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Comparison of The Large-Scale Environment over The Tropical Eastern Atlantic During August 1994-1997

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1. Introduction

The 1997 Atlantic hurricane season produced 7 named storms, 3 of which became hurricanes. This is a significant reduction in the number of named storms from the seasons of 1995 (19 named storms 12 became hurricanes) and 1996 (13 named storms, 9 became hurricanes). There was no tropical storm development in August 1997. In contrast, 7 storms originated in August of 1995 and 4 in August of 1996. Another sharp contrast between 1997 and the previous two years is that no named cyclone developed in tropical Atlantic Ocean east of 45W in 1997, while 6 developed in that region in 1995 and 1996, respectively. Figure 1 shows the tracks of tropical cyclones for these 4 years.

The sharp reduction in tropical cyclone activity in the Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico in 1997 from the previous 2 years was due in part to the strong on-going El Niño event. In a special climate summary published by the Climate Prediction Center of the National Centers for Environmental Predictions (NCEP), the author attributed the decreased number of tropical storms in 1997 to stronger vertical westerly wind shear, normally found in El Niño years, and a weaker equatorward-shifted African easterly jet. This study will examine the large-scale environment during the month of August with emphasis on the conditions that led to suppressed tropical cyclone activity over the eastern Atlantic Ocean in 1994 and 1997. The data from August 1994 is included in this study because the hurricane season of 1994 also had a relatively suppressed Atlantic hurricane activity with 7 named storms, 3 of them hurricanes. Another reason to include 1994 in this study is that only two tropical storms developed over eastern Atlantic Ocean.

Rawindsonde reports from the Caribbean and western African stations, satellite images and NCEP global spectral model analyses are used in this study.

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2. Results

2.1 Vertical wind shear

Figure 2 shows the August mean zonal wind profiles from Guadeloupe (16.2N 61.5W), Barbados (13N 59.5W), Sal (16.7N 22.9W) and Dakar (14.7N 17.5W). August 1997 recorded the strongest westerly vertical shear over the two eastern Caribbean stations while August 1995 had very little vertical shear. Anomalous upper level westerly winds can be found over portions of the western and southeastern Caribbean Sea in Fig. 3. However, over the tropical Atlantic Ocean, the anomalous westerly winds were mainly located south of the equator. The mean August zonal winds profiles from the western African stations (Fig. 2c-d) indicated very little vertical wind shear in August 1997.

2.2 Static stability

The static stability from the above rawinsonde stations was also examined. One of the indicators of cyclogenesis is increased convection in the vicinity of a tropical disturbance. In 1995 and 1996 all of the tropical cyclones that formed over the eastern Atlantic Ocean evolved from westward propagating African waves. These waves normally have convection associated with them as they move across west Africa. For a wave to develop into a tropical cyclone over the eastern Atlantic, it must be able to maintain and increase the amount of convection in the vicinity of the wave trough.

Fig. 4 is shows the Hovmoller diagrams of twice-daily satellite images. Each strip covers a latitude band from 5N to 15N and from 70W to 60E. Convection associated with the African waves was very active over west Africa in 1994. However, except for a one week period started in mid-August, deep convection associated with the waves quickly dissipated over the eastern Atlantic. The waves continue to propagate westward but were not able to generate organized deep convection. During that one week period in August 1994, one tropical storm (Chris) formed and later intensified into a hurricane.

The Hovmoller diagram for 1995 shows that organized deep convection associated with the African waves remained well defined as the waves moved over the eastern Atlantic Ocean. During the second half of August 1995, organized deep convection actually increased as the waves moved off the west coast of Africa. Many of the waves developed into tropical storms and hurricanes. The phenomena continued into early September of that year.

A similar increase in organized deep convection as the African waves moved over the eastern Atlantic can be found in the second half of August 1996. Several of those tropical waves developed into tropical cyclones over the eastern Atlantic.

The pattern for August 1997 is quite different. Convection over Africa was less impressive than the previous 3 years. Deep convection over the eastern Atlantic Ocean was more active than 1994 but less than 1995 and 1996.

