Contrasting High North-East Pacific Tropical Cyclone Activity with Low North Atlantic Activity

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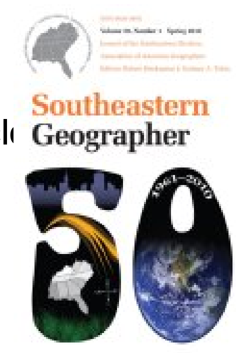

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Contrasting High North-East Pacific Tropical Cyclone Activity with Low North Atlantic Activity

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Teleconnections between different basins have previously been examined in the literature and that research shows no evidence of a significant inter-basin relationship between North-East Pacific (NE Pacific) and North Atlantic (N Atlantic) tropical cyclone frequency. However, it has been suggested that the NE Pacific basin should be divided into two sub-regions, east and west of 116°W, to gain increased understanding of the factors which influence tropical cyclone formation in the NE Pacific. Using this subdivision to examine the period 1972–2006, it is observed that significant negative relationships are found between tropical cyclone frequency in the west region of the NE Pacific and tropical cyclone frequency in the N Atlantic, i.e. less tropical cyclones in the west region of the NE Pacific are associated with more tropical cyclones in the N Atlantic. The causes of these relationships are examined.

Las teleconexiones entre distintas cuencas han sido previamente examinadas en la literatura. Distintas investigaciones no muestran evidencia de una relación significativa entre la cuenca del noreste del Pacífico (NE Pacífico) y la frecuencia de ciclones tropicales del Atlántico Norte (N del Atlántico). Sin embargo, se ha sugerido que la cuenca del Pacífico NE debe ser dividida en dos sub-regiones, al este y al oeste de 116° O, para obtener un mejor entendimiento de los factores que influyen en la formación de ciclones tropicales en el Pacífico NE. Al utilizar esta subdivisión para examinar el periodo de 1972–2006, se observa que las relaciones negativas significativas se encuentran entre la frecuencia de ciclones tropicales en la región oeste del Pacífico NE y la frecuencia de ciclones tropicales en el Atlántico norte, es decir, menos ciclones tropicales en la región oeste del Pacífico NE están asociadas con más ciclones tropicales en el Atlántico N. Las causas de estas relaciones son examinadas.

KEY WORDS: hurricanes, tropical cyclones, teleconnections, inter-basin relationships

INTRODUCTION

The relationship between North Atlantic (N Atlantic) tropical cyclones and North-East Pacific (NE Pacific) tropical cyclones has been previously examined by Lander and Guard (1998). They looked at basin prolific and meager years between 1966 and 1995. They showed a positive correlation between NE Pacific and NW Pacific tropical cyclones, with a correlation coefficient of 0.32, which is significant at the 10 percent level. The relationship they found between the NE Pacific and the N Atlantic is weak and negative with a correlation coefficient of −0.02. This insignificant result alludes to the fact that the amount of tropical cyclone activity in the N Atlantic bears little relation to

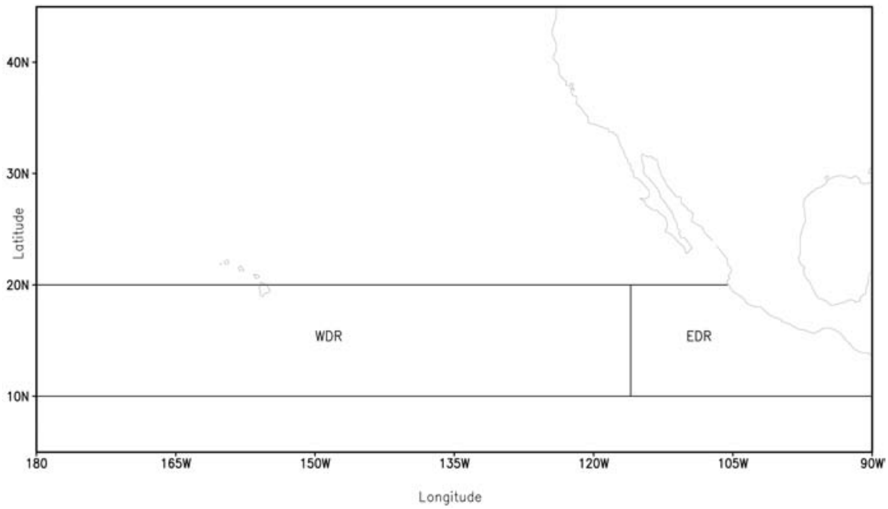

Figure 1. Location of the NE Pacific tropical cyclone development areas: Western Development Region (WDR) and Eastern Development Region (EDR).

tropical cyclone activity in the NE Pacific. However, Zhao et al. (2009) used a global atmospheric model with roughly 50 km horizontal grid spacing to simulate the interannual variability of tropical cyclones using observed sea surface temperatures (SSTs) as the lower boundary condition and they note negative correlations ranging from −0.40 to −0.74 between the NE Pacific and the West Atlantic using data from 1981–2005. Frank and Young (2007) analyzed global data for each ocean basin for a nineteen year period and concluded that there is not a tendency for enhanced storm activity in one basin to be compensated by reduced net storm activity in the others. They noted that globally stronger storms tend to show stronger inter-basin correlations (mostly showing anticompensation or positive correlations) and stronger relationships to the El Niño Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO) than do weaker storms, although for the NE Pacific they observed a negative correlation for the intense hurricane category only.

