ITCZ CLOUD CLUSTERS IN ASSOCIATION WITH AFRICAN EASTERLY WAVES DURING SUMMER SEASONS OF El NINO AND LA NINA YEARS

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ABSTARCT

El- Nino and La- Nina conditions have been reported during the years of 1997 and 1998 respectively. Composite anomalies of sea surface temperature SST and surface precipitation rate of NCEP/ NCAR reanalysis data set for July and August months of 1997 and 1998 have been investigated through this study. Day-to-day variations in conditions, location, width and activity of the Intertropical Convergence Zone, ITCZ, cloud band have been investigated over Africa using longitude time sections, constructed from successive daily METEOSAT images during the same period. The ITCZ cloud clusters had been observed more active and covered larger areas during July and August months of 1998 compared with those observed during 1997. Westward propagating cloud lines, constructed from successive images of individual cloud clusters, could be detected over West Africa and the Atlantic Ocean. During 1998, the cloud lines could be observed more active, well defined and more regular than those observed during 1997. The cloud lines showed significant characteristics similar to those of the African easterly waves. Over Eastern Tropical Africa, the ITCZ cloud clusters appeared almost stationary, only meridional oscillations and variations in shape and intensity could be observed. However, one may suggest that disturbances of the ITCZ cloud clusters can be considered as the visual evidence of easterly waves over Africa.

1. INTRODUCTION

The Intertropical Convergence Zone, ITCZ, is one of the most important meteorological systems acting in the tropics. The ITCZ could be defined as a narrow east-west band of vigorous cumulonimbus convection and heavy precipitation along the equator ward boundary of the trade wind regimes (Holton et. al., 1971). Within this region precipitation exceeds evaporation by a factor of 2 or more, the excess being provided by the moist, converging low-level flow. Bates (1970), defined the ITCZ as the location where most of the enormous quantity of latent heat acquired by evaporating water from the tropical oceans into the trades is converted to sensible heat. Its influence on precipitation in the African, American, European and Asian continents has been accepted and showed in several works such as Hastenrath and Heller (1977), Sikka and Gadgil (1985), Citeau et al. (1988b) and others. In planetary scale, the ITCZ is located in the ascending motion branch of the Hadley cell, transferring heat and moisture from the inferior levels of the atmosphere of the tropical regions to the superior levels of the troposphere and to mid and high latitudes. Shifts and preferred latitudes of the ITCZ observations and theory were investigated by Bates (1970), Gruber (1972), Krishnamurti and Bhalme (1976), Waliser and Somerville (1994), Philander et al.(1996) and others.

Analysis of satellite images by Chang (1970), Reed and Recker (1971) and El Rafy (1996) presented strong evidence that the ITCZ cloud clusters could be identified with large-scale, westward-propagating wave disturbances. These disturbances are marked by heavy precipitation which requires strong low-level convergence, strong ascent at middle levels and strong upper level divergence. Therefore, in climatological sense, the ITCZ could be considered as the locus of the cloud clusters associated with westward propagating wave disturbances (Holton et al.,1971).

El Nino / Southern Oscillation (ENSO) is the most important coupled Ocean-atmosphere phenomenon to cause global climate variability on interannual time scales, El-Nino can be regarded as the oceanic component of the phenomenon. Generally, El-Nino event is the invasion of warm water from the western equatorial Pacific into the central and/or eastern equatorial Pacific Ocean, in conjunction with a cessation of upwelling of cold water along the equator (Rasmusson and Carpenter, 1982). La Nina or anti-El-Nino event can be referred to as the appearance of colder than average sea surface temperatures SST in the central or eastern equatorial Pacific region. A strong signal of climate variability in the Tropics is derived from El-Nino (Cane 1983, Rasmusson and Carpenter 1983). Many studies have shown that El-Nino /Southern Oscillation ENSO have a significant influence on climate in many parts of the globe (Shukla and Paolino1983, Ropelewski and Helpert 1987, Price et al 1998, Diaz and Markgraf 2000, El Rafy 2008 and others**).**

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This work includes farther studies to rely better understanding of atmospheric variations in the tropical region, notably over Africa. The aim of the present work is to investigate the different conditions of the intertropical convergence zone ITCZ cloud clusters, the associated wave like disturbances and the prevalence of rainfall over tropical Africa during summer seasons of El Nino and La Nina years. This is of great importance to Egypt since these climatic variabilities are amongst the factors controlling water resources of river Nile and its tributaries.