There are several factors that may affect the ability of the African waves to produce deep convection in the vicinity of their wave troughs, such as: the intensity of the waves in terms of the magnitude of the low level convergence, the static stability of the environment, the sea surface temperature, and the magnitude of the large-scale lifting (e.g convergence in the Intertropical Convergent Zone). Some of these factors may be interrelated.

Table 1 lists the August mean 1200 UTC convective available potential energy (CAPE) from the four rawinsonde stations. For the west African stations August 1995 has the largest value, followed by 1996. The CAPE for Dakar and Sal in 1994 and 1997 are significantly smaller. The change in the static stability can be attributed to the change in large-scale low level meridional winds as shown in Fig. 5b. Both 1994 and 1997 show stronger mean northerly winds in the lower troposphere over Dakar. The cooler boundary layer air over Sal (Fig. 5c) and Dakar (Fig. 5d) is consistent with the stronger northerly winds. Although the August mean CAPE was higher in 1994 than in 1997, the below normal sea surface temperature over north Atlantic Ocean in 1994 may have further suppressed the development of deep convection in that year.

2.3 Large-scale lifting

Data from NCEP global model analyses was used to study the difference in large-scale lifting over the tropical eastern Atlantic Ocean. Figure 6 shows the August mean velocity potential during these 4 years. Differences between the two active years and the two suppressed years are very much in evidence. Both 1995 and 1996 show strong mean 200 MB divergence over the tropical eastern Atlantic Ocean. The strong zonal component of the divergent flow over the Caribbean Sea in 1995 weakened and was replaced with meridional divergent flow in the second half of August (not shown). Weaker 200 mb divergence over the tropical Atlantic Ocean between 5N and 15N can be found for both 1994 and 1997 and indicates weaker large-scale lifting in that region. The pattern for the two active years suggests stronger Hadley circulations over the tropical Atlantic Ocean and the Caribbean Sea. The pattern for the two suppressed years suggests a weaker Hadley circulation but stronger Walker-like circulation. The August 1994 mean shows 200 mb center of divergence over west Africa and weak divergence over adjacent eastern Atlantic Ocean. Upper level convergence can be found from 45W westward to over the eastern Caribbean Sea. The upper level divergence pattern agrees very well with the distribution of cloudiness for 1994 as shown in Figure 4.

3. Conclusions

The weaker tropical cyclone activity in August of 1994 and 1997 is partially related to the stronger westerly vertical wind shear found over the Caribbean Sea. The lack of cyclogenesis in the eastern Atlantic Ocean is clearly related to the more stable environment that resulted in less deep convection found in the vicinity of the troughs of the African waves. The weaker Hadley circulation over that region also suppressed the development of deep convection by providing less background uplift. The cooler than normal sea surface temperature in 1994 further reduced the amount of convection and thus the chance of cyclogenesis over the tropical eastern Atlantic Ocean. The cooler sea surface temperature and the large-scale upper level convergence may be responsible for below normal rainfall over the northeast Caribbean.

