2A.2 Precursor Climate Aspects of the 2005 Atlantic Hurricane Season

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1. INTRODUCTION

Extreme tropical cyclone (TC) activity was seen in the Atlantic basin during 2005 with overall Accumulated Cyclone Energy (ACE; Bell et al. 2000) the highest observed since records began. The record activity was under-forecast by the various groups that forecast seasonal hurricane parameters. It is instructive to take a look at the climate factors that are well known to precede active TC seasons and compare whether 2005 fits the mold. High-latitude blocking seems to have played a large role in the maintenance of record warm sea-surface temperatures (SSTs) in the tropical Atlantic. Prevailing steering currents are also examined and contrasted to 2004, another active landfall year.

2. CLIMATE PARAMETERS

Perhaps the most well known of Atlantic seasonal forecast parameters is the El-Niño Southern Oscillation (ENSO). The influence of ENSO on seasonal TC activity was first documented by Gray (1984), who showed that warm (cool) ENSO episodes tend to diminish (increase) Atlantic TC activity. It is notable that El Niño was not a factor in this record season. 2005 continued an anomaly seen in 2004 where, despite near or slightly above-normal temperatures in the equatorial Pacific Ocean, record levels of TCs were noted.

A well-accepted parameter linked to increased TC activity in the Atlantic is the SST anomaly (SSTA). TC activity tends to be increased when Atlantic basin waters are warmer-than-average (green box, Figure 1). 2005 was the warmest year on record in this region since 1871. The warm SST signal was apparent even before the typical peak of the season. Figure 1 shows the warm SSTs in the tropical Atlantic.

One reason for the exceptionally warm water was the dominant mid-latitude pattern during the weak El Niño winter of 2004-2005. A mean deep-layer low pressure system was beneath a blocking ridge over the central north Atlantic, causing much weaker-than-average northeasterly trade winds (Figure 2) that did not cool the Atlantic waters as much as typical, through less evaporation and mixing (Gray et al. 1997). This pattern was very conducive to keeping warmer-than-average water in the tropical Atlantic. The winter circulation anomalies are consistent with the results of Enfield and Mayer (1997) that suggest that the summer after an El Niño, tropical Atlantic SSTs tend to be warmer-than-average because of the weak trade winds.

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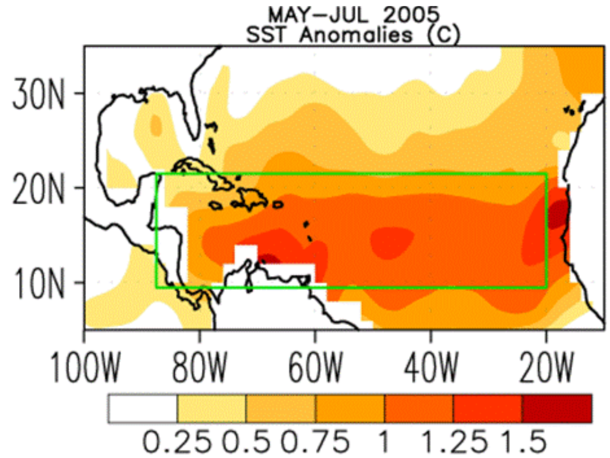

Figure 1- 2005 May-July SSTA (°C) in the tropical Atlantic (base period 1971-2000).

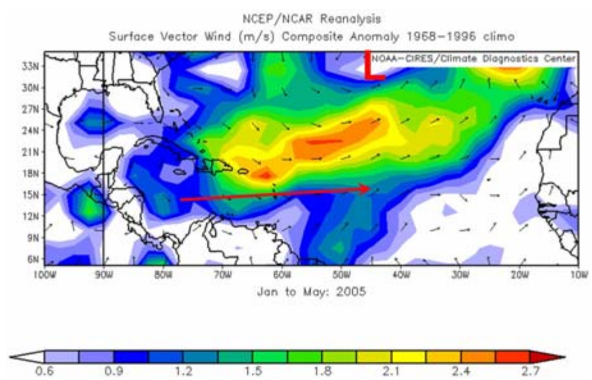

Figure 2- 2005 Jan-July Surface wind anomalies. A large area of tradewinds that are 1.5 m s^{-1} or more weaker than normal is green or warmer.

