3C.5 ENVIRONMENTAL VERTICAL WIND SHEAR AND TROPICAL CYCLONE INTENSITY CHANGE UTILIZING ENHANCED SATELLITE DERIVED WIND INFORMATION

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1. Introduction

The effects of vertical wind shear on a tropical cyclone's (TC) structure and intensity change are qualitatively well known in the tropical community. For low (high) values of vertical shear, a storm will generally intensify (weaken) provided other parameters that affect TC intensity remain constant. However, quantitative relationships have remained elusive, mainly due to the lack of temporal and spatial continuity in measurements of the three-dimensional wind field structure over data sparse regions such as the tropical oceans.

The University of Wisconsin Cooperative Institute for Meteorological Studies (UW-CIMSS) computes high-resolution satellite-derived wind vectors globally using geostationary satellite imagery. UW-CIMSS has automated a process to derive vertical wind shear using this wind information (Gallina and Velden 2000) and is providing these fields in real-time via the Internet. This study expands on Pasch and Velden (1999) who proposed using these fields to quantitatively investigate the relationship between vertical wind shear and TC intensity change. Preliminary results from their study suggested the presence of time lags between the onset of detrimental shear and subsequent TC weakening. The goal of the present study is to expand on their work by examining a large number of TC cases and provide more insight on critical shear magnitudes, time lags, and vertical shear's effect on TCs with different strengths and thermodynamic potentials.

2. Methodology and Database

The procedure used to create the wind shear fields starts by analyzing the multi-spectral satellite-derived winds on a 1-degree grid using a three-dimensional recursive filter method. The analysis weights and quality control parameters are tuned to high-density data in a hurricane environment. An inner grid near the TC is reanalyzed with relaxed quality control restrictions on winds in the near TC environment. The analysis uses wind values from the Navy NOGAPS or NCEP Aviation model forecasts as background fields. The resulting analyses (12 levels) are used to create two mass-weighted layer-mean wind fields: lower-layer (700-925mb) and upper-layer (150-350mb). These two layers were chosen due to good satellite-derived wind vector coverage and advanced vector height assignment methodology that is superior to the traditional assumption of assigning the cloud tracked winds to only 850mb (cumulus) or 200mb (cirrus) levels. Also, using layer-averages can show the significance of the vertical depth of the wind shear, as opposed to the shear value obtained from winds at only two particular levels.

The storm circulation is filtered from the environmental wind analyses by applying a Laplacian gridpoint filter that operates over a prescribed radius from the TC center (currently set at 400 km for the upper layer and 800 km for the lower layer). The procedure removes the grid values within this storm-centered circle, then blends the surrounding environmental wind information into the vortex region. This attempts to isolate the effects of the environmental wind shear on the TC. Finally, the magnitude of the vector difference is calculated from the two-layer-mean filtered fields to derive the vertical wind shear field.

Our study's database is comprised of UW-CIMSS vertical wind shear fields, Maximum Potential Intensity (MPI) fields obtained from Greg Holland (BMRC), and Best Track information from NHC and JTWC for Atlantic and Pacific storms during the period 1996 - 1998.

3. Results

Figures 1 and 2 show the primary results of our study. The graphs indicate the mean effects of vertical wind shear on TC intensity out to 36 hours from the time of the shear estimate. The bar shades represents a particular shear category (ms^{-1}) and each group of 5 bars is the sample-mean, total TC intensity tendency for time periods (6 to 36 hours) after the shear analysis time t(0). For example, the values at +24 represent the sample-mean total pressure change between observation time and 24 hours for selected categories of vertical shear.

Within each time category in Fig. 1 (Atlantic sample) and Fig. 2 (Western North Pacific (WPAC) sample), a general linear pattern emerges; lower (higher) shear magnitudes lead to a mean deepening (filling) effect. This result is consistent with our qualitative knowledge of vertical shear's effects on TC

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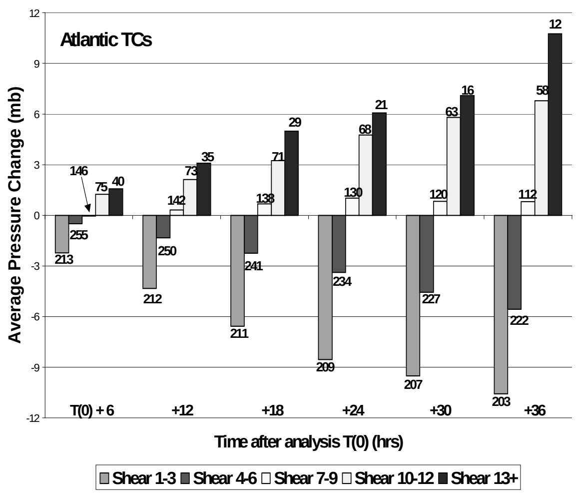

Figure 1. Average Total Pressure tendency per shear magnitude bin (ms^{-1}) for 6 subsequent time intervals (6 to 36 hrs) after the shear analysis at T(0) in the Atlantic basin. Number of cases for each shear category is shown in bold near each column.