This research follows from the work of Collins and Mason (2000) and Collins (2007), who show that the NE Pacific basin should not be considered as one entity for tropical cyclone development. Instead they suggest that the basin should be divided into two sub-regions east and west of 116°W (Eastern Development Region, EDR: 10°N to 20°N, N American coastline to 115.9°W and Western Development Region, WDR: 10°N to 20°N and 116° W to 180° W). To gain increased understanding of the factors which influence tropical cyclone formation in the NE Pacific, this research will also use this sub-division (Figure 1) of the NE Pacific to re-examine the relationships with N Atlantic tropical cyclones for a 35 year period. Others have since divided the NE Pacific basin into sub-regions (e.g. Lupo et al. 2008) although they have not examined these sub-regions in relation to activity occurring in the N Atlantic.

When examining a number of environmental variables to account for seasonal tropical cyclone frequency, Collins (2007) found no significant relationship between the environmental factors and tropical cyclone frequency in the NE Pacific EDR. However, a significant positive relationship was found between thermodynamic environmental factors (particularly relative humidity) and tropical cyclone frequency in the NE Pacific WDR. This was argued to operate as a result of ENSO influences with El Niño providing conducive conditions (higher relative humidity) to hurricane formation in the NE Pacific WDR. This is in agreement with Landsea and Gray (1989) who considered storms in the NE Pacific and concluded that the mean number of tropical cyclones in the vicinity of Hawaii during an El Niño year is higher than during a non-El Niño year. In the N Atlantic, the effect of ENSO has been long established to operate via vertical tropospheric wind shear with El Niño years promoting stronger upper level winds in the N Atlantic (Gray and Sheaffer 1991). In addition, more recently it has been suggested (Tang and Neelin 2004) that the anomalous tropospheric temperatures communicated from the Pacific by wave dynamics during an El Niño, which affect column stability relative to equilibrium with N Atlantic sea surface temperature, inhibits tropical cyclone formation in the N Atlantic. These findings have been supported by Camargo et al. (2007) who constructed composites of a genesis potential index with regard to ENSO and noted that in El Niño years, relative humidity and vertical shear are important for the reduction in genesis seen in the Atlantic basin. With these findings noted above, it is hypothesized that there will be a significant negative relationship between Atlantic and NE Pacific WDR tropical cyclone frequency and possibly no relationship between N Atlantic and NE Pacific EDR tropical cyclone frequency.

DATA AND METHODS

The source for the tropical cyclone indices used in this study is the official historical tropical cyclone track database obtained from the Tropical Prediction Center/National Hurricane Center (TPC/NHC) best track file for the NE Pacific (Brown and Leftwich 1982; TPC 1998) and N Atlantic (Jarvinen et al. 1984; TPC 1998) basins. These data represent the most complete and reliable source of all NE Pacific and N Atlantic tropical cyclones. The best track data records were compiled from various publications and represent a rigorous, post season analysis of all tropical cyclone intensities and tracks every six hours. Categories of tropical cyclone development considered include tropical storm, hurricane, and intense hurricane. For each category of tropical cyclone, the location used to determine which subregion it belonged to is the point where the storm reached the wind speed appropriate to the category (34 knots ($17 ms^{-1}$), 64 knots ($33\ ms^{-1}$) and 96 knots ($50\ ms^{-1}$), respectively).When considering the numbers of each, the categories are not exclusive in that if a hurricane is considered, it will be given a count for hurricane category and tropical storm category if they reached these categories within the same region. Tropical depressions, the weakest category of a tropical cyclone, are not included since the data are considered by some to be unreliable. There has been large uncertainty in classifying a tropical depression and often it is just confused with a cloud cluster (Bracken and Bosart 2000). The analysis focuses on the years 1972–2006. Data are considered reliable since 1972 in the NE Pacific when the Dvorak (1975) scheme for estimating the intensity of tropical cyclones was first used operationally (Whitney and Hobgood 1997). When determining the months which were to be considered in this analysis, characteristics of the N Atlantic and NE Pacific development season were taken into account. By a significant margin the majority of tropical only N Atlantic hurricanes (those originating from a tropical disturbance and developing to hurricane intensity devoid of enhancing mid-latitude baroclinic influences) occur during August and September (Elsner and Kara 1999). There are only a small number of baroclinically-enhanced hurricanes (those originating in an environment of strong temperature and moisture contrasts) in any given season and while more fronts occur in October than previous months that could potentially generate more hurricanes in this month, this is not the case as the oceans are cooler and there is more wind shear so the frequency of baroclinically-enhanced systems is actually higher in September than October. Therefore it was considered that there would be a minimal bias of examining NE Pacific tropical cyclones that began in July, August, and September (JAS) and N Atlantic tropical cyclones which began in August, September and October (ASO) since these are the months in which the majority of tropical cyclones occur in each basin.

