DEVELOPING AND NON-DEVELOPING AFRICAN EASTERLY WAVES AND THEIR RELATIONSHIP TO TROPICAL CYCLONE FORMATION

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ABSTRACT

As African (Tropical) Easterly Waves (AEW) form in eastern to central Africa, convective storms propagate across Northern Africa. Tropical cyclone genesis is a tough question; however, under stronger tropical wave circumstances, hurricanes are more likely to develop. During summer of 2006, two field experiments called African Monsoon Multidisciplinary Analyses (AMMA) and NASA AMMA gathered valuable tropical upper-air data that is available to further study AEW. The observations permit the distinctions of the stronger AEW to the weaker ones. Meridional wind anomaly plot shows strong signals of AEWs' propagation. The plot will be analyzed to determine the exact date of trough axis passage. Using the dates, Infrared images will be analyzed to determine the differences of developing and non-developing AEWs. This study confirms some of previous studies' findings on structures of AEW. This study shows that the stronger meridional wind relates to the Cape Verde Storms. All the lesser meridional wind waves did not develop. Satellite imagery shows that the differences of convective cloud fields are not easily noticeable between developing and non-developing waves.

1. INTRODUCTION

Many fascinating studies have been done on Tropical Cyclone (TC) formations and how TC's relate to African Easterly Waves (AEW). Understanding these waves' life cycle development, from initiation to decay (Thorncroft et al. 2001), and identifying an AEW's potential for developing into a hurricane may improve hurricanes forecasting by detecting potential hurricane during their early life cycle.

Large field experiments on AEW's such as GARP (Global Atmospheric Research Program) Atlantic Tropical Experiment (GATE), more than three decades ago, helped us gain extensive available to study tropical atmosphere and AEW. The GATE project involved 40 research ships, 12 research aircraft, numerous buoys from 20 countries all equipped to obtain the observations specified in the scientific plans that try to understand the tropical atmosphere and its role in the global circulation of the atmosphere (GARP, 1998). Structural studies have covered on AEW from observations using streamline pressure and wind charts, surface and upper-air observations, also weather forecasts data (e.g., Burpee 1974; Reed et al. 1977; Pytharoulis et al. 2001). Typical wave structures describe as follows:

1.) At wavelengths about 2000km to 2500km, AEWs move westward around 8 meters per second, and about 6 to 7 degrees per day. A typical wave has a period of 2.5 to 5 days (Albignat et al, 1980).
2.) AEWs have their stronger signal near 600mb to 850mb level (Thorncroft et al. 2001).
3.) Colder temperatures are associated with southerly wind, and warmer temperature is associated with Northerly wind (Pytharoulis et al. 2001).
4.) There is a strong relationship between the wave pattern and the convective cloud pattern which appears ahead of wave trough. (Reed et al. 1977).
5.) A weaker Storm track is dominated by 600mb activity equatorward of 15° N (Pytharoulis et al. 2001, Thorncroft et al. 2001).

6.) A stronger storm track is dominated by 850mb poleward of 15° N (Pytharoulis et al. 2001, Thorncroft et al. 2001).
7.) Baroclinic instability maintains AEW structure. (Pytharoulis et al. 2001).

During the summer of 2006, two projects were carried out may also help to answer many questions on AEWs. NASA African Monsoon Multidisciplinary Analyses (NAMMA) project, concentrates on formation and evolution of TCs in the eastern and central Atlantic, and their impact on the U.S. east coast. The project also studies the compositions and structures of the Saharan Air Layer (Figure 1), whether aerosols affect cloud precipitation and influence cyclone development. African Monsoon Multidisciplinary Analyses (AMMA) project, an international research activity designed to study the development of tropical storms over the Atlantic Ocean and how the TS's evolve from preexisting easterly waves that develop over Africa. The projects are able to provide important data on AEWs' develpment.