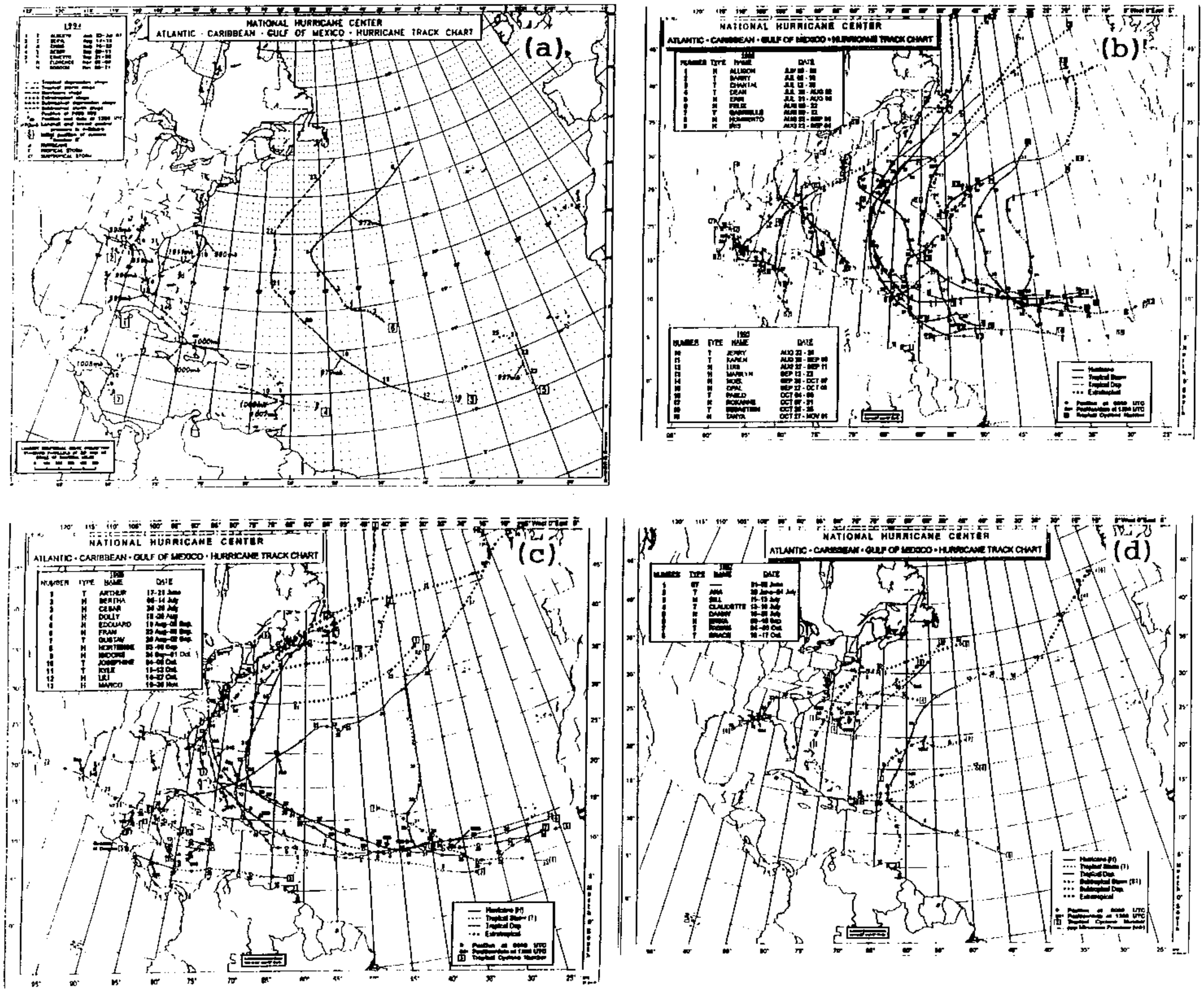

Figure 1. Tropical cyclone track charts for (a) 1994, (b) 1995, (c) 1996 and (d) 1997.

