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RELATIONSHIPS BETWEEN TROPICAL WAVES AND CYCLOGENESIS

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1. INTRODUCTION

The authors recently completed a study of zonally propagating waves in the tropical atmosphere using 10 years of satellite imagery and global analysis fields. Spectral filtering and compositing techniques were used to prepare a global climatology of the major tropical wave types and to analyze their mean structures, movement, interactions with topography and with each other (Roundy and Frank, 2004 a,b). This paper extends that work to examine when, where, and how large-scale tropical waves impact the formation of tropical cyclones in each of the Earth's tropical cyclone basins.

The climatological conditions associated with tropical cyclogenesis have been well known since the late 1960s. However, attempts to apply climatological relationships to prediction of tropical cyclone formation have not generally been successful. The question as to why one disturbance becomes organized and intensifies while others don't remains something of a mystery. Our hypothesis is that the ubiquitous waves in the tropical atmosphere play a major role in modulating the formation of tropical cyclones by organizing and sustaining regions of enhanced convection and by altering the vertical shear. Since tropical waves are predictable to some degree for periods of at least one to two wave periods, the results offer hope for improving forecasts of tropical cyclogenesis.

2. METHODOLOGY

The data used in the present study are 10 years of Outgoing Longwave Radiation (OLR) data and global analysis wind fields. The data are spectrally filtered to isolate the eastward-propagating intraseasonal oscillation (ISOe, also called the MJO), equatorial Rossby waves (ER), mixed Rossby-gravity waves MRG), Kelvin waves, and TD-type waves (essentially off-equatorial Rossby waves, such as the African waves of the Atlantic NH summer). In this study, we combined the MRG and TD-type waves into a single wave type since they occupy similar spectral space, but future work will examine the two wave types separately. All of the tropical cyclones that formed equatorward of 20 degrees latitude were included in the cyclone data set.

Relationships between wave phases and intensity and each incident of tropical cyclogenesis were analyzed in two ways. First, we computed the percentage of storm genesis events that occurred in the negative OLR anomaly region of each wave filter band to examine whether genesis tended to occur in the convectively active regions of these larger waves. Second, we calculated the fraction of genesis events that occurred when the OLR variance of each wave type was above a threshold (which was equal to the mean seasonal variance of the wave type plus a small extra amount to account for the pre-storm disturbance itself). This latter product was designed to measure whether the storms formed during periods when the waves were unusually active, which would suggest that stronger waves are more likely to form tropical cyclones than are weaker waves. Finally, we constructed composites of the wave structures relative to the time and place of cyclogenesis to see the relationship between the anomalous wave flow and the genesis location in each basin.

3. RESULTS

There were major variations in the relationships between waves and cyclogenesis from basin to basin. About 75-80% of all tropical cyclones tend to form in the negative-OLR-anomaly regions (convectively active portions) of ISOe and ER waves. (All the wave types are divided almost exactly 50-50% between the negative and positive anomaly regions.) The one exception is in the N. Atlantic, where there is only a very slight relationship between OLR and genesis in the ISOe band. However, the ER-genesis correlation is very strong in this region.

Kelvin waves show some correlation between negative OLR and genesis, but the relationship is weaker than for the ISOe and ER bands. About 50-70% of storms form in the negative anomaly regions of this band, with the strongest relationship occurring in the N. Indian Ocean.

The negative anomaly regions of the combined MRG/TD-type band showed virtually no correlation with genesis in any basin. This may seem odd, given the strong relationships between African waves and genesis in the N. Atlantic. However, in these smaller waves the low-level vorticity center and the maximum convection are usually not in phase with each other.

Relationships between genesis and wave variance are much more variable. In the N. Indian and E. Pacific basins there is a strong tendency for storms to form during periods of high wave variance within the storm season. This is less true in the other basins. In the N. Atlantic hurricanes tend to form when the MRG/TD-type variance is unusually strong, but the same relationship is not found for the other waves. This does not mean that the other waves are unimportant.

All of the analyses suggest that the ER waves are more strongly associated with tropical cyclogenesis than may be commonly recognized.

Relationships between wave phase and structure and the location of the cyclone formation will be discussed in the talk. One composite analysis is shown below as an example (Figure 1). This figure is a composite for the MRG/TD-type band in the NW Pacific. In this figure the average genesis point is the small circle near 10 N and centered at 0 relative longitude. The arrows shown are 850 hPa winds and are drawn only where significant. The background shading is the total composite OLR pattern relative to genesis point, and the dark contours show the wave-filtered OLR anomaly (solid is for negative OLR, dashed for positive). Note that the storms form within the low-lever rotation maximum but to the west of the primary convective region. The genesis occurs within a wave train that is moving off the equator toward the west, as has been reported in case studies in this region (e.g. – Dickinson and Molinari, 2002).

4. REFERENCES

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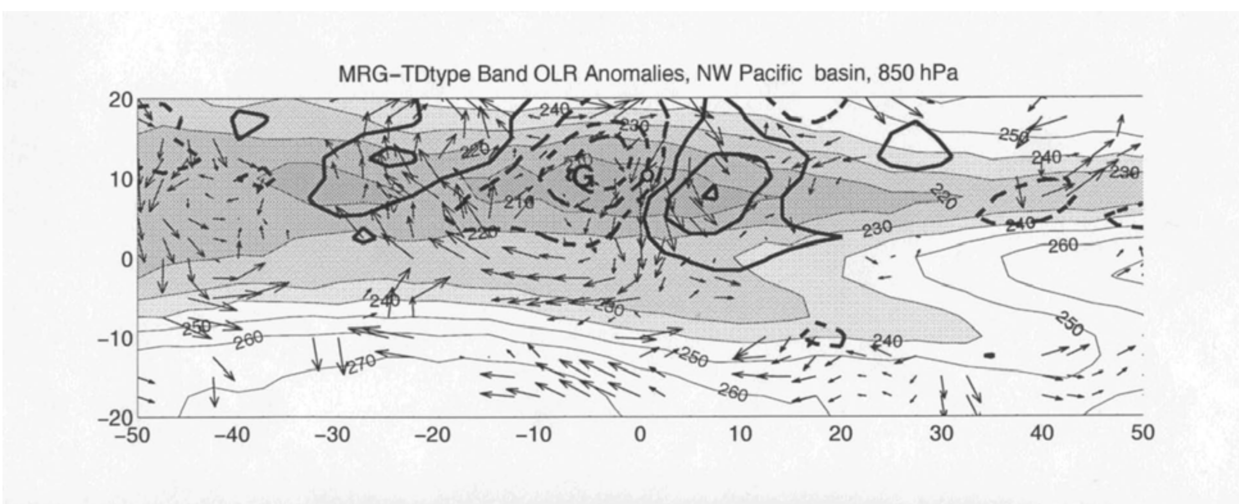

Figure 1: Composite relative to the location of tropical cyclogenesis (shown by the small circle at approximately 10 degrees N and at longitude 0). The background shading is the total OLR, the heavy contours are OLR anomalies for the MRG-TDtype filter band (solid for negative, dashed for positive), and the wind vector arrows are at 850 hPa and are shown only where significant.