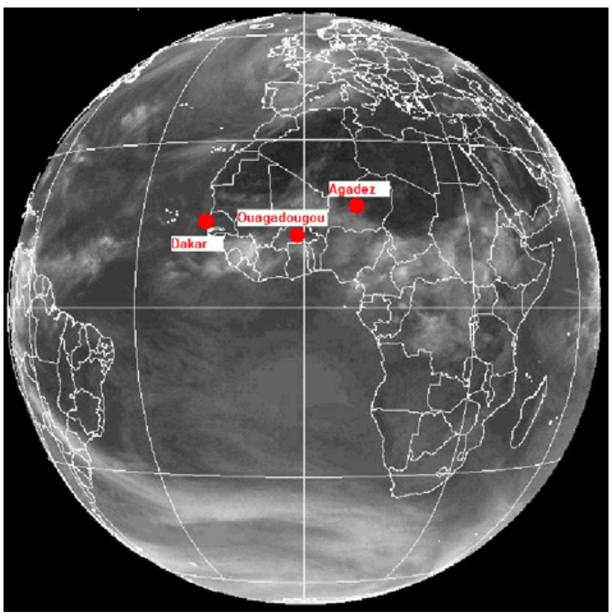

Fig. 1. Locations of 3 radiosonde stations used in this study.

AEW were studied extensively during the 1970's during and after the GARP Atlantic Tropical Experiment (GATE) project. Many structural features of AEW are identified after GATE project. The objective of this paper is to present the methodologies that are used upon reaching the conclusions using new NAMMA and AMMA data and to confirm previous findings and to draw some conclusions on the differences between developing and non-developing AEWs.

2. DATA ANALYSIS

AMMA project established numerous stations inland of Africa. Many stations collected high resolution, per 2 seconds, upper-air sounding data. Dakar and Bamako are the two classic stations many previous authors have mentioned. Agadez is a big city in Niger (Figure 1). Ouagadougou is a city in Burkina Faso. Agadez, Ouagadougou and Dakar stations gathered more complete data than other stations and shows better evolution of AEW.

Previous studies suggest that meridional wind perturbation is strongest near 600mb to 800mb (Reed et al. 1977). Figure 2 shows the perturbation is near 700mb. Temperature perturbation is strongest near 850mb. By comparing wind anomaly and temperature anomaly plot, AEW passage brings warmer temperature during northerly wind periods and cooler temperature during southerly wind periods.

Time height plot shows how AEW evolve over African Continent. Northerly wind follows southerly wind signals trough passage. Construct Meridional wind anomaly (MWA) plot is easier way to identify those trough passages. Agadez station shows lesser wind anomaly intensity, while some waves are still detectable which suggests the initiation of AEWs is somewhere more eastern. Ouagadougou MWA plot shows more defined trough passages. Dakar station near west coast of Africa shows the most intensification of AEWs' meridional wind development. Not only the intensities are greater, but also the waves' amplitude is greatest near 700mb. From NAMMA website, there are seven waves occurred. Five of those waves did not develop, and two of the waves became TS Debby, and Hurricane Helene. The only two waves that have white contours are the waves that became developing ones. Other five non-developing waves did not reach the intensity.