The National Centers for Environmental Research/National Center for Atmospheric Research (NCEP/NCAR) reanalysis project (Kalnay et al. 1996) provides the data for the environmental variables investigated including pressure at mean sea level, relative humidity at 500 hPa, sea surface temperature, pressure vertical velocity at 500 hPa (which is a measure of convection/subsidence), precipitable water, upward long-wave radiation flux, wind shear between 850 and 200 hPa and relative vorticity. These variables were chosen to consider thermodynamic as well as dynamic factors and have been shown to have an important influence on hurricane frequency (Palmén 1948; Namias 1954; Riehl 1954; Gray 1979). The NCEP/NCAR reanalysis project has two unique characteristics, the length of the period covered and the assembly of a very comprehensive observational database. These factors make the data ideal for this study. The global data are now available on a 2.5° x 2.5° latitude/longitude grid for many vertical levels (the number of which depends on the variable in question) and have a six-hourly and monthly time resolution. Confidence in these data has been addressed by Collins and Mason (2000) and Kalnay et al. (1996). The monthly environmental data are also averaged over the months July to September to correspond with peak tropical cyclone activity in the NE Pacific.

An analysis of the relationships between tropical cyclone numbers between the different basins is conducted. For small numbers of tropical cyclones, the errors are heteroscedastic, therefore the Pearson's product-moment correlation and least squares linear regression is inappropriate. Therefore, generalized linear modeling with Poisson errors is utilized

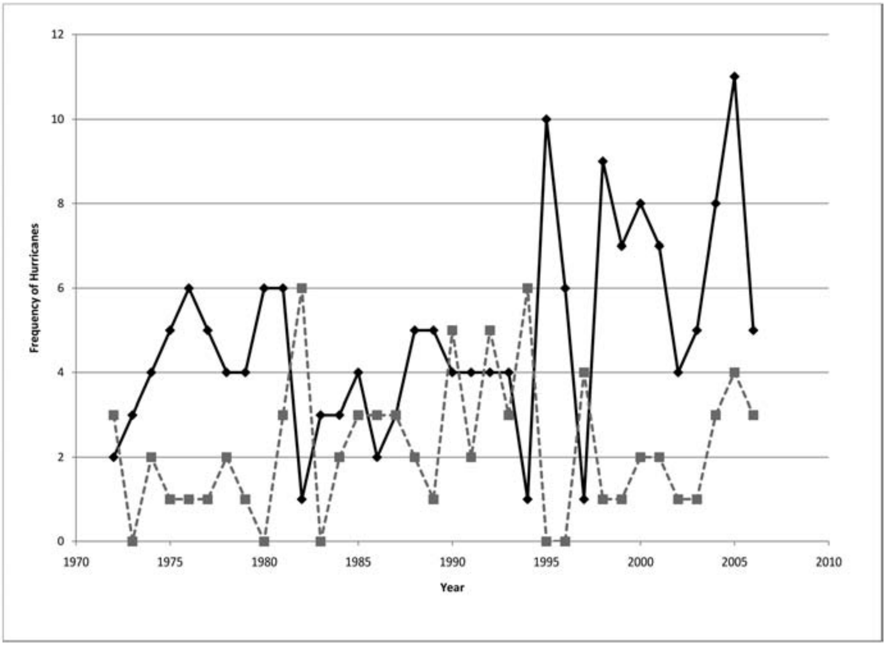

Figure 2a. N Atlantic—August, September, October (Black)—and NE Pacific WDR—July, August, September (Gray)—hurricane frequency.

(McCullagh and Nelder 1989). Poisson regression of NE Pacific tropical cyclones is carried out with two independent variables, the number of North Atlantic tropical cyclones and time using the Statistical Package for the Social Sciences (SPSS). Time is included to estimate any effects of long term trends since we are concerned with interannual variation. Consequently, the fitted model is of the form:

$$Ln(\lambda) = a + bx + ct$$

where λ is the expected number of NE Pacific tropical cyclones, x is the number of N Atlantic tropical cyclones, t is the time, a is the intercept with the y-axis and b is the slope of the line of the number of N Atlantic tropical cyclones and c is the slope of time (the slope of the line gives an indication of the direction of the relationship). This analysis was conducted for each category of the tropical cyclone: tropical storm, hurricane and intense hurricane. The significance of the b parameter in equation 1 is noted from the associated p-value outputted from the likelihood test from SPSS.

RESULTS AND DISCUSSION

The frequency of hurricanes in the N Atlantic and NE Pacific WDR and EDR is compared. There are clearly more hurricanes in the N Atlantic (a mean of 4.8, with a minimum of 1 and a maximum of 11 over the 1972–2006 period) than the NE Pacific WDR (a mean of 2.2 with a minimum of 0 and a maximum of 6 over the

