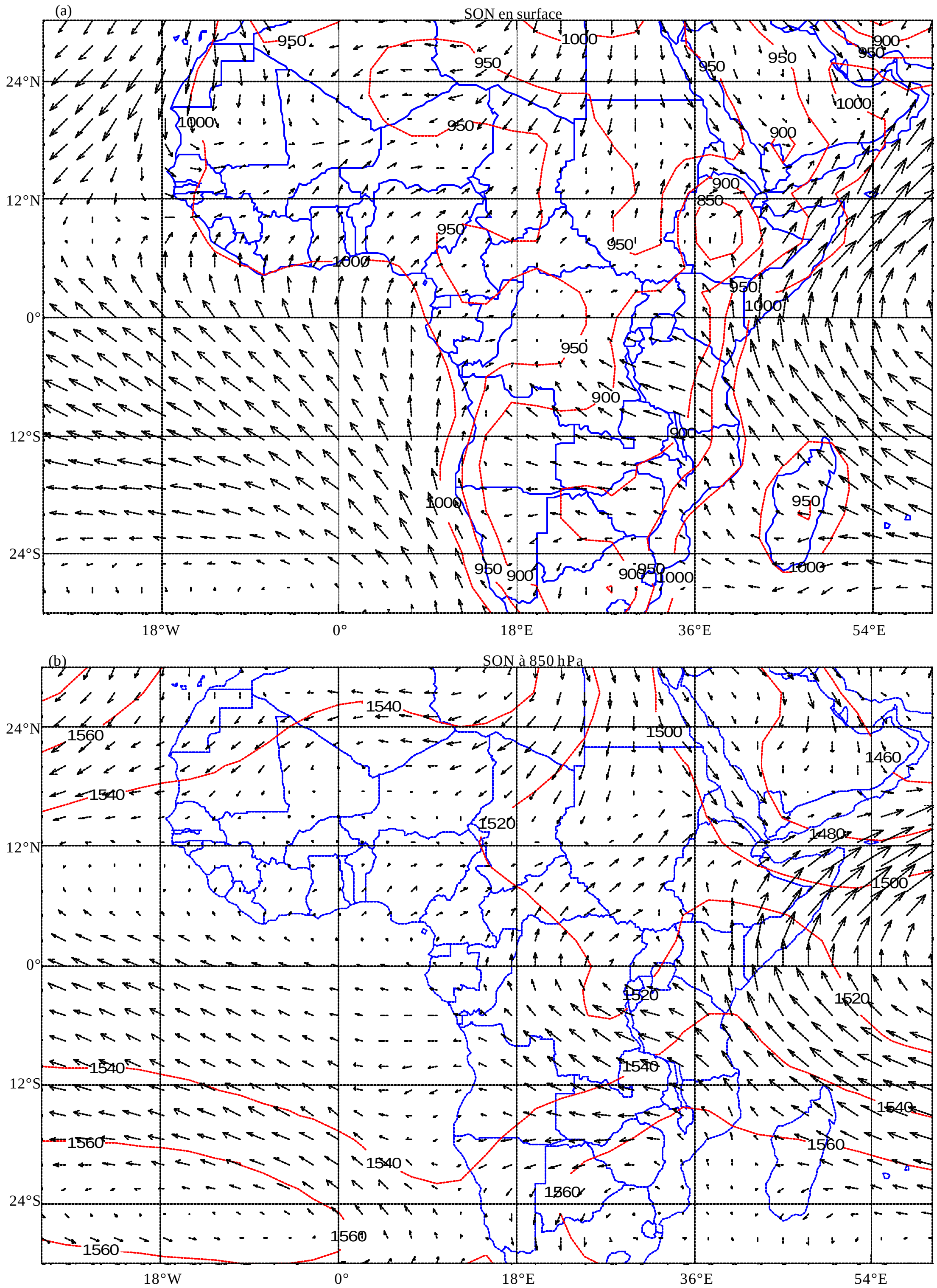


Fig. 3(a-e): JJA season: (a) Sea-level pressure (isobars) and the Field average surface wind flow (black arrows) and Average geopotential height (m) and wind (m sec^{-1}) at (b) 850 hPa; (c) 700 hPa; (d) 500 hPa and (e) 200 hPa