2. DATA AND METHODOLOGY

The NCEP/NCAR Reanalysis data of composite anomalies of sea surface temperature SST and surface precipitation rate from July to August were obtained from Climate diagnostics center (NOAA, boulder, Colorado) through the Web Site: //www.cdc.noaa.gov/composites. Each field have been investigated through the years 1997 and 1998 in order to compare the distribution of rainfall over Africa during El-Nino and La Nina conditions.

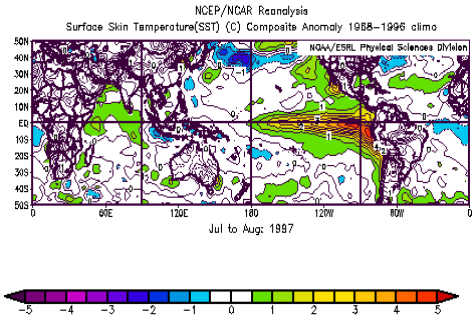
Also, satellite images in the IR spectra for the period 1 July to 31 August of the years 1997 and 1998 have been used. The METEOSAT images used in this study were prepared by the European Satellite Operations Center (ESOC) at Darmstadt, Germany. Different conditions, location, width and activity of the intertropical convergence zone ITCZ have been investigated using longitude-time sections, constructed from successive daily satellite images, cut into thin zonal strips. Each image strip covers five latitudinal degrees of tropical Africa during the period of study.

3. ANALYSIS AND DISCUSSION

Dramatic changes in sea surface temperature SST in Equatorial Pacific Ocean have been observed during the years of study. Fig.(1) shows composite anomalies of sea surface temperature SST over Pacific Ocean for the period from July to August of the years 1997 and 1998. A wide tongue of high positive SST anomalies (warm water) can be observed to extend zonally from the south American coast westward to the date line during 1997 , which can be considered as typical El Nino condition (Fig.1 a). During the summer of 1998 the warm water (+ve anomaly) has been detected in the east only, with cold water (-ve anomaly) along the Equator in the central part of the Pacific Ocean, which may represent the initiation of La Nina condition.

Composite anomalies of surface precipitation rate for the two seasons of study have been presented in Fig.(2). During 1997, -ve anomalies of precipitation rate (below normal) dominate north of the Equator over tropical Africa and the Atlantic Ocean, while +ve anomalies (above normal) dominate south of the Equator over central Africa and the Indian Ocean. Above normal rainfall (+ve anomalies) can be observed over western and central tropical Africa between the Equator and latitude 12 ^{o} N during the

(a) 1997



(b) 1998

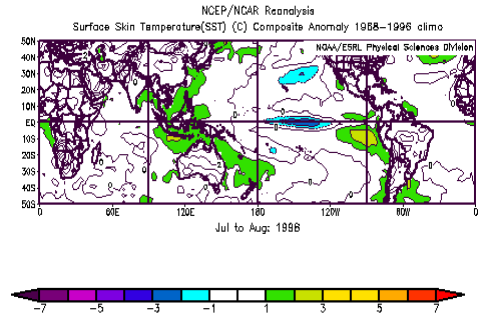
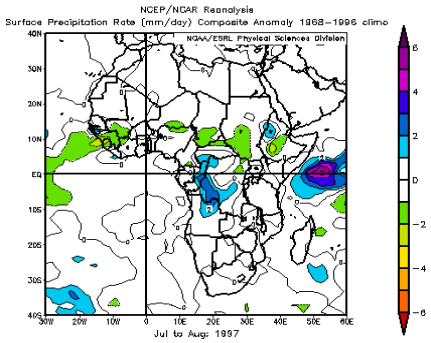


