10A.6 FLORIDA HURRICANE DECLINE LINKED TO SURFACE WARMING

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1. INTRODUCTION

The recent increase in Atlantic hurricane activity has not increased the threat of landfalls in the United States. In fact, there has been a significant decline in hurricanes over Florida since the middle 20th century. Florida's decline results from fewer hurricanes passing through the Bahamas and the western Caribbean Sea. Here we show a trend in surface-air temperatures, consistent with global warming, that appears to be linked to less deep convection over the Greater Antilles and adjacent waters leading to tropospheric flow patterns increasingly unfavorable for tropical cyclogenesis throughout this region. Improving hurricane risk assessment will potentially reduce societal vulnerability through greater preparedness and insurance mechanisms.

2. FLORIDA HURRICANE DECLINE

Florida gets hit by more hurricanes than elsewhere in the United States. Century-long records of U.S. hurricane activity reveal inter-annual variability related to El Niño-Southern oscillation (ENSO) and the North Atlantic oscillation (NAO), but no long-term trends (Elsner et al. 2001). Long-term trends in regional coastal activity have yet to be examined systematically. Here we identify a reduction in the rate of hurricanes across eastern Florida and show that the decline is unrelated to NAO and ENSO. Florida hurricane counts are obtained from the National Hurricane Center. An eastern Florida hurricane is a tropical cyclone that makes a direct landfall between Key Largo and the Florida/Georgia border at hurricane intensity (maximum sustained near-surface wind speeds $\geq$33 m s^{-1}). Counts are plotted in Fig. 1 for hurricanes and major hurricanes (maximum sustained near-surface wind speeds $\geq$ 50 m s^{-1}) affecting eastern Florida since 1900. More than three times as many hurricanes and more than four times as many major hurricanes struck eastern Florida before 1951 than after.

Using a Poisson regression model, we determine that the reduction in hurricane numbers explains a significant ($P = 0.0056$) additional portion of the inter-annual variation in hurricane rates after accounting for NAO and ENSO. Index values for the NAO are calculated from sea-level pressures recorded at Gibraltar and at a station over southwest Iceland (Jones et al. 1997). Values are averaged over the pre- and early-hurricane season months of May and June as a compromise between signal strength and timing relative to the hurricane season. Equatorial

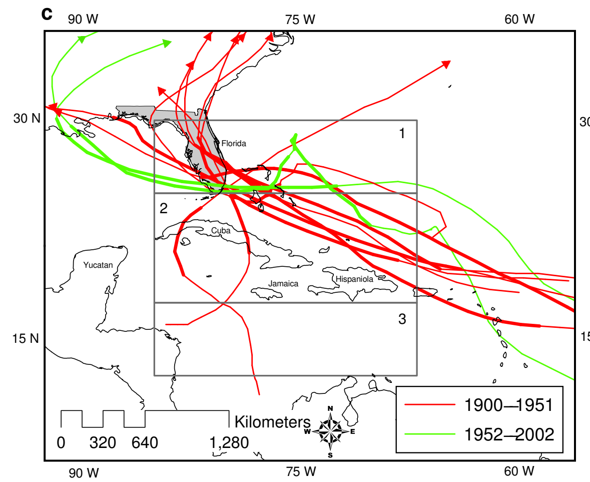

Fig. 1: Track map. Tracks of the 11 eastern Florida major hurricanes since 1900. Dark (red) tracks are hurricanes before 1952. Thick lines indicate hurricane at major hurricane intensity. Florida is shaded. Averaging boxes (1, 2, & 3) are numbered. More than three (four) times as many (major) hurricanes struck eastern Florida before 1951 than after.

fluctuations in sea-surface temperature (SST) over the Pacific Ocean (6°N–6°S, 180°–90°W) (Deser and Wallace 1990) averaged from August through October are used as an index for the ENSO. The correlation between the rate shift at 1951 and the NAO (ENSO) is -0.17 (-0.12) indicating independence of the rate shift. Thus the reduction in hurricane activity along Florida's east coast results from regional-scale changes not associated with changes in ENSO or the NAO.