A second reason for the much-above normal water temperatures is the Atlantic Multidecadal Oscillation (Goldenberg et al. 2001), and its associated weaker-than-average tropical easterly and northeasterly trade winds (Bell and Chelliah 2006). These conditions are typical of active hurricane eras, and we are now 11 years into a very active era that began in 1995.

One seasonal forecast predictor that has been known since the 1930s (Ray 1935) is the early-season sea-level pressure anomaly (SLPA) in the Caribbean basin. Active hurricane seasons tend to be more likely when the SLPA is below average. Klotzbach and Gray (2004) and Blake and Gray (2004) showed the key area of anomalously low pressure extends from the Caribbean into the subtropical Atlantic Ocean. The NCEP Reanalysis dataset (Kalnay et al. 1996) shows the June-July SLPA for the Atlantic basin was the lowest on record since 1948, indeed a strong precursor signal for high activity during 2005 (Figure 3).

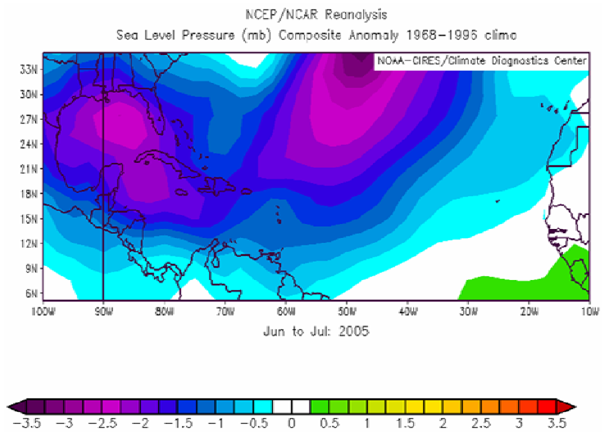

Figure 3- 2005 June-July SLPA. Areas of dark blue or cooler refer to pressure anomalies of 1 mb or more.

Another hallmark of active hurricane seasons is the occurrence of TC formation in the eastern Caribbean Sea or tropical Atlantic before 1 August (Gray et al. 1998). The Gray research group originally used this parameter in their 1 Aug hurricane forecast in 1997 and substantially improved hindcast results. During 2005, a record seven named storms formed prior to 1 August, and two major hurricanes formed in the deep tropics. This unprecedented activity presaged the record season.

Early-season vertical wind shear is also an indicator for activity in the Atlantic basin (Gray 1984). When shear in the deep tropical Atlantic and Caribbean Sea is less than average in June/July, TC activity for the rest of the season tends to be above average. Figure 4 shows that shear was much below-average throughout the western part of the basin before 1 August.

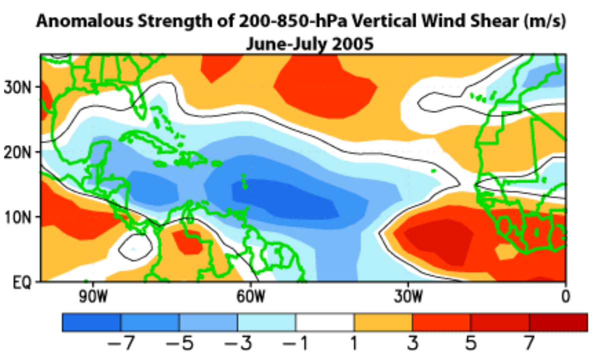

Figure 4- 2005 June-July wind shear anomalies (base period 1971-2000).