Figure (1): Composite anomaly of sea surface temperature SST for July to August in the Pacific Ocean for the years (a) 1997 and (b)1998

(a) 1997



(b) 1998

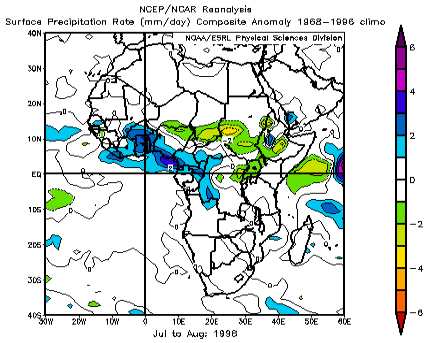


Figure (2): Composite anomaly of surface precipitation rate (mm/day) for July to August for the years (a)1997 and (b)1998

summer season of 1998, while below normal rainfall (-ve anomalies) can be noticed along latitude 12 ^{o} N over central tropical Africa and over the Indian Ocean. This may indicate that El Nino condition is usually associated with drought condition during summer season over tropical Africa, while La Nina condition is usually associated with rainy season.

Useful information had been derived from longitude-time sections, constructed from successive daily satellite images, cut into thin zonal strips, for the periods of study. In the present work the ITCZ will be regarded as the total cloud clusters on satellite images over the tropics. The width of the ITCZ could be determined in terms of the north-south extension of the cloud band. The activity had been determined in terms of the quantity of Cb clouds or the area obscured by them within the band. Fig.(3) covers the latitude band of 15 ^{o} -20 ^{o} N. It is possible to visualize weak westward propagating cloud "lines", constructed from successive images of individual cloud clusters. The intensity of the clouds varies from day to day, if one disregards these variations of intensity, the time continuity is readily apparent. The ITZC cloud clusters appeared more active and covered larger zonal area during 1998 than those observed during1997. It is obvious that the northern boundary of the ITCZ lie within this latitudinal band over Africa during the two seasons of study.

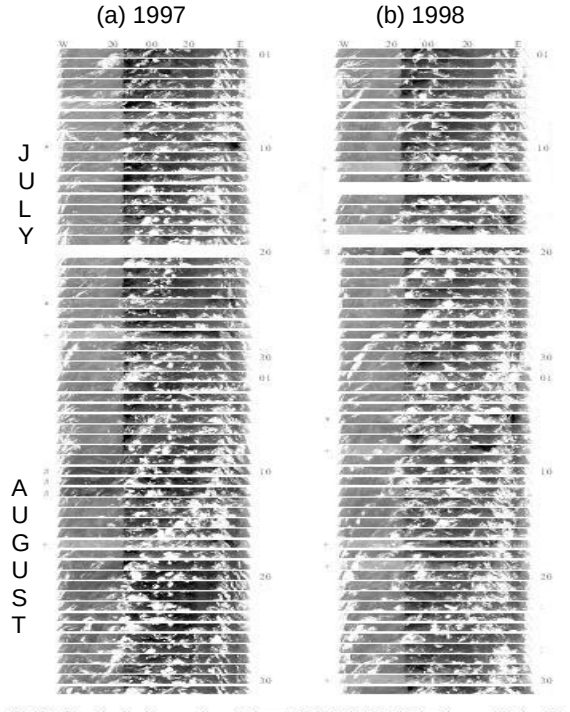


Figure (3): Longitude-time section of METEOSAT (IR1800 GMT) images during the period 1 July-31 August for the years (a)1997 and (b)1998, for the 15 ^{o} -20 ^{o} N latitude band over Africa. The missing images had been replaced by : # for IR 0000 GMT, * for IR 0600 GMT and + for IR 1200 GMT.

