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Genesis of Atlantic tropical storms from African Easterly Waves – a comparison of two contrasting years

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1. Introduction

The weather and climate of West Africa has a strong impact on Atlantic tropical cyclone activity. At daily timescales, most Atlantic tropical cyclones form in association with African easterly waves (AEWs) that originate over the African continent (e.g. Avila and Pasch 1992). AEWs are synoptic scale systems with a preferred wavelength in the 2000-4000km range and also possess sub-synoptic scale structures that are associated with non-linear developments (e.g. Thorncroft and Hoskins 1994b), Potential vorticity (PV) anomalies generated by convection in MCSs (e.g. Schubert et al. 1991) or a combination of these. We also recognize however that other mechanisms may also operate to influence the probability of tropical cyclogenesis just downstream of West Africa including SSTs (Goldenberg et al. 2001), vertical wind shear (Aiyyer and Thorncroft 2005) and "wave accumulation" in association with zonal variations in the zonal wind (c.f. Webster and Chang 1988).

Using the ECMWF ERA40 reanalysis data and an automatic tracking technique (Thorncroft and Hodges 2001), we have found that there exists large variability in the number of storms (as seen in the tracked, coherent vorticity features) that emanate from the West African coast on seasonal and interannual-to-decadal timescales (Hopsch et al. 2005). While the low-frequency variability is well correlated with other large-scale variations of e.g. Tropical Storm activity, West African rainfall and SSTs (Goldenberg et al. 2001), we found that the variation of the storm tracks on interannual timescales is not as easily explained. In contrast, however, a significant positive correlation was found between the interannual variation of the 2-6 day filtered meridional wind, which provides a synoptic-scale measure of African Easterly Wave activity, and Atlantic tropical cyclone activity.

The goal of this presentation is to provide a more detailed analysis and investigation of the nature of the weather systems themselves, including description of possible environmental influences.

2. Approach

Toward helping us interpret the interannual variability of the relationship between AEWs and tropical cyclones we consider two contrasting years, 1988 and 1989 (see Fig. 1), which contained the least active and most active seasons in the storm track data over the Guinean Highlands area, one of the most important source regions of storm tracks. The two years also showed an interesting difference in genesis location for most MDR tropical storms, as will be described in the results below.

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To augment our understanding of the differences between the two years, special attention is given to the precursor disturbances which ultimately became Gilbert (1988) and Hugo (1989) respectively. These two tropical storms were chosen since the locations of cyclogenesis were representative of the two years considered here.

3. Results

Figure 1 shows that in 1988 relatively few coherent storms were generated over the Guinea Highlands, with more storms being generated further west over the tropical Atlantic, westward of a cold SST anomaly. In contrast, the ERA40 tracks for 1989 showed that many storms were generated over the Guinea Highlands and the adjacent tropical Atlantic. While seven named Atlantic tropical storms formed within the MDR in both years, the location of genesis differed markedly. Namely, the tropical storms generally formed west of 40ºW during 1988, whereas they formed directly offshore of West Africa in 1989.

The differences between the two seasons from a synoptic-scale perspective can also be seen in the Hovmöller plots, Fig. 2. The Hovmöller plots, averaged over 9º-19ºN, show the 2-6day filtered meridional winds on 600hPa level for July 1, 1988 to October 31, 1988 on left panel, and for 1989 on the right panel. Overlaid are also the genesis locations of the named tropical storms found in the MDR from the NHC best track data. The arrows point to the genesis points of Gilbert (1988) and Hugo (1989) respectively. Consistent with the annual summaries for the two years (Avila and Clark, 1989; Avila, 1990), it is seen that these hurricanes were associated with AEWs, as identified here in the ERA40 data set. A clearer view of the AEW-connection for Gilbert 1988 is provided in Fig.3, showing maps using CLAUS brightness temperatures (shading), streamfunction of the 2-6 day filtered meridional wind on 600hPa, relative vorticity on 850hPa and location for tracked, coherent vorticity centers (diamond). The location of the synoptic-scale trough lines of the AEW associated with Gilbert in 1988 are drawn with a solid, heavy line. Panel a) shows when the AEW is located over West Africa; in panel b) convection has decreased considerably and the weakened AEW is found over the mid-Atlantic area, and c) shows the system 6 hours before the system is declared a tropical depression in the NHC best-track data set. Figure 4 shows the evolution of the precursor disturbance of Hugo 1989. Panel a) shows that the associated AEW is found just east of the Greenwich meridian, behind a relatively large convectively active area. By the time the system reaches the Guinea Highlands (b) the convection has induced sufficient low level vorticity to allow a coherent vorticity track to form (diamond just ahead of the trough line). As the system emerges off the West African coast, the low level vorticity increases further and is officially declared a tropical depression at the time shown in c).