movement of the sun with a delay from four to six weeks. On the oceans, it manifests itself by a narrow strip parallel to the equator and reflects the convergence and the ancestry of the air resulting from both hemispheres. During the DJF season the average position of the ITCZ on the ground is to be located on the Central African territory, the meeting place of the north and south trade winds. At 850 hPa its position is more in the South of the basin. In the low layers, the migration of the ITCZ is relatively low. The migration seems to be more important in longitude than in latitude. In surface on the other hand, the migration is strong, because it is linked to the zenith movement of the sun. On the Congo basin, its structure is complex in southern summer because of the distortion between a structure close to the oceanic type and the continental structure. During the JJA season, the track on the ground of the ITCZ is towards the North of the Congo basin, even at 850hPa the ITCZ still stays in the North (Fig. 3b).

The Inter-Oceanic Convergence Zone (IOCZ) is the second discontinuity in the region. Its shows the limit of the respective influences of the air masses stemming from the Atlantic Ocean and from the Indian Ocean. The stream stemming from the Atlantic Ocean is qualified sometimes as diverted trade wind or sometimes as a real monsoon. The oriental stream is sometimes a sea continentalised trade wind, sometimes a continental trade wind. The IOCZ marks the limit between streams originating of the same hemisphere, the southern hemisphere. It is limited by the low layers and its hillside is generally sloped in the direction of the Atlantic stream above which the oriental stream rises. The IOCZ is like the InterTropical Front (ITF) for southern Africa that is a zone limiting streams of the masses of the same hemisphere.



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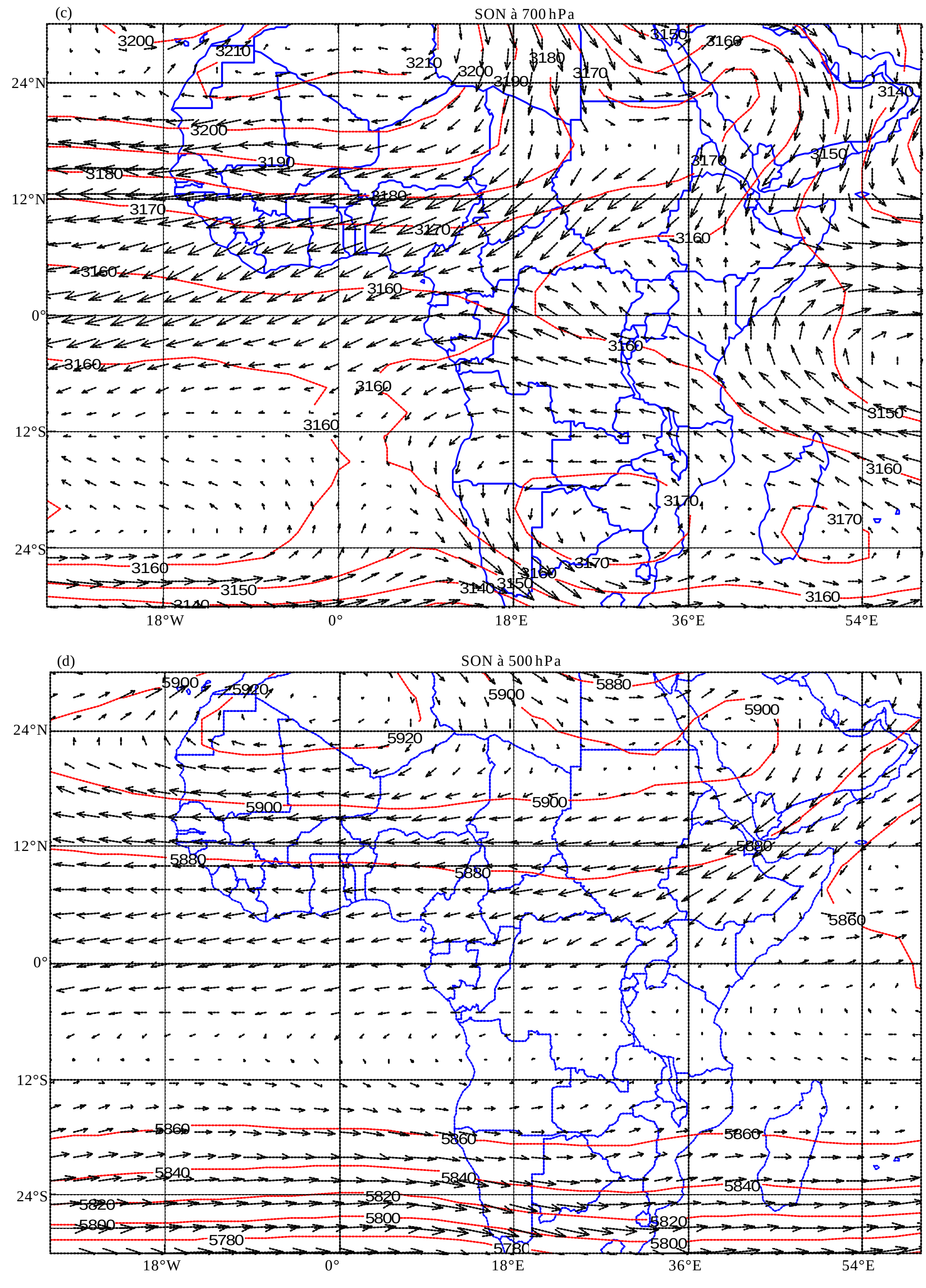

