SEASONAL ENVIRONMENTAL CONDITIONS RELATED TO TROPICAL CYCLONE ACTIVITY IN THE NORTHEAST PACIFIC BASIN

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1. INTRODUCTION

In a recent paper, we showed that an improved understanding of interannual variations of tropical cyclone (TC) frequency can be achieved in the NE Pacific basin by subdividing the basin (Collins and Mason, 2000). For the western development region of the NE Pacific (WDR: 10°N to 20°N, 116°W to 180°W), it was shown that several environmental factors have a significant relationship with TC frequency and other factors such as the QBO do not. No significant relationships were found for the eastern development region (EDR: 10°N to 20°N, 93°W to 116W). Here we extend that work by finding the best models to explain interannual hurricane variations in the WDR, and examining the underlying causes of these relationships.

2. METHODOLOGY

The data used for this study are described by Collins and Mason (2000). We examine the period 1972-1997, averaging data for the months July-September. We use deviance tests (McCullagh and Nelder, 1989; Elsner et al., 2001) to find the dominant environmental variables explaining interannual variations in hurricane frequency in the WDR. To explore the underlying causes for these relationships we then look for correlations between these dominant variables and other environmental factors (both local and non-local).

3. RESULTS

The deviance test shows that the best model for the hurricane category is a single variable model containing mid-tropospheric (500 mb) relative humidity (RH). The second best is a single-variable model containing sea surface temperature (SST). Both models are significant to the 99% level.

Figure 1 shows that the variation in RH in the WDR for active and inactive hurricane years (which is, for the most part, mirrored by an equivalent variation in SST) is largely characterised, for active (inactive) years, by a northward (southward) shift in the boundary between the main trade wind region to the north (with cooler SST and dry mid-tropospheric air above the trade inversion) and the region of warmer SST further south (with deep convection and moist mid-tropospheric air). SST and RH are two of Gray's (Gray, 1979) thermodynamic parameters, requiring values above a threshold for TC genesis to occur, and it is likely that they act to increase (reduce) hurricane numbers in the WDR by providing conducive (non-conducive) conditions over a larger fraction of the WDR's area. Spatial averaging of SST and RH over the WDR then produces the relationships seen. There will also be an 'intensity-frequency' effect, whereby increased SSTs, by increasing average TC intensities, increase the number of TCs reaching a particular category (e.g. hurricane strength) in high-SST years. Whether the intensity-frequency effect provides a significant contribution to the observed relationships, however, is unclear.

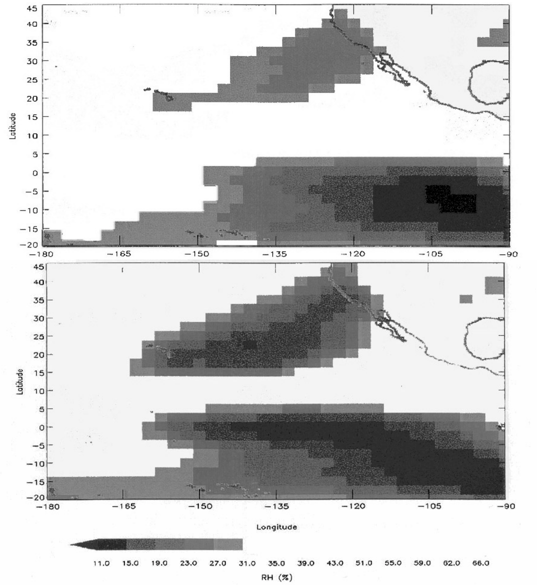

Figure 1. Plots of RH, averaged for July-September, for (a) the 6 most active and (b) the 6 least active hurricane years in the record.

An examination was made of the influences on the interannual variations of RH in the WDR (being the dominant model variable). It was found that interannual variations of ENSO (best described by the Niño4 index – SSTs within the region 5°S to 5°N, 160°E to 150°W) and of the thermal low that develops in the summer months over southern North America (quantified by its minimum value at 30°N, 112.5°W) together best describe these RH variations. Table1 shows the percentage of variance explained by each model. Based on the deviance, the multiple model is significantly better than either single model. It should also be noted that ENSO and the thermal low are found to operate largely independently of each other.

As expected, each of these controls on RH acts by shifting the relative locations of the trade inversion and deep convection regions within the WDR (Figures 2 and 3). In each case the mechanism appears to involve an associated change in the surface wind field. Figure 1 is a composite of the six warmest ENSO years in the record subtracted from the six coldest years. For the western part of the Niño4 region and extending into the southwestern part of the WDR, northeasterly wind vector differences result. Thus, in an El Niño, the winds have a weaker northerly component, and the warm water and associated deep convection (allowing for a higher RH) in the Niño4 region has spread further north. Furthermore, in the eastern part of the WDR, the wind vector differences, though smaller, are mainly northerly and westerly, showing that the trade winds, which are approximately northeasterly in La Niña years, become slightly less northerly and more easterly during El Niño years, when the cooler trade inversion region is located further north.