Figs.(4 and 5) cover the latitude bands of 10 ^{o} -15 ^{o} N and 05 ^{o} -10 ^{o} N, respectively. The following common significant features could be noticed: These two bands seemed to lie within the ITCZ cloud band. West of longitude 20 ^{o} E, 9-11 cloud "lines" can be observed, to propagate westward towards the Atlantic. So, one may suggest that about 9-11 disturbances can be detected. Thus, it is reasonable to estimate an average period of 5-7 days for each disturbance. Following the clusters westward, a phase speed in the order of 6-8 m/s can be deduced. The corresponding horizontal scale is therefore in the order of 2600-4800 Km. During 1998, the cloud "lines" could be observed more active, well defined, more regular and covered larger zonal area than those observed during 1997. East of longitude 20 ^{o} E the cloud clusters appeared almost stationary, only day to day variations in intensity and shape could be observed. A separating region between cloud clusters observed over East and West tropical Africa can be seen to locate along longitude band 10 ^{o} -20 ^{o} E.

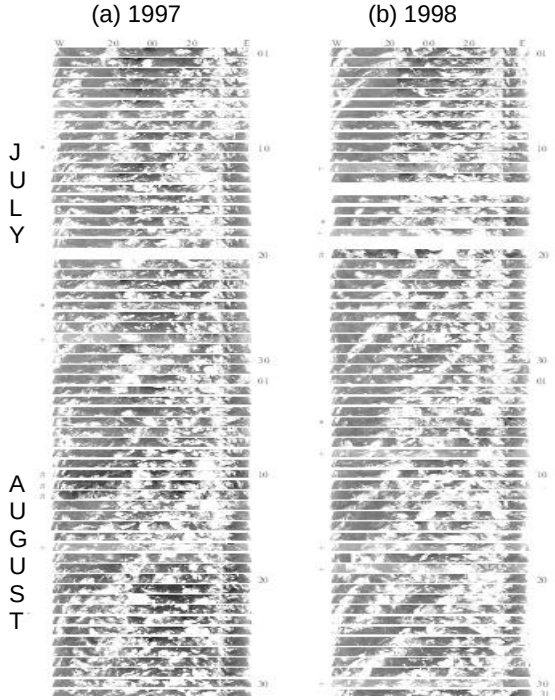


Figure (4): Longitude-time section of METEOSAT (IR1800 GMT) images during the period 1 July-31 August for the years (a)1997 and (b)1998, for the 10 ^{o} -15 ^{o} N latitude band over Africa. The missing images had been replaced by : # for IR 0000 GMT, * for IR 0600 GMT and + for IR 1200 GMT.

Fig.(6) covers the latitude band of 00 ^{o}-05 ^{o}N. Over West Africa, the region west of longitude 00 ^{o} E can be seen free of clouds during 1997, while 9-10 weak cloud "lines" still can be detected during 1998. This may indicate that the southern boundary of the ITCZ lied to the north of this band during 1997 (EL-Nino year), while

the southern boundary of the ITCZ lied within this band during 1998 (La Nina year). Over eastern tropical Africa, east of longitude 00 ^{o} E, cloud clusters could be noticed almost stationary during 1997 to become more active and covered larger zonal area during 1998. Fig. (7) covers the latitude band of 05 ^{o} S-00 ^{o}N. Weak cloud clusters could be observed only east of longitude 20 ^{o} E during 1997, while more active cloud clusters could observed east of longitude 10 ^{o} E during 1998. Over the latitude band of 10 ^{o}S-05 ^{o}S, as shown in Fig.(8), weak cloud clusters could be observed only to the east of longitude 10 ^{o} E, notably during August 1998. This may indicate that the ITCZ cloud band may extend more southward over eastern tropical Africa, notably during La Nina condition.