4. Final Comments

The year-to-year variability of AEWs and associated weather systems over West Africa is large (Hopsch et al. 2005). An example of two contrasting years illustrates the very different character the two seasons had from an environmental, synoptic-scale as well as sub-synoptic scale perspective. Some of the most interesting tasks are to find and describe the reasons for why the two seasons were so different from the vorticity tracking perspective but showed similarities in e.g. the number of named tropical storms in the MDR. Using those results we can gain a much better understanding at how disturbances of African origin interact with the environment or how they develop into tropical storms.

In future work we will extend the case-studies, analyze the vertical structure of the systems, and examine their interaction with the large-scale AEWs. We will also provide a composite study to help us better understand this interannual variability. We also intend to further highlight the processes that lead to cyclogenesis over the mid-ocean region vs. cyclogenesis close to the West African coast.

Acknowledgement:

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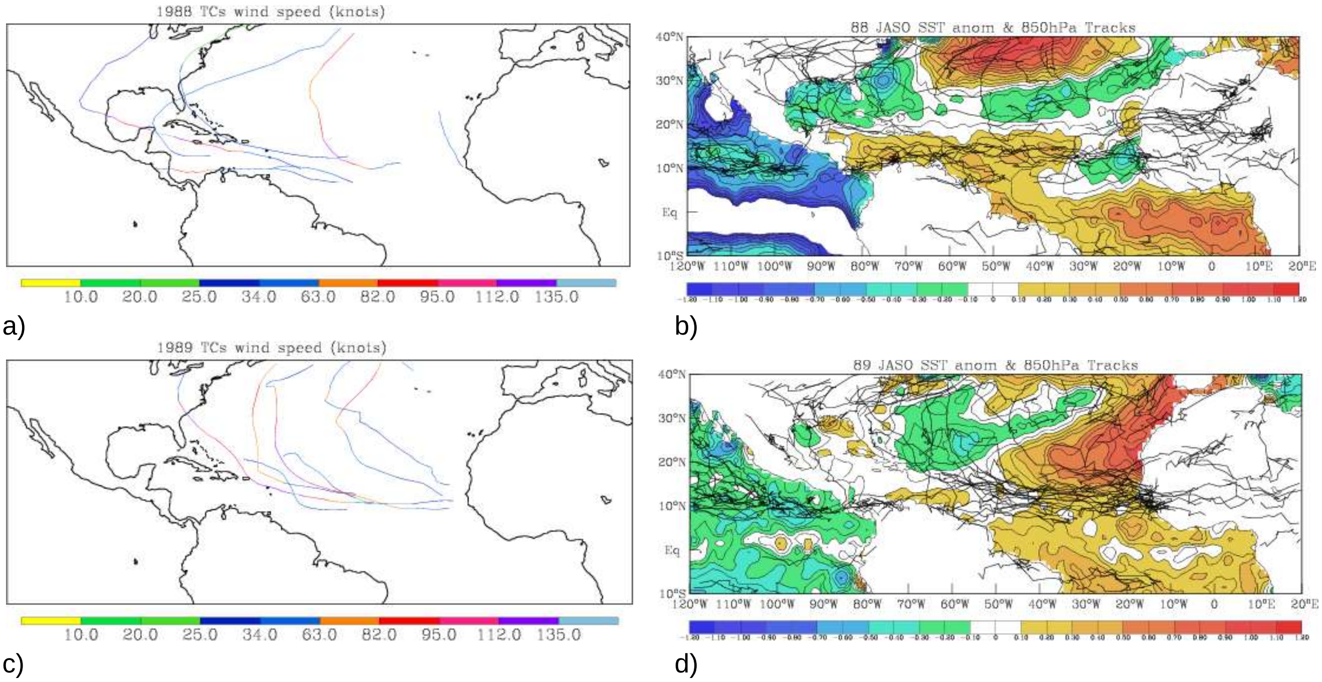


