Atmósfera 28(3), 161-178 (2015)
doi: 10.20937/ATM.2015.28.03.02

On the distinct interannual variability of tropical cyclone activity over the eastern North Pacific

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Received: January 1, 2015; accepted: May 19, 2015

RESUMEN

La cuenca del Pacifico tropical nororiental presenta una gran variabilidad interanual en cuanto a la frecuencia de ocurrencia de ciclones, con años muy activos (con más de 20 ciclones durante la temporada) y años muy poco activos (con sólo ocho ciclones). En este estudio se investigan los factores de gran escala que pueden influenciar la variabilidad interanual analizando los compuestos de siete años muy activos y 10 años muy poco activos durante los 49 años del periodo 1965-2013. Los resultados del análisis de compuestos indican que la vorticidad a niveles bajos y la humedad relativa en la troposfera media son poco favorables para la ciclogénesis tropical durante los años activos. La temperatura superficial del mar (TSM) parece desempeñar un pequeño rol modulando la frecuencia, y la disminución observada en la cizalladura del viento entre 850 y 200 hPa domina la ciclogénesis durante los años activos, confirmando resultados previos de Camargo *et al.* (2007). Se investigan además los factores ambientales de gran escala que afectan la intensidad de los ciclones tropicales en la cuenca con un modelo numérico de intensidad (Emanuel *et al.*, 2006, 2008), el cual predice la intensidad con base en la cizalladura del viento, la TSM y las trayectorias observadas. Los resultados indican que la variabilidad interanual en la frecuencia de huracanes mayores (categorías 3 a 5) se simula mejor cuando ambos parámetros se combinan. También es posible que los cambios en las trayectorias puedan ser determinantes para la intensidad alcanzada. En particular, durante los años activos, la zona de ciclogénesis se desplaza hacia el este y hay más ciclones con trayectoria norte-noroeste, lo cual determina que tengan una vida más larga y sean de mayor intensidad que los que se desarrollan en años con poca actividad en la cuenca.

ABSTRACT

The tropical eastern North Pacific (ENP) basin exhibits very large interannual variability in the frequency of occurrence of tropical cyclones, presenting very active (more than 20 tropical cyclones per season) and very inactive years (only eigth tropical cyclones). The large-scale factors that may influence the distinct interannual variability are investigated in this study, by analyzing the composites of seven years of high activity and 10 years of low activity from 1965 to 2013. The results of composite analyses indicate that the low-level vorticity and mid-tropospheric relative humidity are mostly unfavorable for tropical cyclogenesis during active years. The sea surface temperature (SST) may play a small role modulating the occurrence of tropical cyclones, but the reduced vertical shear of the horizontal wind between 850 and 200 hPa is the main contributor to cyclogenesis during the active years, confirming earlier results by Camargo *et al.* (2007). We use an intensity model (Emanuel *et al.*, 2006, 2008) to further investigate the key environmental factors affecting TC intensity, exploring the relative roles of changes in SST, vertical wind shear and TC tracks. The results indicate that the interannual variability in the frequency of major hurricanes (categories 3 through 5)

is best simulated when the effects of both SST and vertical wind shear are combined. Furthermore, changes in TC tracks may play an important role in the intensity achieved. In particular, during the years with high activity, the location for cyclogenesis shifts eastward and more TCs have west-northwestward tracks, leading to longer lifetime and higher intensity, compared to years with low TC activity in the basin.

Keywords: Interannual variability, large-scale factors, intensity model, eastern Pacific basin.

1. Introduction

The eastern North Pacific (ENP) basin (0-30º N, 140-80º W) exhibits a high level of tropical cyclone (TC) activity, being the second most active region in the globe after the western North Pacific (WNP) basin and the most active in terms of tropical cyclones developed per unit area. About 15 TCs develop in the ENP basin per year on average, accounting for about 19% of global TCs. Since most TCs tend to move westward and/or northwestward, TCs in the ENP make landfall less frequently when compared to other basins; hence, TC activity in the ENP basin has possibly received relatively less attention. However, ENP TC activity is an important factor in the summer precipitation regime across Central America and southwestern North America (Englehart and Douglas, 2001, 2002; Corbosiero *et al.*, 2009; Wood and Ritchie, 2013). These regions are projected to experience prolonged drought-like condition in the future climate, so a better understanding of TC activity in the ENP basin has not only scientific relevancy but also a profound socioeconomic impact.

There is currently no generally accepted theory on TC genesis; however, many studies throughout the decades have proposed that a number of physical conditions are needed for, and affect, tropical cyclogenesis. Environmental factors that affect TC genesis include: the Coriolis parameter, sea surface temperature (SST), low-level vorticity, mid-tropospheric humidity and vertical wind shear (Gray, 1968; Mcbride and Zehr, 1981; Klotzbach and Gray, 2008). The formation of TCs largely occurs over warm waters with SSTs greater than 26.5 ºC, away from the equator and in environments with strong cyclonic low-level relative vorticity, moderate/high mid-tropospheric humidity and weak vertical wind shear. A genesis potential index (GPI) was developed based upon those large-scale parameters (Gray, 1979; Watterson *et al.*, 1995; Emanuel and Nolan, 2004) to understand the variability of TC genesis and to aid in the prediction of TC activity.

The interannual variability of TC activity in various ocean basins is strongly influenced by ENSO, as summarized in reviews by Landsea (2000) and Chu (2004), but its impact varies from basin to basin. In the North Atlantic basin, the number of TCs is usually below normal during El Niño years (Gray, 1984; Knaff, 1998) and above normal during La Niña years. In addition to TC frequency, ENSO also impacts TC intensity (Landsea, 2000), genesis location (Elsner and Kara, 1998) and landfall probabilities in the US and Caribbean (Bove *et al.*, 1998; Pielke and Landsea, 1999). In the western North Pacific basin, ENSO has no significant impact on TC frequency but has a significant impact on TC intensity, location and track (Nicholls, 1979, 1992; Dong, 1998; Wang and Chan, 2002; Zhao *et al.*, 2010; Zhao and Raga, 2014).

Whitney and Hobgood (1997) found no effect of ENSO on the TC frequency in the ENP basin, although the number of intense TCs tends to increase during El Niño years (Gray and Sheaffer, 1991; Collins and Mason, 2000; Romero-Vadillo *et al.*, 2007), similarly to the effect observed in the WNP basin. Using GPI anomaly composites associated with ENSO, Camargo *et al.* (2007) concluded that over the eastern North Pacific, vertical wind shear is the main contributor towards the ENSO effect on cyclogenesis with potential intensity also playing a role, and vorticity and relative humidity acting in the opposite sense to the total observed anomaly.

An inverse relationship has been noted between TC activity in the North Atlantic and ENP basin as a function of the ENSO phase (Gray, 1984; Lander and Guard, 1998; Larson *et al.*, 2005). These studies indicate that the anti-correlation can be partly explained by the different effects of ENSO on the tropospheric zonal wind shear in the North Atlantic and ENP basins. Moreover, the ENSO-related signal in ENP TC activity seems to be statistically weaker than that in the North Atlantic (Gray, 1984; Magaña *et al.*, 2003; Frank and Yong, 2007), and the robustness of the relationship between ENSO and TC activity in the ENP basin has been questioned (Whitney and Hobgood, 1997; Ralph and Gough, 2009).

While the relation between cyclogenesis and SST globally was postulated several decades ago