Next we examine regional changes using NCEP-NCAR Reanalysis (NNR) data over the domain of box 2 shown in Fig. 1. The August-October warming trend explains 33% of the annual variability amounting to 0.087$\pm$0.017 K decade^{-1} ($P < 0.0001$). Precipitation rates show a decreasing trend of -3.73 ± 0.73 kg m^{-2} s^{-1} decade^{-1} ($P < 0.0001$) explaining 31% of the inter-annual variability. The precipitation decline over the Greater Antilles is consistent with recent rainfall deficits and frequent droughts over Puerto Rico (Stallard 2001). We find no long-term trend in vertical shear of the zonal (east-west) wind or sea-surface temperature (SST), both of which are related to basin-wide hurricane activity (DeMaria et al. 2001; Shapiro and Goldenberg 1998). Instead we suggest that warming along the archipelago contributes to fewer hurricanes over Florida through a decrease in relative humidity.

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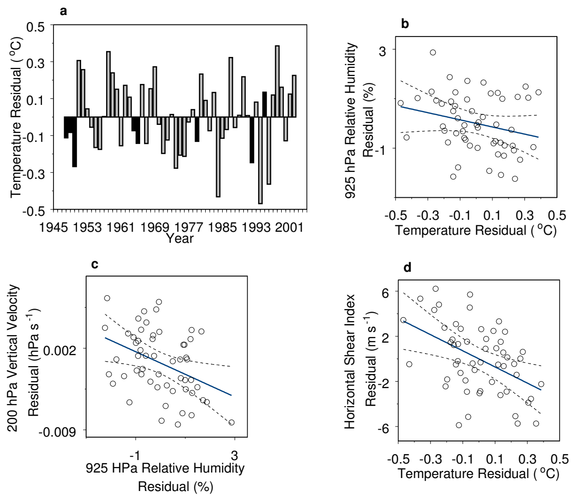

Fig. 2: Regional relationships. **a**, Surface-air temperature residuals from a linear regression model of temperature on year. Black bars indicate years in which eastern Florida received a direct hurricane hit **b**, Regression of the 925 hPa relative humidity residuals on surface-air temperature residuals **c**, Regression of the 200 hPa vertical motion residuals on the 925 hPa relative humidity residuals **d**, Regression of the horizontal shear index (HSI) residuals on surface-air temperature residuals. The HSI is computed as $(u1_{200} - u3_{200}) - (u1_{850} - u3_{850})$ and measures the degree to which the large-scale atmospheric flow is conducive to tropical cyclogenesis. $u1$ is the zonal wind component in box 1 (see Fig. 1). Positive values indicate anticyclone rotation above cyclonic rotation (favorable for hurricanes). The solid line is a best-fit linear regression and the dashed lines are the simultaneous 99% confidence bounds.

3. CONJECTURE

With less humidity, the atmosphere produces less organized deep convection leading to circulation anomalies that are opposed to cyclone genesis and that encourage storms to bypass this region. To examine this conjecture, we first show a significant relationship between surface air temperatures and southeast Florida hurricanes by modeling the annual counts of southeast Florida hurricanes and major hurricanes since 1948 using temperature as a covariate. The Poisson model, which also includes “year" as a factor, indicates that temperature explains a significant portion of the inter-annual variability of southeast Florida hurricanes ($P = 0.069$) and major hurricanes ($P = 0.031$) after accounting for the trend. During the 27 years of negative temperature anomalies (below the long-term trend), there were 8 eastern Florida hurricanes, 4 of which were major (Fig. 2). This compares with only 1 hurricane and no major hurricanes during the 28 years of positive temperature anomalies. Thus, surface warming over the Greater Antilles is statistically linked to fewer hurricanes over Florida.

Global warming coupled with local influences from urbanization and land-use changes (especially over Haiti) might be responsible for increases in surface air temperature over the Greater Antilles. The additional warmth leads to lower relative humidity and less large-scale ascent and deep convection along the island chain. Less convection leads to drying aloft and large-scale circulation anomalies, both of which inhibit tropical cyclones. Alternatively, changes in the large-scale environment could lead to fewer tropical cyclones. It has been argued that above normal sea-level pressures (SLP) are associated with increased subsidence and a reduction in middle level moisture leading to radiative cooling and increased vertical shear (Knaff 1997). Although we find significant SLP rises in the region, they are associated with middle level warming rather than cooling. Moreover, we find no significant relationship between SLP and vertical shear over the Greater Antilles (box 2). It appears that increased surface pressures may result from flow anomalies forced by surface warming. Our results support the idea of local forcing as important in modulating environmental conditions conducive to tropical-cyclone genesis (Inoue et al. 2002).

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