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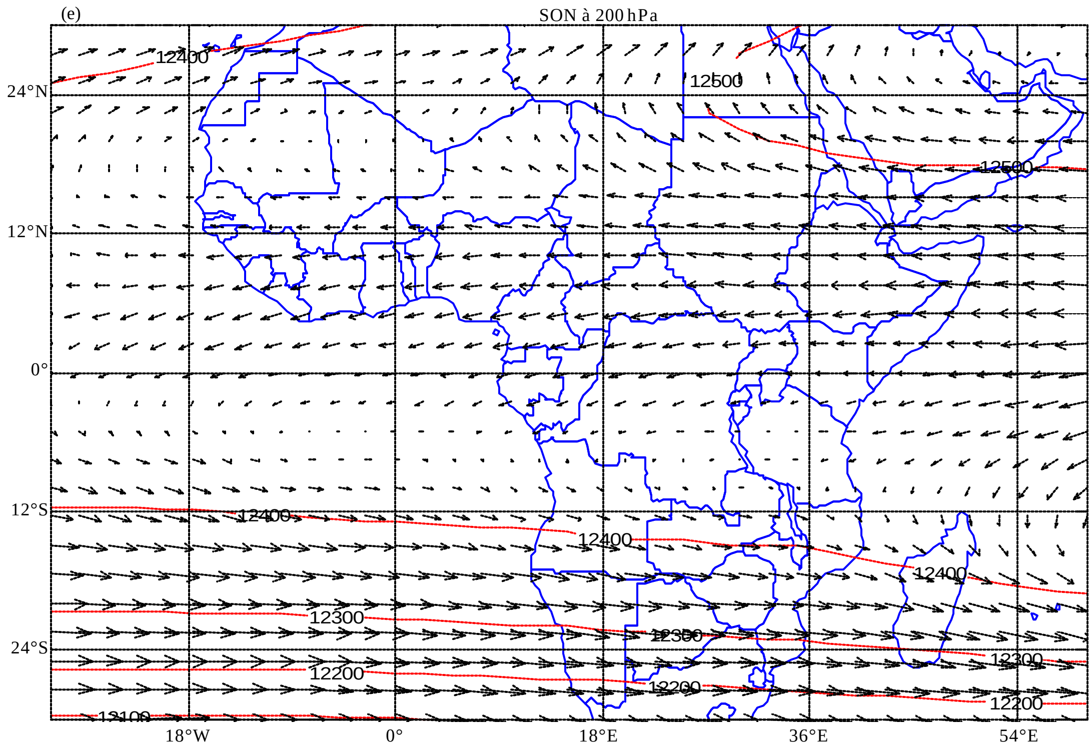

Fig. 4(a-e): SON season: (a) Sea-level pressure (isobars) and the Field average surface wind flow (black arrows) and Average geopotential height (m) and wind (m sec^{-1}) at (b) 850 hPa; (c)700 hPa; (d) 500 hPa and (e) 200 hPa

Pluviogenes mechanisms: The first required condition so that it rains lies in the more or less big abundance of steam which the air contains, the condition determining the stability or the instability. The Congo basin is by far a zone of big evaporation. It is the place of the refill in humidity of the air with ascensions in the troposphere. Air mass getting most frequently the Congo basin in surface is those conveyed by the winds of sector SW, that is the Atlantic trade wind and sometimes the sector SE of the Indian Ocean. Whatever their origin is, these masses affect the Congo basin after a course of several kilometres of warm seas where a strong evaporation is exerted. Warmed by their basis and moistened, these masses are characterized in surface by the contribution of high temperatures (of 20 in 27°C) and a rather big relative humidity often superior to 70%.