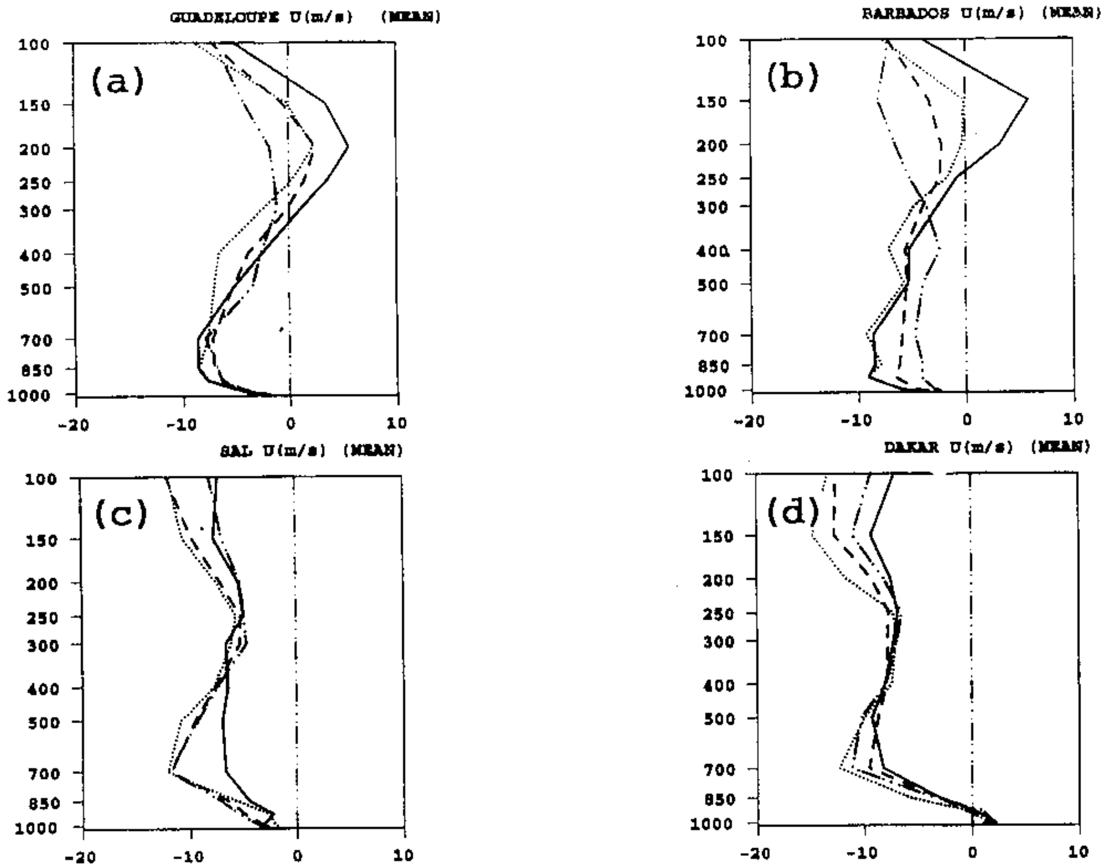

Figure 2. August mean zonal wind profiles for (a) Guadeloupe, (b) Barbados, (c) Sal and (d) Dakar. The dotted lines are for 1994, dash-dotted line for 1995, dash lines for 1996 and the solid lines for 1997.