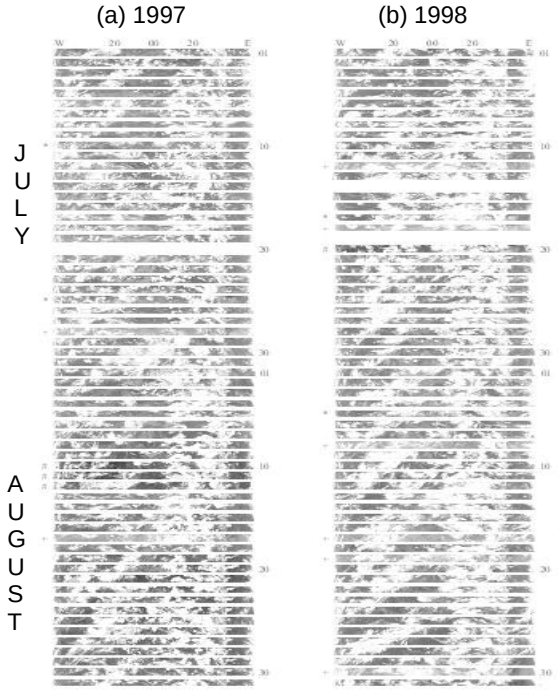


Figure (5): Longitude-time section of METEOSAT (IR1800 GMT) images during the period 1 July-31 August for the years (a)1997 and (b)1998, for the 05 ^{o} -10 ^{o} N latitude band over Africa. The missing images had been replaced by : # for IR 0000 GMT, * for IR 0600 GMT and + for IR 1200 GMT.

4. RESULTS AND CONCLUSIONS

The 1997/98 El Nino event has been hailed as the El Nino of the 20th century. El- Nino conditions begin to appear on February and continue to December 1997, while La Nina showed itself firstly in May 1998 and continued to the end of the year. Below normal rainfall dominates over tropical Africa during summer of El Nino year 1997, while above normal rainfall dominates during La Nina years 1998. The ITCZ cloud clusters had been observed more active and covered larger areas during July and August months of 1998 compared with those observed during 1997.

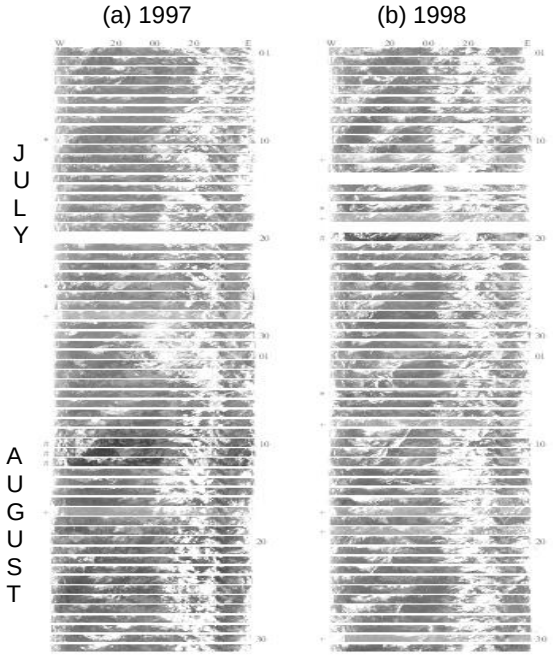


Figure (6): Longitude-time section of METEOSAT (IR1800 GMT) images during the period 1 July-31 August for the years (a)1997 and (b)1998, for the 00 ^{o} -05 ^{o} N latitude band over Africa. The missing images had been replaced by : # for IR 0000 GMT, * for IR 0600 GMT and + for IR 1200 GMT.