Fig. 1a: Tropical storm tracks from NHC best track data for MDR storms (wind speed in knots), formed in 1988. b: storm tracks (solid black) for July-October,1988, from ERA40 overlaid on SST anomalies (contours every 0.1ºC, positive anomalies warm colors, negative anomalies cold colors), c) same as in a) but for 1989, and d) is same as in b) but for 1989.

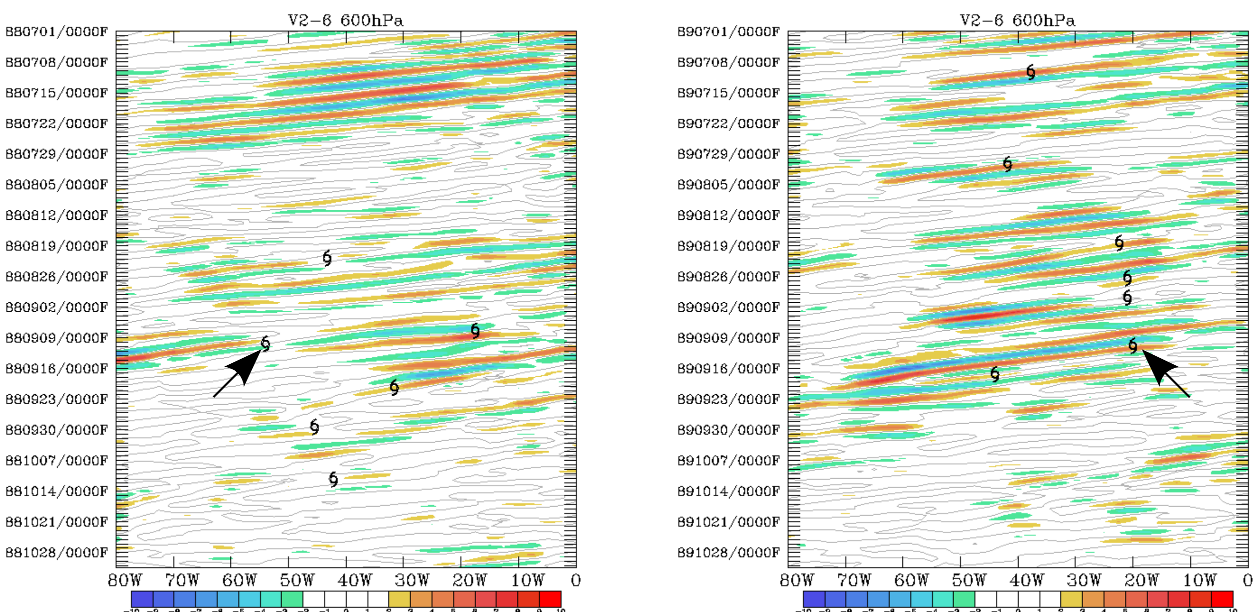
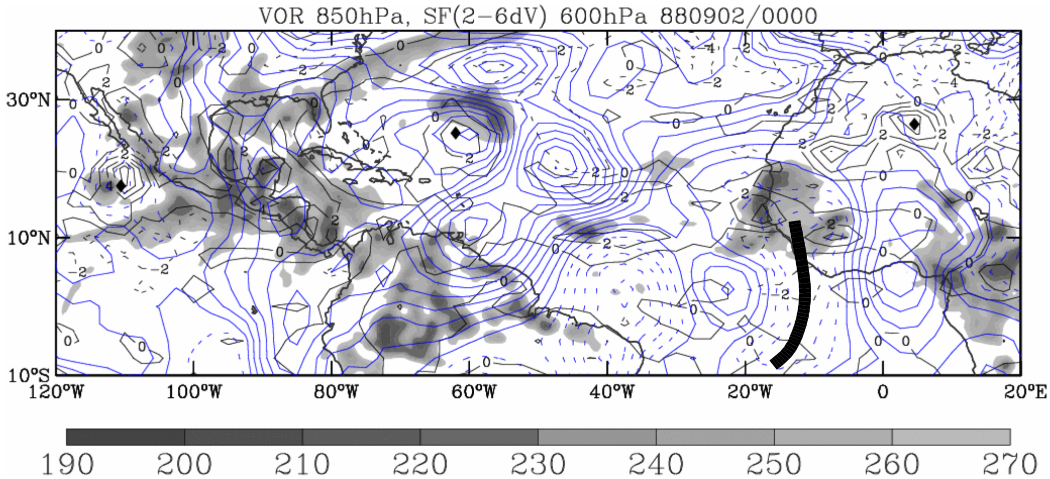