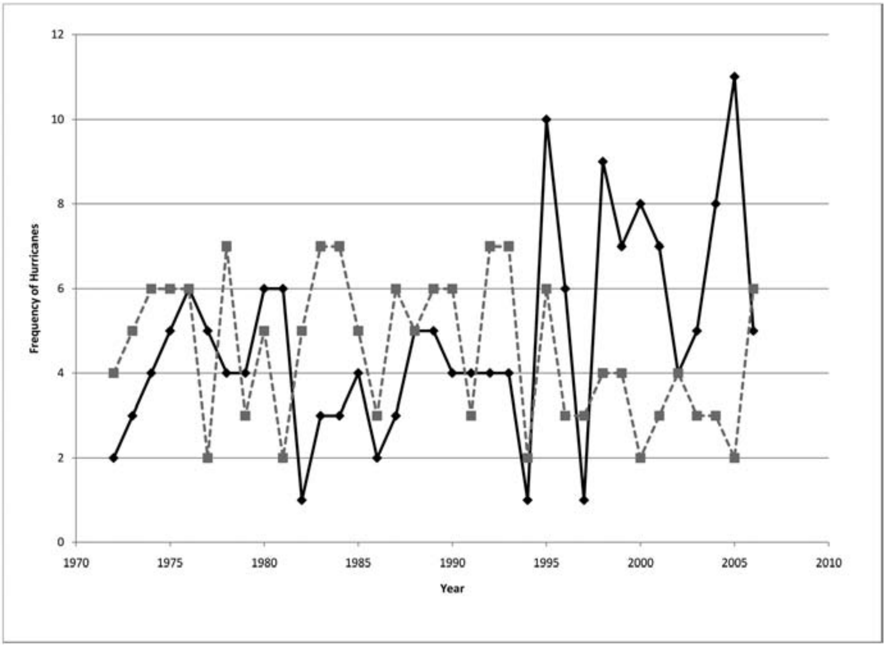

Figure 2b. N Atlantic—August, September, October (Black)—and NE Pacific EDR—July, August, September (Gray)—hurricane frequency.

1972–2006 period). There is also a negative relationship between tropical cyclone frequency in the two regions (Figure 2a). The EDR has a mean hurricane frequency close to the Atlantic (5, with a minimum of 2 and a maximum of 7), but there is no relationship between the two regions (Figure 2b).

This study shows that it is important to divide the NE Pacific into sub-regions in order to find and explain negative relationships between tropical cyclone frequency in the NE Pacific and the N Atlantic. Relationships between categories of N Atlantic and NE Pacific WDR tropical cyclones, and between categories of N Atlantic and NE Pacific EDR region tropical cyclones are shown in Table 1. The slope (*b* obtained from the regression) provides the direction of the relationship. It can be seen that tropical cyclone frequency in the NE Pacific WDR has a negative relationship with tropical cyclone frequency in the N Atlantic for the period 1972–2006 (indicating an inverse relationship where there are fewer tropical cyclones in one basin with larger numbers in another), with significant results (shown by the *p*-values in parentheses) in all categories. Frank and Young (2007) analyzed global data for each ocean basin for a nineteen year period and concluded that there is not a tendency for enhanced storm activity in one basin to be compensated by reduced net storm activity in the others. They noted that globally stronger storms tend to show stronger inter-basin correlations (mostly showing anticompensation or

Table 1. Slope (b) and significance (p-value given in parenthesis) of each regression between NE Pacific and N Atlantic tropical cyclone frequency. The NE Pacific has been split into two sub-regions: Western Development Region (WDR) and Eastern Development Region (EDR).

	WDR, NE Pacific			EDR, NE Pacific		
Category	TS	H	IH	TS	H	IH
TS Atlantic	−0.086	−0.075	−0.104	−0.004	0.005	−0.049
	(0.012)	(0.045)	(0.026)	(0.854)	(0.859)	(0.253)
H Atlantic	**−0.208**	**−0.166**	**−0.212**	−0.014	−0.014	−0.069
	(0.000)	(0.002)	(0.002)	(0.622)	(0.713)	(0.250)
IH Atlantic	**−0.277**	**−0.278**	**−0.415**	−0.040	−0.030	−0.120
	(0.001)	(0.003)	(0.001)	(0.390)	(0.642)	(0.232)

Tropical cyclone categories considered are Tropical Storm (TS), Hurricane (H) and Intense Hurricane (IH). Relationships significant to the 1 percent level are highlighted in boldface and underlined; those to the 5 percent level are underlined only. Negative *b*-values indicate an inverse relationship where there are fewer tropical cyclones in one basin with larger numbers in another.

positive correlations) and stronger relationships to the El Niño Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO) than do weaker storms, although for the NE Pacific they observed a negative correlation for the intense hurricane category only.

Hurricanes in the N Atlantic basin have been divided up into systems which are baroclinically enhanced or tropical only in their formation (Kimberlain and Elsner 1998). This is based mainly on whether the systems interacted with a mid-latitude weather system to be classified as the former. However, Kimberlain and Elsner (1998) stress that these divisions apply only to the tropical storm stage, as higher category storms make it difficult to discern the different categories since each type may enter environments which do not reflect their origin. Landsea et al. (1999) later generalized that tropical systems north of 23.5° N could be called baroclinically enhanced, while those to the south, tropical only. Such a latitude distinction in their formation is not relevant in the NE Pacific where the majority of hurricanes form between 10°N–20°N, within the equatorward side of the Tropic of Cancer and hence are termed tropical only. It is rare in this basin that a mid-latitude front would come into the tropics and interact with the surrounding environment. The tropical cyclones in the NE Pacific WDR are examined to identify whether the relationship found with the N Atlantic is due to tropical only or baroclinically enhanced Atlantic hurricanes. No dominant relationships were found. The tropical cyclones in the NE Pacific WDR were then compared to a) tropical cyclones in the Gulf and b) tropical cyclones in the main development region (MDR) of the N Atlantic (following the definition of the MDR given by Saunders and Harris [1997] and Goldenberg and Shapiro [1996] as 10°N–20°N, 20°W–60°W). No result significant to the 5 percent level was found in the Gulf region. On