Several factors contributed to the weak vertical shear during the 2005 season. In the lower atmosphere, an additional weakening of the easterly trade winds and an associated increase in low-level cyclonic vorticity occurred in response to 1) a northeastward shift and strengthening of the ITCZ over the Eastern Pacific (Figure 5), and 2) exceptionally low SLP across the western part of the basin. In the upper troposphere, an extensive area of easterly wind anomalies over the tropical Atlantic basin can be linked to the ongoing multi-decadal signal and to a very strong ridge over the eastern U.S. and western Atlantic. The combination of anomalous upper-level easterlies and lower-level westerlies then produced an expansive area of exceptionally low vertical wind shear across the tropical Atlantic and Caribbean Sea. These conditions persisted for much of the season. As a result, tropical waves that entered the western tropical Atlantic and Caribbean Sea encountered a very favorable low-level and upper-level environment, making these preferred TC genesis regions.

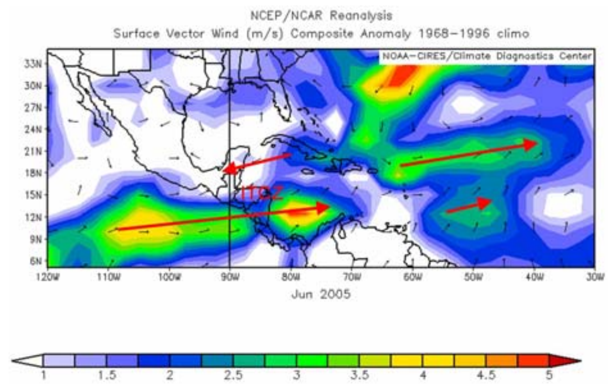

Figure 5- June 2005 surface wind anomalies.

In addition 2005 will be known for a record number (4) of major hurricanes striking the U.S., causing the most U.S. damage ever recorded. Steering patterns during the summer of 2005 showed a large mid-level ridge over eastern N. America that directed hurricanes toward the United States (Figure 6). This pattern has similarities to August-October (ASO) 2004, which also resulted in a very destructive hurricane season.

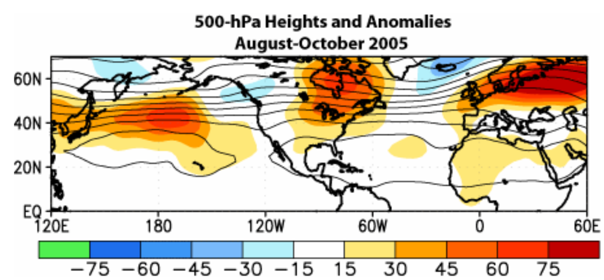

Figure 6- Aug-Oct 2005 500 mb height anomalies (base period 1971-2000).

A supplemental way of measuring the steering currents during hurricane season is to use the Arctic Oscillation (AO) during ASO, as described in Larson et al. (2005). They found that about 75% more tropical storms and hurricanes hit the United States during ASO when the AO is in the upper tercile, i.e. positive, versus the lower tercile, or a negative AO. During ASO 2005, the AO index was squarely in the upper tercile, which is consistent with the much-above average number of TCs hitting the U.S.

during that period. In fact, it is striking how much Fig. 6 resembles Figure 10a from Larson et al. (2005), albeit the latter figure was for the 200 mb, rather than the 500 mb, level. It should be noted, however, that the last hurricane to make landfall in the U.S., Wilma, crossed Florida from southwest to northeast in late October. By that time, the steering pattern must have shifted significantly from that implied by Fig. 6.

3. DISCUSSION AND CONCLUSIONS

Before the start of the hurricane season, available predictors indicated that an above-average season was quite likely, with the very warm waters the main signal. During the first two months of the season, it became increasingly apparent that 2005 was going to be a historic year for Atlantic hurricanes. Vertical wind shear became very favorable for deep tropical systems to start developing about 4-6 weeks ahead of average. Large-scale surface pressures (which had already been quite low during the previous several months) stayed very low, resulting in weak tradewinds that helped to maintain the warmest SSTs ever recorded in the deep tropical Atlantic and Caribbean Sea. By 1 August, various seasonal forecast groups were forecasting record or near-record levels of activity in accordance with these favorable parameters. However even these updated forecasts were still too low.