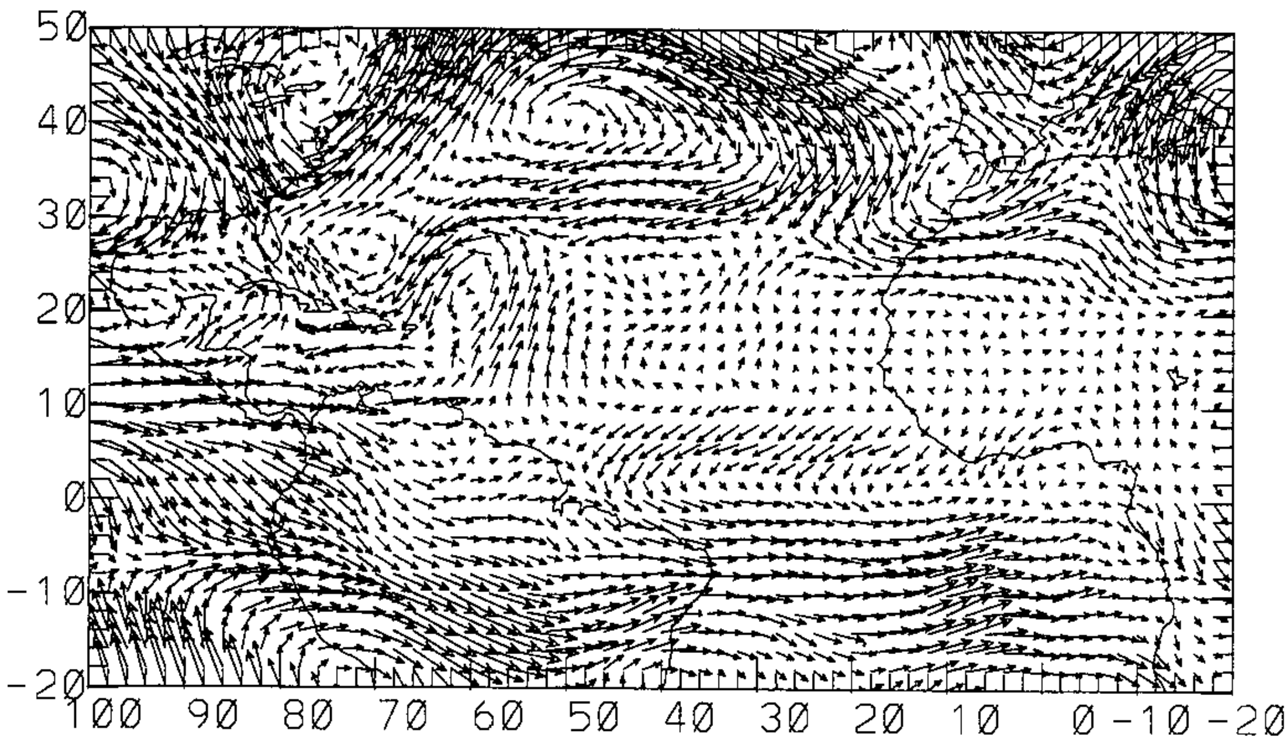

Figure 3. August mean 200 MB wind anomaly.