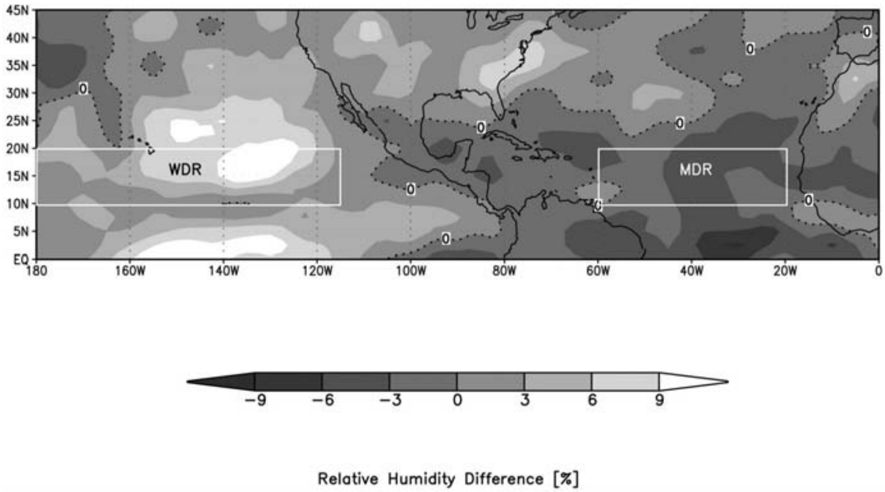

Figure 3. Relative humidity (500 hPa) anomalies: NE Pacific WDR composite 6 active—5 inactive years. The white boxes show the Western Development Region (WDR) and the Main Development Region (MDR).

the other hand, for the MDR, significant results to the 5 percent level were found with the NE Pacific WDR for all categories of tropical cyclones considering the intense hurricane and hurricane categories in the MDR. These relationships likely account for the relationships shown in Table 1. Although the relationships with the tropical storm category in the MDR were not significant to the 5 percent level, the sign of the relationship was the same as the other categories, i.e. negative.

It is hypothesized herein that there might be a negative relationship between the NE Pacific and the N Atlantic since it has been noted that many of the NE Pacific hurricanes have origins that can be traced to African easterly waves (Avila 1991; Avila and Pasch 1992). Mekonnen et al. (2008) also note that some African easterly waves traverse a long way into the Pacific. Thus, when the N Atlantic season is particularly active, more of the waves are likely to develop into N Atlantic tropical cyclones (providing the required convergence) and thus there will be fewer waves remaining to traverse into NE Pacific. If tropical cyclones in the NE Pacific WDR had a negative relationship with those in the N Atlantic for this reason, then it would be expected that tropical cyclones in the NE Pacific EDR would also have a significant negative relationship with those in the N Atlantic. Since this is not the case, one has to look for other explanations to account for the observed negative relationship found between the NE Pacific WDR and the N Atlantic.

An alternative hypothesis is that the environmental variables between the N Atlantic and NE Pacific WDR have a negative relationship. An examination of Figure 3, showing a composite of the six most (1982, 1990, 1992, 1994, 1997, 2005) minus five least (1973, 1980, 1983, 1995, 1996) active NE Pacific WDR hurricane

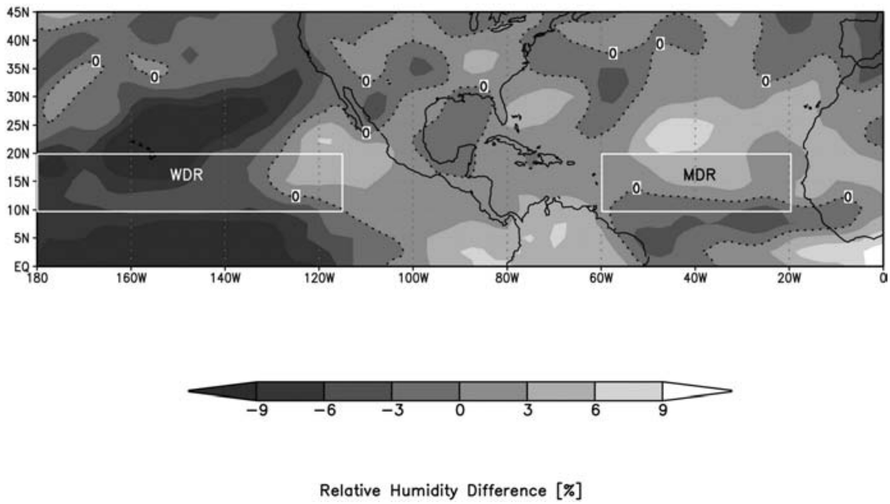

Figure 4. Relative humidity (500 hPa) anomalies: N Atlantic composite 5 active—5 inactive years. The white boxes show the Western Development Region (WRD) and the Main Development Region (MDR).