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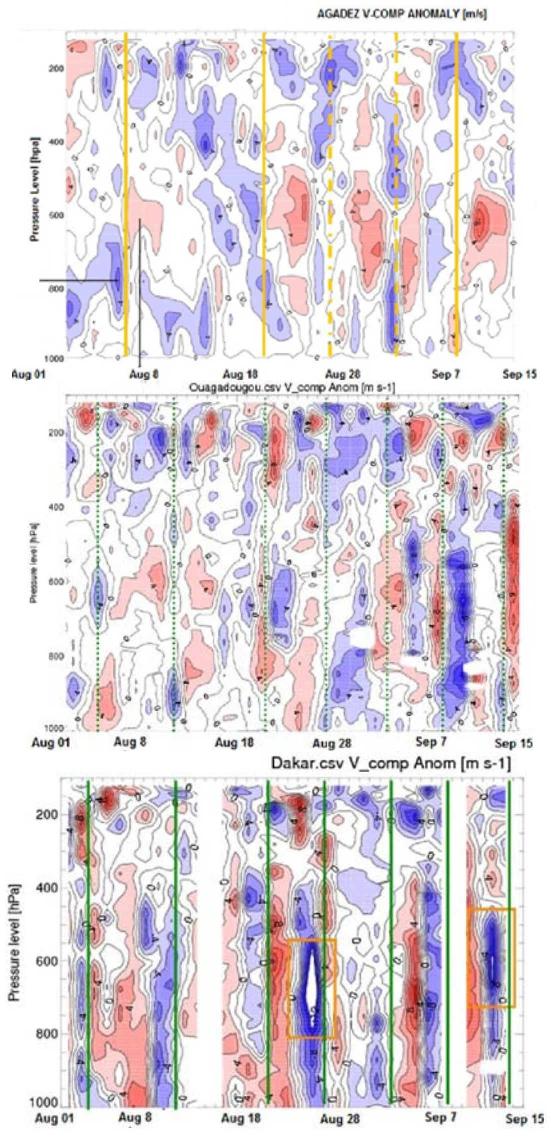

Fig 2a-c. Time-height sections of meridional wind at 3 radiosonde stations in west Africa showing the increase in wind amplitude as one goes west.

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3. SATELLITE IMAGERY

Previous studies suggested that AEW are recognizable on satellite images. Studying Visible and IR images during August 1^{st} and September 15^{th}, with 15 minutes interval, one can visualize AEWs in great detail (Figure 4). General features are easily noticeable. Cloud free region near Sahara desert shows subtropical high, and cloudiness show African Monsoon or ITCT. The boundaries between the two air masses are clearly defined. Low level and cirrus clouds movement shows vertical wind shear. Time heights plot also shows vertical wind shear profile. From previous studies, convective clouds are associated with AEW. Depicting this feature was also easy. The meteosat seven satellite images grid from 5° south to 20º north, and 50º east to 10º west. The most western station is Niamey where observation soundings data are available, and most eastern station is Praia. From the satellite images, although not easy, one can trace AEWs' movements; however, it is very difficult to find clues to say one wave will develop into TS or TC and another wave will perish.

4. COMPOSITE IR IMAGES

Advantages of looking at composite image are Cloudiness is enhanced and Diurnal variability is reduced, and The IR images are concentrate more on meaningful features such AEW. The concept is to see how progressions of cloudiness evolve as AEW amplifies. The strips are cut from IR images from 5N longitude to 20N and 50W and 10E. The strips are stacked so that the date trough axis passes Dakar is at the middle. The top strip at the top is presenting the fifth day prior to zero day, and the bottom strip is presenting the fifth day after trough passage. Every strip is a composite of daily average of all IR images taken that day. Despite such effort, the differences are still hard to see. The only inferred conclusion is that developing waves are showing concentrated cloudiness. The non-developing waves have scattered cloudiness. More methods should be developed to further investigate these IR images, such as subtracting non-developing IR composites from developing IR composites in hope that the differences might show more clearly.