An issue that has not been resolved clearly is the relationship between the wintertime AO (or the closely related North Atlantic Oscillation, NAO) and summertime AO/NAO. Klotzbach and Gray (2004) suggest that a wintertime negative NAO is favorable for more hurricanes during the next hurricane season. In addition, Elsner et al. (2006) document an inverse relationship between Oct-Jan NAO and the number of landfalling hurricanes the next summer. However Larson et al. (2005) showed that a positive AO in the summer, as was the case in 2005, is more favorable for both larger numbers of TCs and U.S. landfalling cyclones. It is unclear why the AO/NAO signal apparently changes signs. There might be an important difference between using the NAO versus the AO as an index but the two are closely correlated. Further research will be needed to explain the discrepancy.

One possible area of research regards the importance of ENSO in very active hurricane seasons. Historically-speaking, the most active hurricane seasons have generally occurred in La Nina episodes. It is not known why the last two years (weak El Nino and neutral conditions) were so different from the long-term results, but perhaps the extreme warmth of the tropical Atlantic Ocean is playing a large role in the last two busy years. Bell and Chelliah (2006) suggest that a modulation of the ENSO teleconnection occurs during the active versus inactive eras, rendering it less important during the warm Atlantic SST decades.

4. REFERENCES

Bell, G. D. et al., 2000: Climate Assessment for 1999. *Bull. Amer. Meteor. Soc*., **81**, S1-S50.

Bell, G. D. and M. Chelliah, 2006: Leading tropical modes associated with interannual and multi-decadal fluctuations in North Atlantic hurricane activity. *Submitted to J. Climate.*

Blake E.S. and W. M. Gray, 2004: Prediction of August Atlantic Basin Hurricane Activity**.** *Wea. Forecasting*, **19**, 1044–1060.

Elsner J. B. et al., 2006: Forecasting U.S. Hurricanes 6 Months in Advance. *Submitted to Geophys. Res. Letters.*

Enfield D. B. and D. A. Mayer, 1997: Tropical Atlantic sea surface temperature variability and its relation to El Nino-Southern Oscillation. *J. Geophys. Res.*, **102**, No. C1, 929-945.

Goldenberg, S. B., C. W. Landsea, A. M. Mestas-Nuñez, and W. M. Gray, 2001: The recent increase in Atlantic hurricane activity: Causes and implications. *Science*, **293**, 474-479.

Gray, W. M., 1984: Atlantic seasonal hurricane frequency. Part I: El Niño and 30 mb QBO influences. *Mon Wea. Rev*., **112**, 1649-1668.

Gray, W.M., J.D. Sheaffer, and C.W. Landsea, 1997: Climate trends associated with multidecadal variability of Atlantic hurricane activity. "Hurricanes: Climate and Socioeconomic Impacts." H.F.Diaz and, R.S.Pulwarty, Eds., Springer--Verlag, New York, 15-53.

Gray et al., 1998: Updated early August forecast of Atlantic seasonal hurricanes activity for 1998. Dept of Atmos. Sci Report, Colo. State Univ., Ft. Collins, CO, 80523, 30 pp.

Kalnay, E. et al., 1996: The NCEP/NCAR Reanalysis 40-year Project. *Bull. Amer. Meteor. Soc*., **77**, 437-471.

Klotzbach, P. J. and W.M. Gray, 2004: Updated 6-11 Month Prediction of Atlantic Basin Seasonal Hurricane Activity. *Wea. Forecasting*, **19**, 917-934.

Larson et al., 2005: Characteristics of Landfalling Tropical Cyclones in the United States and Mexico: Climatology and Interannual Variability. *J. Climate,* **18,** 1247-1262.

Ray, C.L., 1935: Relation of tropical cyclone frequency to summer pressures and ocean surface water temperatures. *Mon. Wea. Rev*., **63**, 10-12.