years, reveals that, as expected from the tropical cyclone relationships, when 500 hPa relative humidity is high in the NE Pacific WDR, it is low in the N Atlantic. Likewise, for the N Atlantic composite of the five most active (1995, 1998, 2000, 2004, 2005) minus five most inactive (1972, 1982, 1986, 1994, 1997) years (Figure 4), this negative relationship is also observed. The smaller difference of mid-tropospheric relative humidity locally in the N Atlantic between active and inactive years indicates that while relative humidity in the N Atlantic is a factor which affects hurricane formation there (Gray 1979), relative humidity locally is not as significant for determining active/inactive years as it is in the NE Pacific WDR. Note the number of years to include in each group was based on the decision to examine extremes and to consider the number of years with similar counts. For example when considering the NE Pacific WDR inactive years, the five years which were considered had zero hurricanes, then nine years had one hurricane. When considering the active group, six years were chosen based on 1982 and 1994 having six hurricanes, 1990 and 1992 having five hurricanes and 1997 and 2005 having four hurricanes. Hence five years were not examined in this group to avoid a bias with an arbitrary choice between the inclusion of the year 1997 or 2005.

This significant result of mid-tropospheric relative humidity explaining variance in NE Pacific WDR tropical cyclone frequency has been noted by Collins and Mason (2000). It should also be noted that it is likely that the relative humidity signal is due to the environmental conditions themselves rather than the presence or absence of tropical cyclones since Namias (1955, p 155) noted that, “if the period of averaging is long, like a month or season, it becomes highly unlikely that hurricanes,

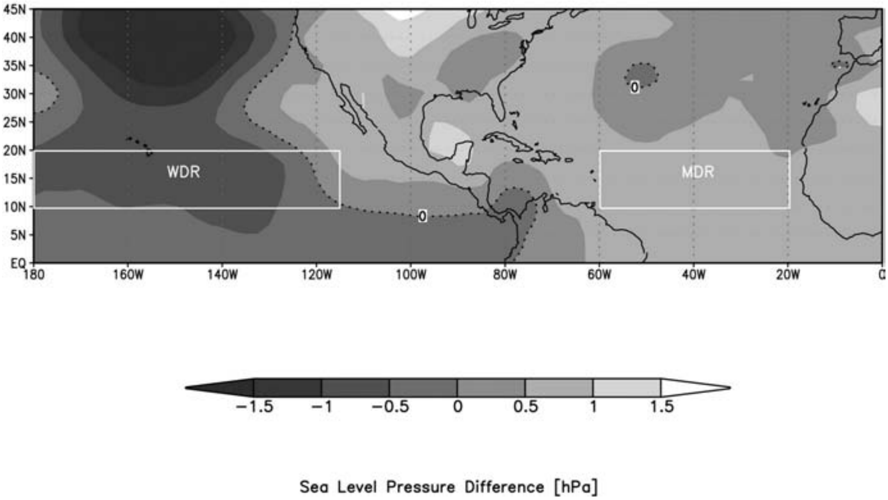

Figure 5. Pressure (at mean sea level) anomalies: NE Pacific WDR composite 6 active—5 inactive years. The white boxes show the Western Development Region (WDR) and the Main Development Region (MDR).

which are few in number and small in extent, would materially alter the mean patterns". Raper (1993) analyzed sea level pressure data to show that the relationship between tropical cyclone frequency and the intensity of a sub-tropical high is probably not due to the presence or absence of the storms themselves. According to Raper, the storms appear to have "slipped through" the observing network on most occasions and so not had much influence on the mean sea level pressure values. Knaff (1997) and Landsea (1998) reach a similar conclusion regarding the effect of the hurricanes themselves on the environmental variables.

Relative humidity is not the only variable to show this dipolar relationship between the two basins when considering extreme years of hurricane activity. Pressure, sea surface temperatures, precipitable water, upward long-wave radiation flux and pressure vertical velocity also exhibit this relationship (see Figure 5 which shows pressure as an example). However, no negative relationship is observed between N Atlantic and NE Pacific WDR wind shear and relative vorticity (see Figure 6 which shows wind shear as an example). This is in agreement to previous work by Collins (2007) who shows that Grays (1979) thermodynamic, not dynamic controls, are necessary for tropical cyclone formation in the NE Pacific WDR.

An extreme case of the negative relationship noted above is the year 1995 which was a prolific year in terms of numbers of hurricanes in the N Atlantic. However, in the NE Pacific WDR it was an extremely meager year (it should be noted that the 2005 record-setting year of activity in the N Atlantic was not matched by a year of inactivity in the NE Pacific WDR.) Again, by examining the 1995 anomalies (from 1972–2006 climatology—Figure 7), it can be clearly seen that the values of