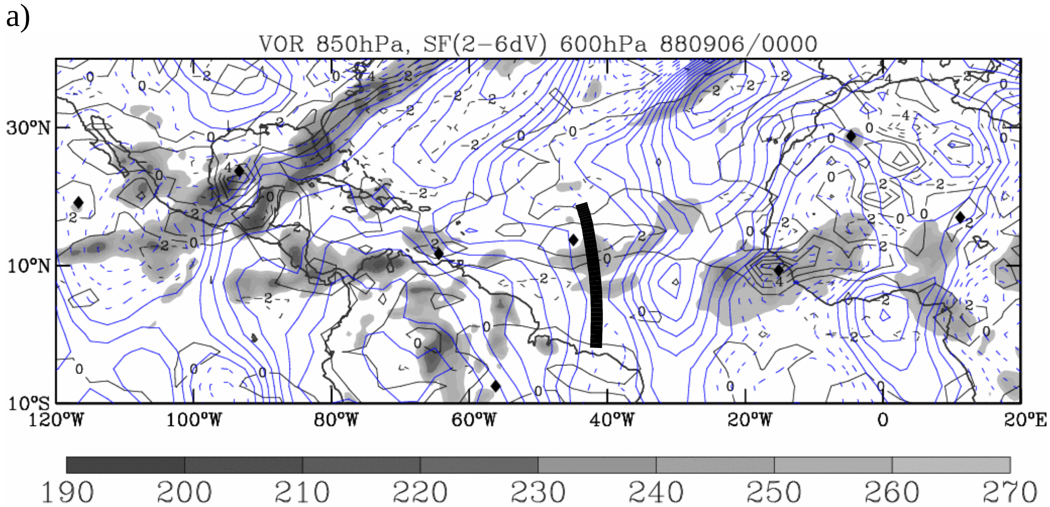


Fig2: Hovmöller plots, averaged over 9º-19ºN, showing 2-6day filtered meridional winds on 600hPa level for July 1, 1988 to October 31, 1988 on left panel, and for 1989 on the right panel. Overlaid are also the genesis locations of the named tropical storms found in the MDR from the NHC best track data. Arrows are pointing to the genesis points of Gilbert (88) and Hugo (89) respectively.



a)