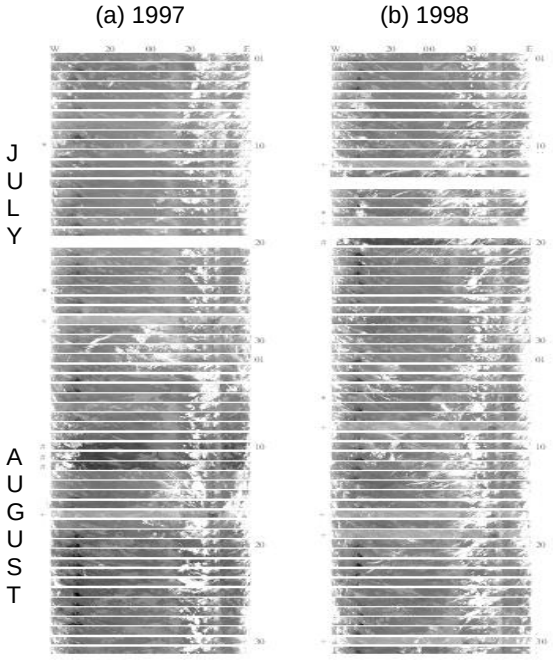


Figure (7): Longitude-time section of METEOSAT (IR1800 GMT) images during the period 1 July-31 August for the years (a)1997 and (b)1998, for the 05 ^{o} S-00 ^{o} N latitude band over Africa. The missing images had been replaced by : # for IR 0000 GMT, * for IR 0600 GMT and + for IR 1200 GMT.

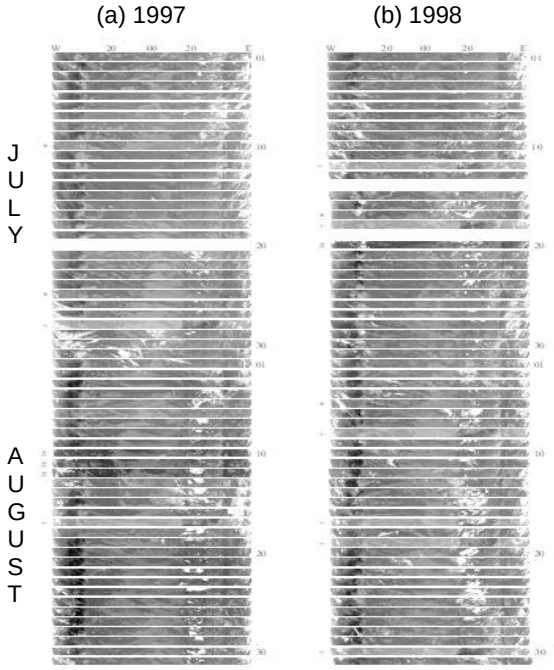


Figure (8): Longitude-time section of METEOSAT (IR1800 GMT) images during the period 1 July-31 August for the years (a)1997 and (b)1998, for the 10 ^{o}S -05 ^{o} S latitude band over Africa. The missing images had been replaced by : # for IR 0000 GMT, * for IR 0600 GMT and + for IR 1200 GMT.

Useful information had been derived from longitude-time sections, constructed from successive daily satellite images for the periods of study. The northern boundary of the ITCZ cloud band over Africa had been found within the latitude band of 15 ^{o} -20 ^{o} N during the two periods of study. A separating region between cloud clusters observed over East and West tropical Africa can be seen to locate along longitude band 10 ^{o} - 20 ^{o} E. Over western tropical Africa, the southern boundary of the ITCZ lied within the latitude band 05 ^{o} - 10 ^{o} N during 1997 , while the southern boundary of the ITCZ lied within the latitude band 00 ^{o}-05 ^{o} N during 1998 . Thus, one may conclude that the ITCZ cloud band had been found Wider during La Nina year than those found during EL-Nino year. Also, one can draw roughly 9-11 cloud “lines” during the period of study over west Africa, which suggested that about 9-11 disturbances can be detected. Thus, it is reasonable to estimate an average period of 5-7 days for each disturbance. Following the clusters westward, a phase speed in the order of 6-8 m/s can be deduced. The corresponding horizontal scale is therefore in the order of 2600-4800 Km. So, one may suggest that the cloud lines showed significant characteristics similar to those of the African easterly waves. Over eastern tropical Africa, the ITCZ cloud clusters had been noticed almost stationary during 1997 to become more active and covered larger zonal area during 1998. The southern boundary of the ITCZ lie within the latitude band 05 ^{o} S-00 ^{o} N during 1997, while the southern boundary of the ITCZ may extend more southward during 1998. Again, one may conclude that the ITCZ cloud band had been found Wider during La Nina year than those found during EL-Nino year. Generally, the more active and wider ITCZ cloud clusters may explain the above normal rainfall over Africa, notably during La Nina condition. However, one may suggest that disturbances of the ITCZ cloud clusters can be considered as the visual evidence of easterly waves over Africa.

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