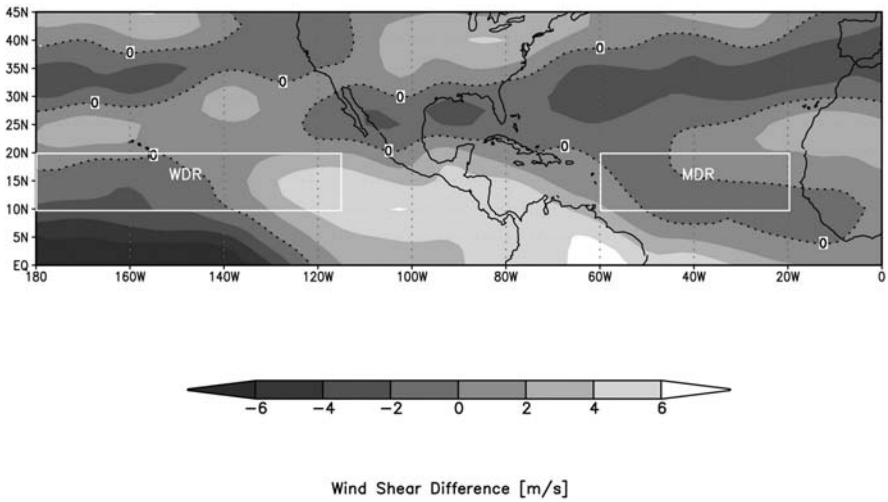

Figure 6. Wind Shear (850 hPa to 200 hPa) anomalies: NE Pacific WDR composite 6 active—5 inactive years. The white boxes show the Western Development Region (WDR) and the Main Development Region (MDR).

mid-tropospheric relative humidity are very different between the two regions (N Atlantic and NE Pacific WDR). What is also interesting to note from these plots is that the relative humidity in the NE Pacific EDR is similar to that in the N Atlantic, i.e. they are in a similar phase to each other, but in an opposite phase to the NE Pacific WDR (although there is not a significant negative relationship between NE Pacific WDR and EDR tropical cyclone frequency). This similarity between the N Atlantic and NE Pacific EDR is observed also in many of the active—inactive year composite plots.

In 1995, The N Atlantic has anomalously high values of relative humidity, whereas the NE Pacific WDR has anomalously low values. An examination (not shown) of some of the other environmental variables (e.g. pressure) also shows anomalies that are in different directions between the two regions. Other variables, such as vertical wind shear (examining the 850 hPa and 200 hPa levels), are more similar between the NE Pacific WDR and the N Atlantic (Figure 8) and thus do not help explain the negative relationship observed between NE Pacific WDR and N Atlantic tropical cyclones in this year. Note too that Collins (2007) did not find a significant relationship locally between NE Pacific WDR tropical cyclone frequency and vertical wind shear.

The relationship is observed if one visualizes the opposite scenario, i.e. a prolific NE Pacific WDR year and a meager N Atlantic year. Providing data from 1994 as an example and examining 1994 anomalies (from 1972–2006 climatology—Figure 9), it can be clearly seen that the values of mid-tropospheric relative humidity are also very different between the two regions with the NE Pacific WDR having anomalously high values of relative humidity, whereas the N Atlantic has anomalously low values. Again, the relative hu-

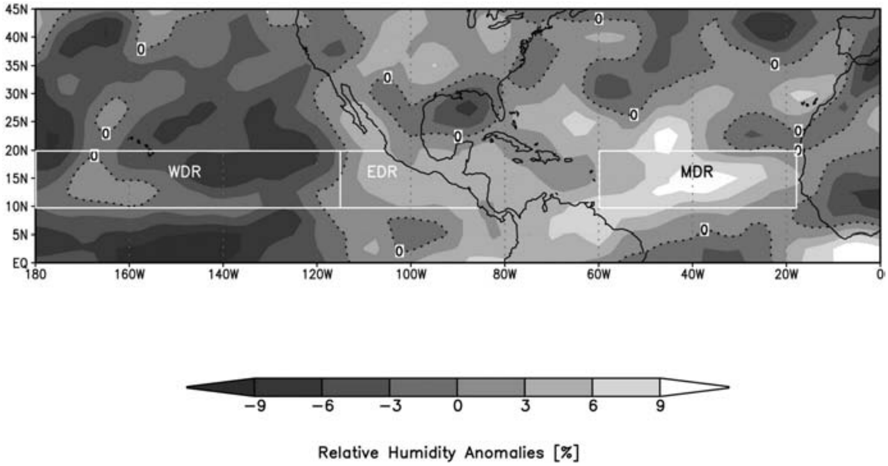

Figure 7. 1995 Relative humidity (500 hPa) anomalies, climatology 1972–2006. The white boxes show the Western Development Region (WDR), Eastern Development Region (EDR) and Main Development Region (MDR).

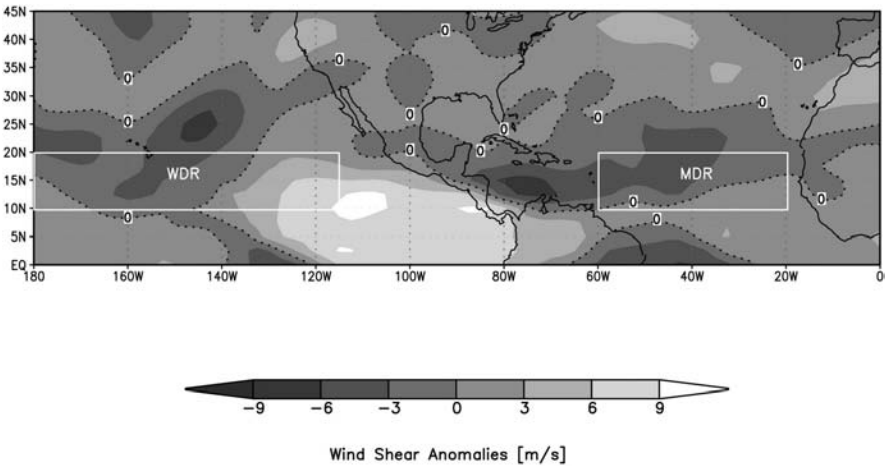

Figure 8. 1995 Wind Shear (850 hPa to 200 hPa) anomalies, climatology 1972–2006. The white boxes show the Western Development Region (WDR) and the Main Development Region (MDR).