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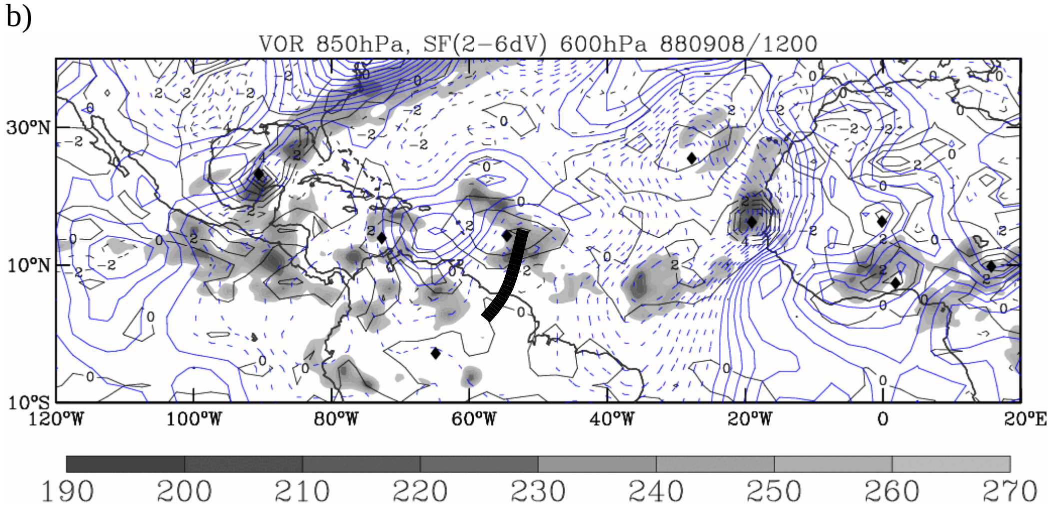
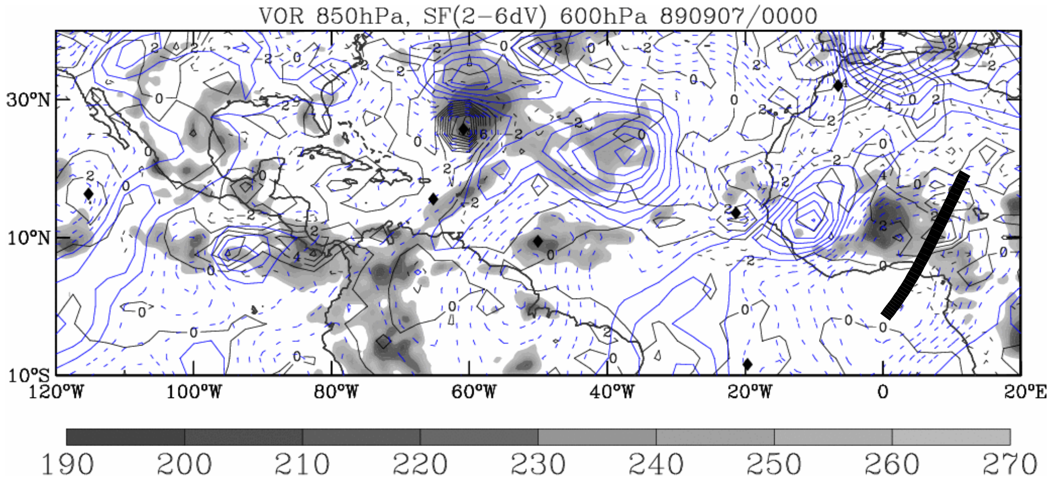
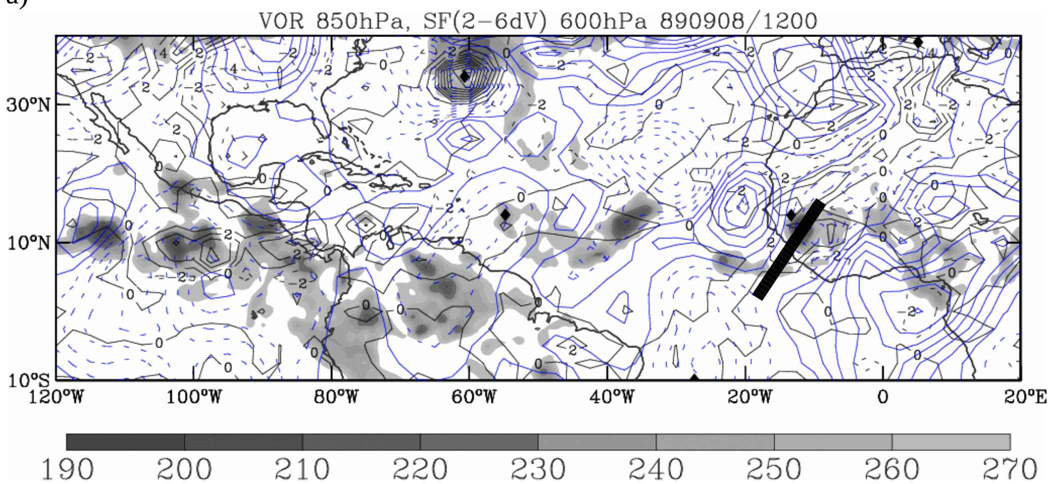