In these air masses of sector SW or SE, after a continental course, appears at weak height, a layer of subsidence sometimes marked by a net and powerful temperature inversion, mostly by a simple homothermous. The thickness of the lower layer is however sufficient /self-important so that ascending movements starting there, the formation of clouds becomes possible. The effects of the surface states of the Congo basin accentuate the cloudiness on this region. Most of the time, the layer of inversion disappears, lets the free field to the ascensions on a bigger thickness: cumuliform clouds become more considerable and benches of cumulus, altocumulus can even develop at the top of the ascensions in the oriental part of the pond. The degree of instability of the wet lower layer, the power and the basic height of the layer determine nuances, even differences but the general plan of the time type remains unchanged.

The ascension of the air is the fundamental factor of the formation of clouds and rain. Conversely however its subsidence creates a clear sky. The thermic convection, stemming from the diurnal heating of the substratum intervenes more especially during the rainy season. By weak pressure gradient, when the air masses stagnate on an overheated ground, convective ascension of thermic origin basin, organizing generative cumulifications of rains and local thunderstorms.

The meeting of an orographic obstacle creates, in the air masses stemming from the Atlantic Ocean, vertical movements or forced ascensions from the wind, then on its descent with a foehn effect on the hillside wind. More often, the low layers of the trade wind are in a latent state of instability because of their hygrometric degree. A light uprising can bring them to saturation with training of stratus, drizzle, rains.

The dynamic phenomena stemming from horizontal convergences well report the distribution of rains. The horizontal convergence results from three processes acting sometimes remotely, sometimes on the contrary, imbricated in a complicated way: the meeting of current aerials of different direction; the confluence of lines of stream inside the same current; the deceleration of amont downstream. In any case, an accumulation of mass occurs in the area of convergence so that the air which can not escape laterally is led to rise; making it, a zone of low relative pressures builds up itself. These three processes find in the Congo basin multiple illustrations. The most frequent case that arose from the meeting of opposite currents or simply from different direction: the pseudo-monsoon and the trade wind determining a large-scale convergence realized by the depression of the Congolese basin in fusion with the Intertropical Convergence Zone. The lines of grains progressing from the east of the basin inward or the West what partially composes little rainy contribution of trade winds stemming from Sainte-Hélène.

DISCUSSION

These barometric characteristics, of zonal and meridian winds, ascensions, generate several remarks at the level of the climatic complexity of the Congo basin. The strong coexistence of rains convective, orographic and of disturbance or line of grains complicates the plan of atmospheric traffic, the absence of the track on the ground of the ITCZ in the heart of the pond. Indeed, the ITCZ in the Congo basin seems to lose its organization to the detriment of the power of low pressure of the Congolese washbasin. The Congo basin acts as a lake of evaporation inhaling all the streams stemming from centres of action (anticyclones). The stream of air mass stemming from the anticyclone of Sainte-Hélène wets the basin although it stays in the same hemisphere,but changes direction. If the monsoon is a stream of trade wind which crosses the meteorological equator and which changes direction, this trade wind diverted towards East presents characteristics which get closer to a monsoon and from this point of view carries the naming of pseudo-monsoon. Because this stream which penetrates the Congo basin by the attraction of the depression of the Congo basin is originally stable on the coastal plain. The contribution of disturbances and the convectif effects partially explains that plateaus Batéké benefits a better exposure in humidity brought by the circulation of Pseudo-monsoon. It becomes unstable when it is integrated into the circulation due to the depression of the Congo Basin. The Congo basin, being in a barometric bog benefits from important local effects of the pluviogenese.

In this general circulation, it is necessary to associate the weight coming from local factors (state of surface) in the atmospheric dynamics and the pluviogenes mechanisms such as the intense thermo-convective activity.

ACKNOWLEDGMENTS

The authors wish to thank the NCEP/NCAR for making the reanalysis dataset available. We also acknowledge Pascal Oettli (Centre de Recherches de Climatologie, Dijon – France), who provided us with the NCEP data.

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