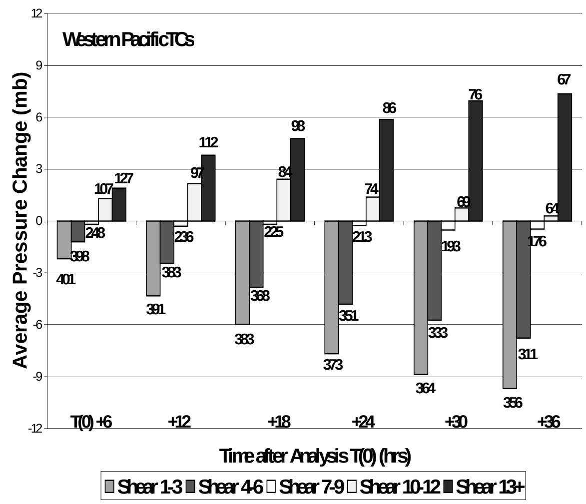

Figure 2. Average Total Pressure tendency per shear magnitude bin (ms^{-1}) for 6 subsequent time intervals (6 to 36 hrs) after the shear analysis at T(0) in the Western Pacific basin. Number of cases for each shear category is shown in bold near each column.

intensity change. These quantitative results also shed light on the magnitude of shear where the pressure tendency changes from deepening to filling. Figure 1 shows that for Atlantic TCs this "critical shear' value is, on average, near 7-8 ms^{-1}.

The WPAC TCs (Fig. 2) average pressure changes are also positively correlated with the magnitude of vertical shear within each time category. One slight difference between the two basins is the magnitude of the "critical shear". The WPAC TCs on average seem to withstand a bit more shear than their Atlantic counterparts, having a "critical shear" value closer to 9-10 ms^{-1}. It is hypothesized that stronger thermodynamic potentials in the WPAC contribute to the resilience of WPAC TCs in greater vertical shear environments.

Another result of our study shows a time lag between the onset of "critical shear" and subsequent response in the pressure tendency of a TC. A TC, predominantly, does not instantaneously begin to weaken when it experiences a detrimental vertical shear. Pasch and Velden (1999) graphically showed examples of TCs that experienced this time lag. The results of this study concluded that on average the time lag peaks between 12 and 24 hours. Larger, more intense TCs typically respond slower near 24 hours, while weak, developing TCs may weaken in 12 hours.

4. Summary

The major findings of this study are: 1) A strong linear correlation exists between environmental vertical wind shear and TC intensity change; 2) A "critical shear" value, above (below) which TCs on average fill (deepen) is typically found near 7-8 ms^{-1} in the Atlantic and 9-10 ms^{-1} in the WPAC; 3) Identification of time-lags between the onset of, or change in, shear magnitude and subsequent TC intensity changes; 4) Variations in the previous three findings depend on storm strength (MSLP) and/or thermodynamic environment (MPI). Findings 3 and 4 will be presented at the meeting.

Further information on this study can be found in Gallina, 2002. From these findings, an algorithm is being created as a guidance tool for forecasters predicting TC intensity changes in different shear environments using the UW-CIMSS analyses.

5. References

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Gallina, G.M, 2002: Environmental Vertical Wind Shear and Tropical Cyclone Intensity Change Utilizing Enhanced Satellite Derived Wind Information. M.S. thesis, University of Wisconsin-Madison, 133 pp. [Available from AOS Library 1225 Rm. 317 W. Dayton Ave. Madison, WI 53706]

Pasch, R.J., and C.S. Velden, 1999: Operational Use of UWISC/CIMSS Vertical Wind Shear Fields for Tropical Cyclone Forecasting at the TPC/NHC. *23rd Conf. on Hurricanes and Tropical Meteor.,* January 1999, Dallas, TX, Amer. Meteor. Soc., Boston, MA.