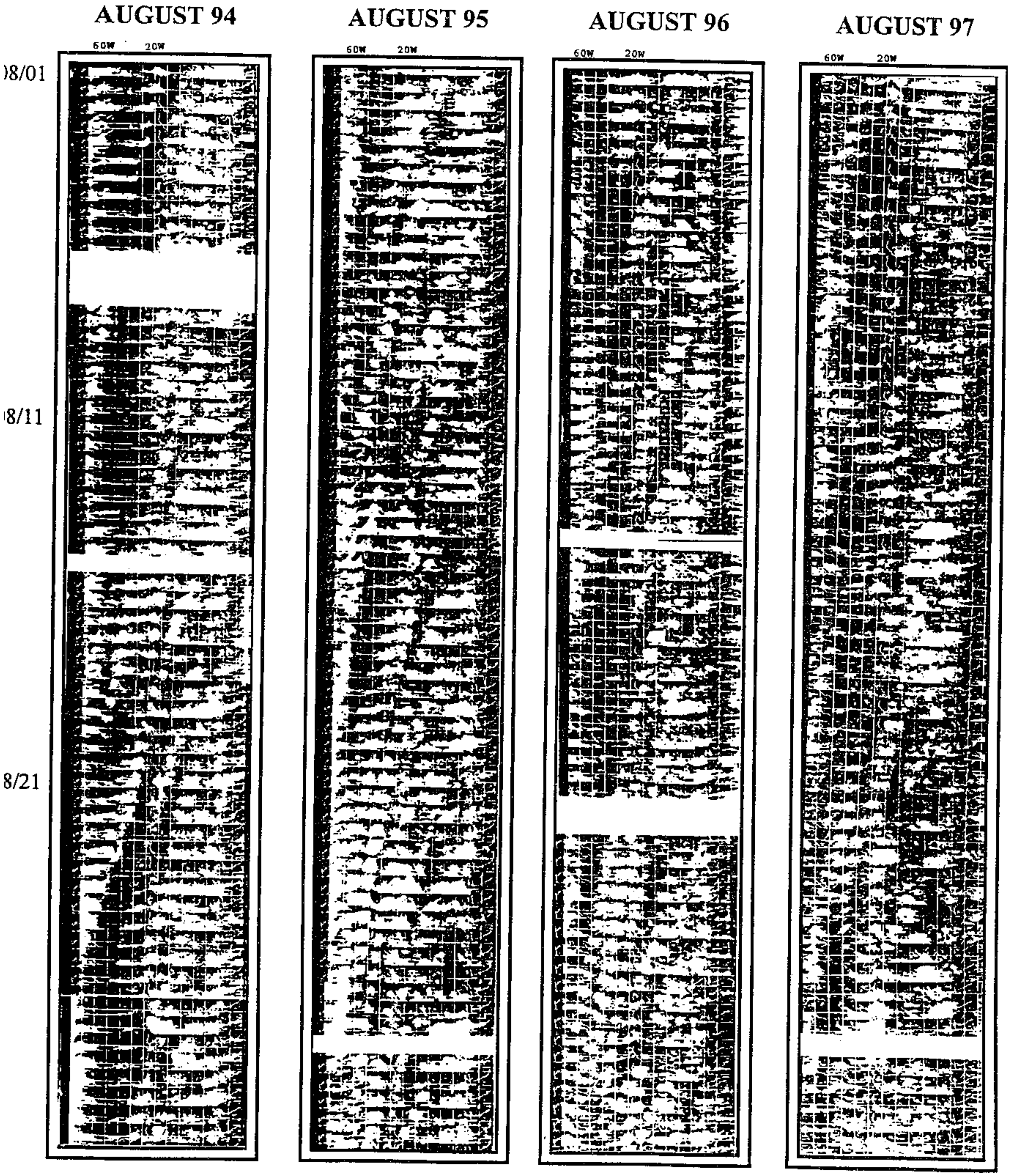

Figure 4. Hovmoller diagrams of twice daily satellite images for the month od August. Each extends from 5N to 15N and from 70W to 60E.

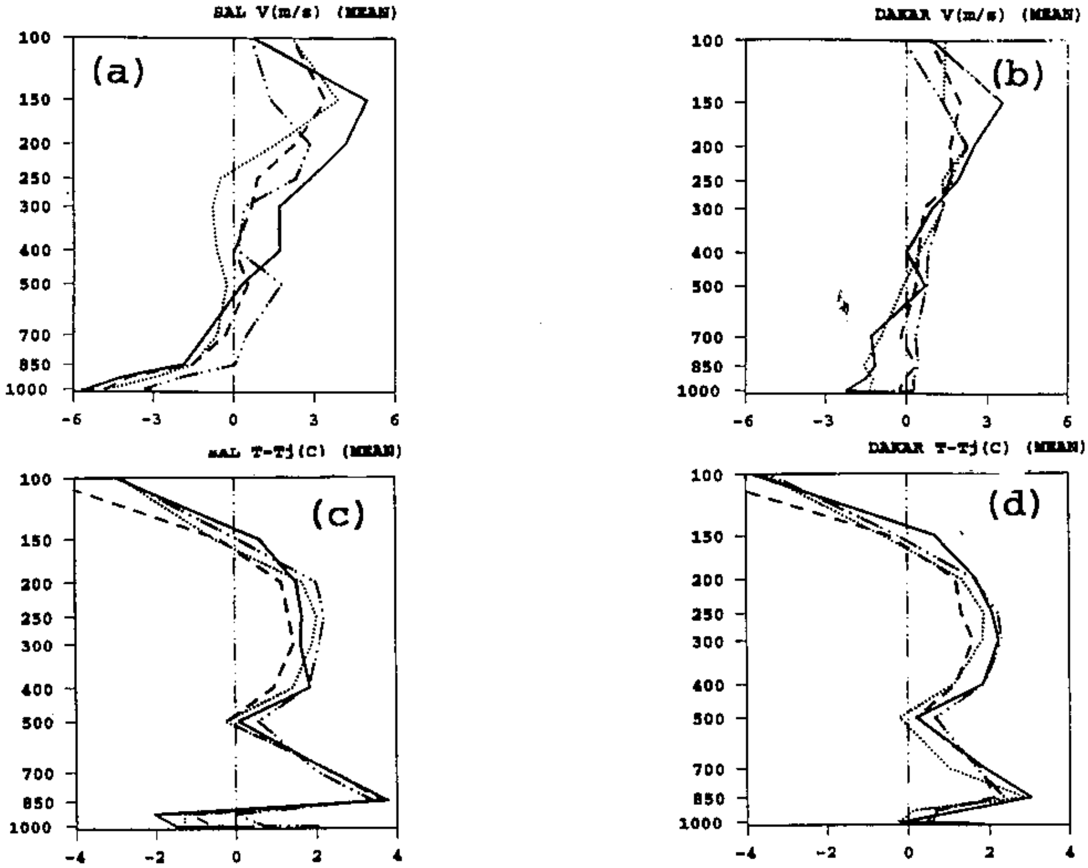

Figure 5. August mean profiles of (a) mean meridional wind at Sal, (b) mean meridional wind at Dakar, (c) temperature relative to Jordan's western Caribbean temperature at sal, and (d) same as (c) except for Dakar.