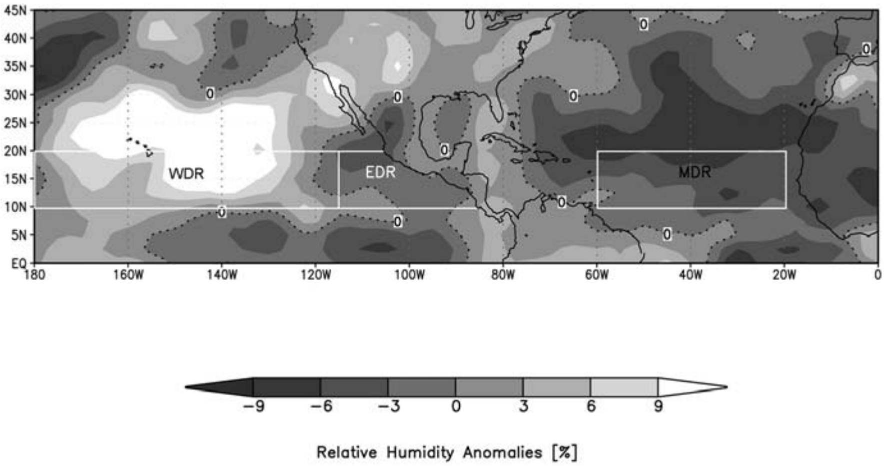

Figure 9. 1994 Relative humidity (500 hPa) anomalies, climatology 1972–2006. The white boxes show the Western Development Region (WDR), Eastern Development Region (EDR) and Main Development Region (MDR).

midity in the NE Pacific EDR is similar to that in the N Atlantic, i.e. they are in a similar phase to each other, but in an opposite phase to the NE Pacific WDR. Again, these relationships are observed with the other thermodynamic variables examined.

The overall driving force causing some of these variables to be in opposite phase to each other between the NE Pacific WDR and the N Atlantic is likely to be ENSO. Tang and Neelin (2004) found a relationship between ENSO and the reduced stability of the tropospheric thermodynamic profile in the N Atlantic, and Collins (2007) found a relationship between ENSO and tropical cyclones in the NE Pacific WDR operating via mid-tropospheric relative humidity. The mechanism suggested is via a slackening of the tradewinds during an El Niño which allows the warm pool of water to not only spread eastwards across the Pacific but also northwards into the NE Pacific WDR. With the warmer temperatures of the sea surface in this region and associated convection, this increases the relative humidity there (which, as noted earlier, has been shown to have the greatest effect on the frequency of NE Pacific WDR hurricanes). These ENSO effects on the relative humidity (and other related thermodynamic variables) partly result in the observed negative relationships between tropical cyclone frequencies between the N Atlantic and NE Pacific WDR. In addition, while ENSO has some opposing thermodynamic effects in the different oceans, dynamic effects are not seen in both basins. While ENSO strongly affects vertical wind shear in the N Atlantic which impacts hurricane frequency there (Gray and Schaffer, 1991), the link with the variable vertical wind shear is not evident for NE Pacific WDR hurricanes with Collins (2007) quoting a correlation between ENSO (measured by Niño4 sea surface temperatures) and vertical wind shear of −0.07. This other ENSO effect in the N Atlantic (while not in the NE Pacific WDR) will also account for some of the negative relationship observed.

CONCLUSIONS

This study shows important relationships between the frequency of tropical cyclones forming in the NE Pacific and N Atlantic basins. Specifically a negative relationship is found between NE Pacific WDR and N Atlantic tropical cyclones so that when there are less tropical cyclones in the NE Pacific WDR, there tend to be more in the N Atlantic. These relationships were significant for all categories of development and highest for the intense hurricane category. This is consistent with Frank and Young (2007) who noted that globally stronger interbasin relationships are observed for stronger storms. An examination of the six most active NE Pacific WDR hurricane years (1982, 1990, 1992, 1994, 1997, 2005) and the five most inactive N Atlantic hurricanes years (1972, 1982, 1986, 1994, 1997) shows some similar years appearing in each group, i.e. the most active hurricane years in the NE Pacific WDR tend to be the least active hurricane years in the Atlantic. These relationships emerge for the first time now that sub-regions of the NE Pacific are considered, rather than taking the basin as one entity. These negative relationships can largely be explained by the environmental variables in the two basins, some of which can be linked to ENSO, with El Niño promoting tropical cyclone development in the NE Pacific WDR while hindering it in the N Atlantic. The significant negative relationships that are observed may lead to useful information when predicting N Atlantic tropical cyclones since the NE Pacific season begins earlier (Davis et al. 1984; Schultz 2008; Lupo et al. 2008). Future work will examine this forecasting potential in light of the statistical study shown here and the recent dynamical study by Zhao et al. (2009).

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