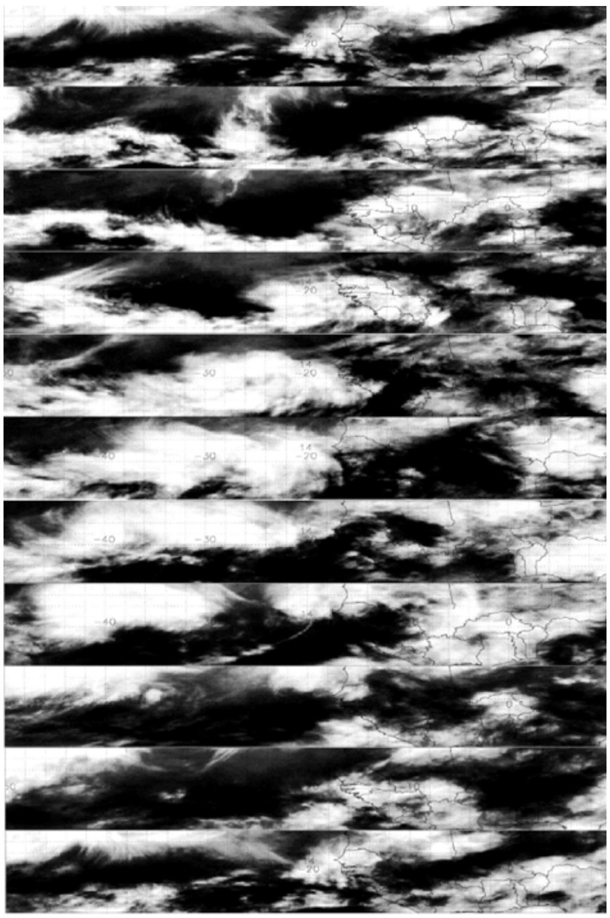
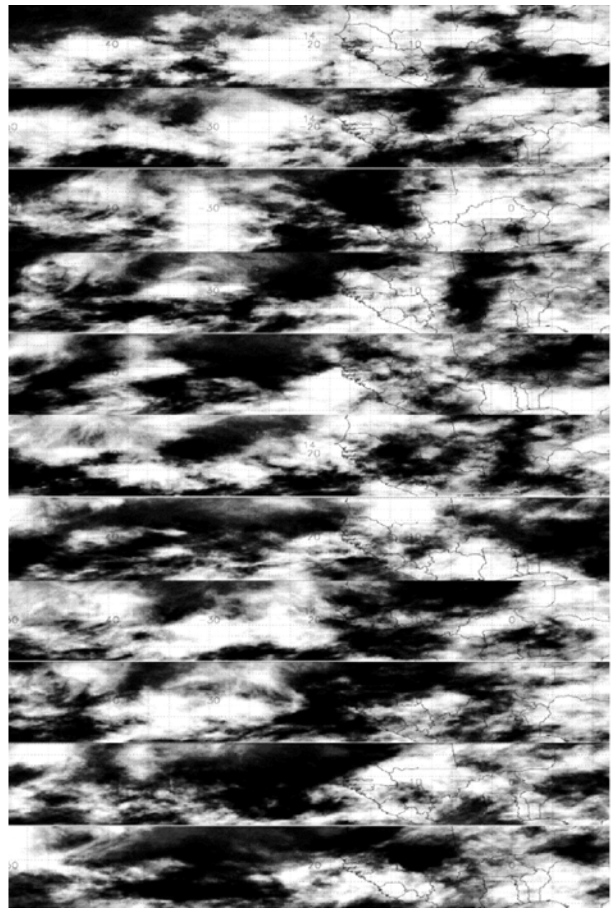


Fig. 3. Hovmoller diagram of average IR brightness temperature for average of 2 developing waves during NAMMA (above) and for 5 non-developing waves (above right). African coast is just to the east (right) of the center of the diagrams; the developing waves show much larger cloudiness over the ocean than non-developing waves.

5. CONCLUSIONS:

AEW has more structural characteristics that is not discussed in this paper due to time. For example, warm cores circulation to the North of African Easterly Jet (AEJ), cold core circulation south of the AEJ, also upper level circulations above 300mb. They are equally interesting and important to AEW development.

Satellite imagery are very essential to depict visual differences between developing and non-developing waves. Further steps should be taken to separate noise, also more date is needed to confirm previous discussion.



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More sounding networks are also need to better visualize AEW development north and south of AEJ. The AEW intensification is more easily seen from meridional winds anomaly plots. High Amplitude waves have more chance of developing into TS's and TC's. From IR composite images, the waves are harder to distinguish; however, the developing waves have more concentration cloudiness, as non-developing waves are scattered, especially off coast.

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