Relationship with RH	***PVE***
ENSO	55
Thermal Low	42
ENSO + Thermal low	72

Table 1: The relationship from an ordinary least squares regression between RH and each variable or combination of variables. *PVE* indicates the percentage of variance explained by each model. ENSO is defined as the Niño4 index and the thermal low is defined as the pressure (at mean sea level) at 30°N, 112.5°W.

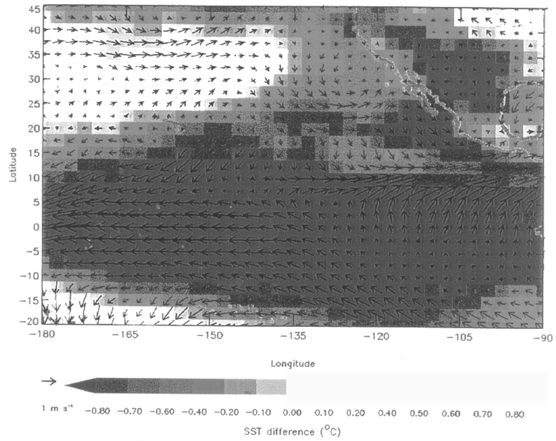

Figure 2: SSTs (and land temperatures) and surface winds (10 m) in the six coldest ENSO (Niño4) years minus the six warmest ENSO years.

As regards the thermal low link, a detailed correlation study suggests that the mechanism again involves the wind field. When there is a deeper thermal low, the pressure gradient between the thermal low and the subtropical high to the west increases, and the overall trade wind field changes with respect to both speed and direction. These changes (Figure 2) are found to be well correlated with RH changes in the WDR. Generally, for a deep thermal low, the winds in the northern (southern) part of the trade wind region become stronger and more northerly (less easterly and more northerly), and this is associated with a general southward shift of the whole trade inversion region.

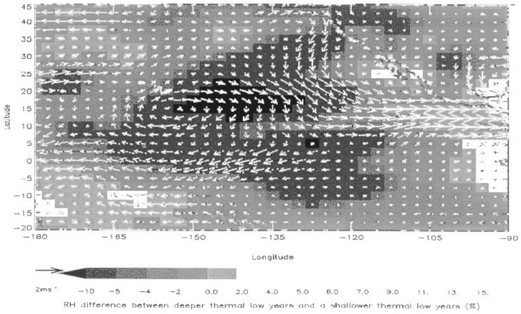

Figure 3: Plot of RH and surface winds (10 m) in the six deepest minus six shallowest thermal low years. Values averaged over July-September.

4. CONCLUSIONS

Finally, two points should be noted regarding the ENSO influence on hurricane frequency in the NE Pacific. First, unlike the indirect effect of ENSO in the North Atlantic, affecting hurricanes there through one of Gray's (Gray, 1979) dynamic parameters, namely wind shear (Gray and Sheaffer, 1991), in the WDR of the NE Pacific there is an indirect effect of ENSO operating through one of Gray's thermodynamic parameters (RH). Second, the fact that there is a relationship with ENSO in both the WDR and Atlantic basins, where warm ENSO years are associated with more (less) conducive conditions in the WDR (Atlantic), and vice versa, accounts for the anti-correlation of tropical cyclone frequency observed between the two basins. It is interesting to note that although there is no significant relationship between ENSO and tropical cyclones in the EDR, the sign of the relationships is such that more TC's tend to occur in a La Niña rather than an El Niño phase.

5. REFERENCES

Collins, J.M. and I.M. Mason, 2000: Local environmental conditions related to seasonal tropical cyclone activity in the Northeast Pacific basin. *Geophysical Research Letters*, **27** (23), p3881-3884.

Elsner, J.B., B.H. Bossak and X. Niu, 2001 (in review): Multi-decadal variability of the ENSO-hurricane teleconnection.

Gray, W.M., 1979: Hurricanes: their formation, structure and likely role in the tropical circulation. Supplement to Meteorology Over the Tropical Oceans (Ed. D.B. Shaw). Published by Royal Met. Soc., James Glaisher House, Grenville Place, Bracknell, Berkshire, 155-218.

Gray, W.M. and J.D. Sheaffer, 1991: EL Nino and QBO influences on tropical cyclone activity. In: Teleconnections Linking World Wide Climate Anomalies (Eds. M. Galntz, R. Katz and N. Nicholls).

McCullagh, P. and J.A. Nelder, 1989: Generalised Linear Models (2nd Edition). Chapman and Hall. London, 511pp.