	1997	1996	1995	1994
Dakar	386	681	838	448
Sal	35	121	181	82
Guadeloupe	886	547	1456	147
Barbados	1800	1378	2812	1343

Table 1. August Mean Convective Available Potential Energy.

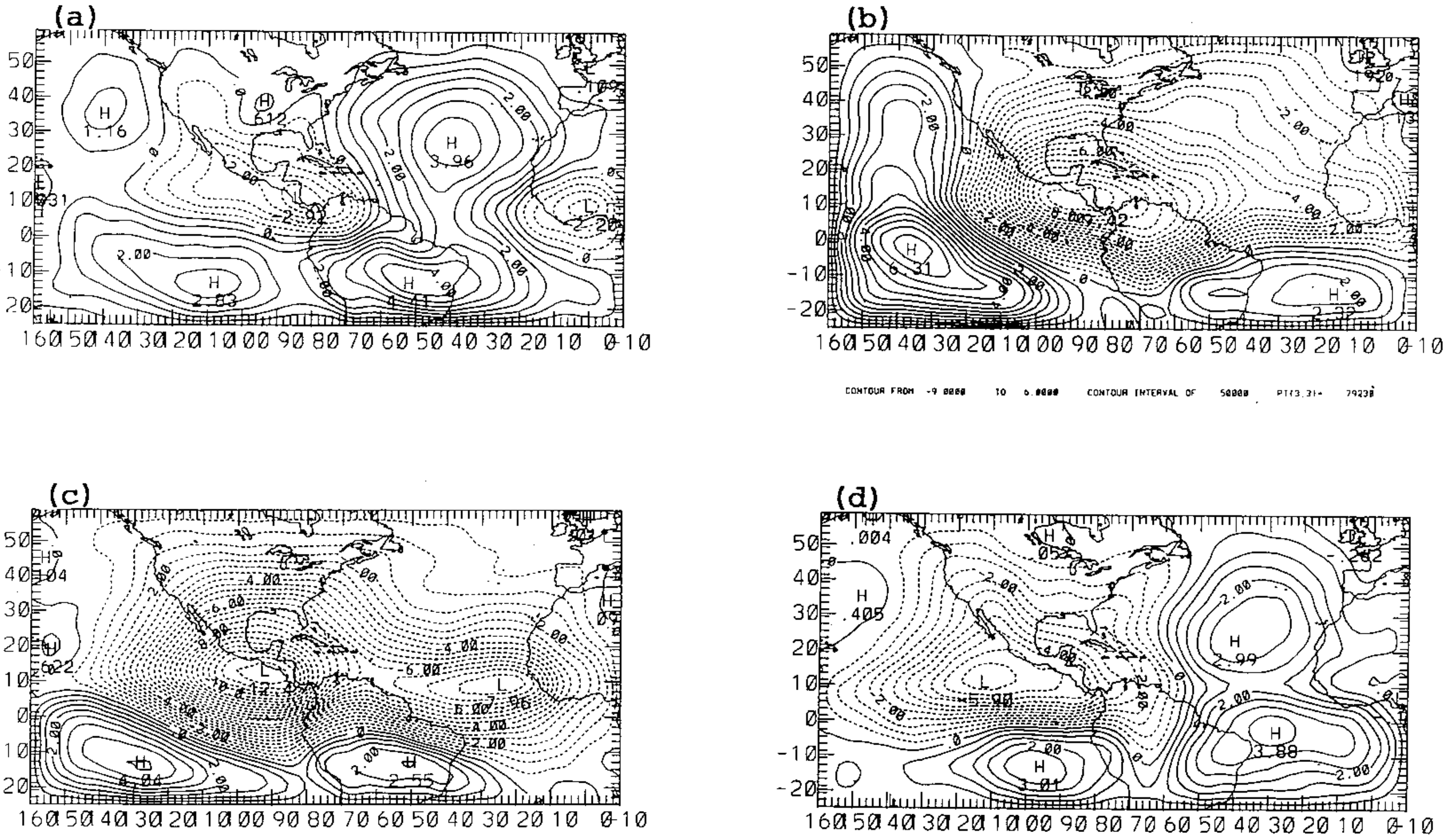

Figure 6. August mean 200 MB velocity potential for (a) 1994, (b) 1995, (c) 1996 and (d) 1997.