c)

Fig 3: Maps showing CLAUS brightness temperatures (shading), streamfunction of the 2-6 day filtered meridional wind on 600hPa (blue contours, positive values solid – negative values dashed), relative vorticity on 850hPa (black thin contours, positive values solid, negative is dashed) and location for tracked, coherent vorticity centers (diamond). The location of the synoptic-scale trough lines of the AEW that is associated with Gilbert in 1988 (a: as the AEW is located over West Africa; b: AEW is found over the mid-Atlantic area, and c: 6 hours before the system is declared a TD by NHC) are drawn with a solid, heavy line.



a)



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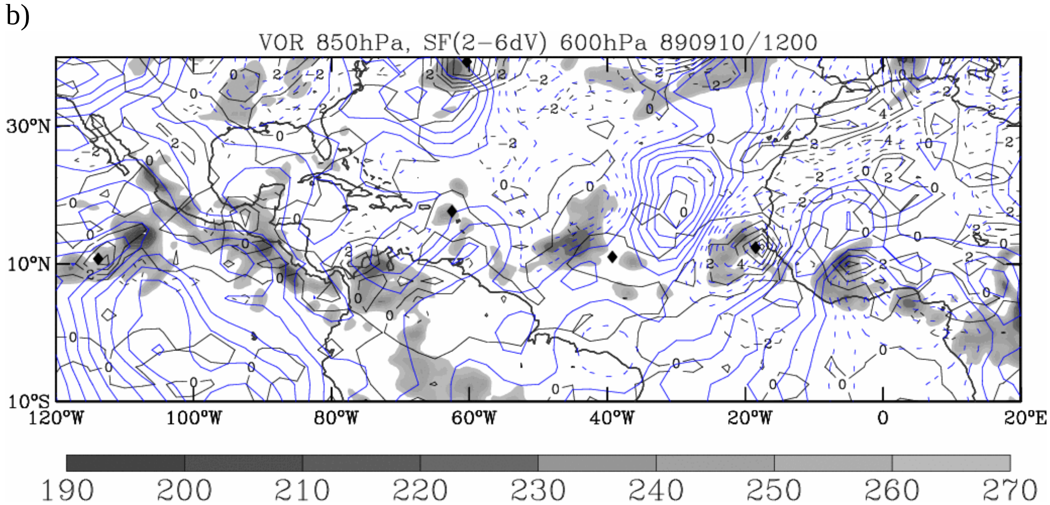

c)

Fig. 4: same as Fig.3 but for Hugo 1989, showing CLAUS brightness temperatures (shading), streamfunction of the 2-6 day filtered meridional wind on 600hPa (blue contours, positive values solid – negative values dashed), relative vorticity on 850hPa (black thin contours, positive values solid, negative is dashed) and location for tracked, coherent vorticity centers (diamond). a: AEW is located just east of Greenwich meridian, b: coherent vorticity track and AEW are located over Guinea Highlands, c: official start of TD that later became Hugo.