Tropical Cyclone Intensity Change

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LONG-TERM GOALS

Our overall goal: to better determine the relationship between observed environmental wind shear and Tropical Cyclone (TC) intensity change.

OBJECTIVES

The primary objectives are to better understand the relationship between vertical shear and TC intensity using observations, and develop methods to quantitatively analyze the shear using high-resolution satellite data.

APPROACH

Our approach was to collect a large, multi-basin database matching TCs with coincident environmental shear fields calculated at UW-CIMSS. These analyses incorporated the most advanced satellite wind observations. A thorough investigation involving a statistical analysis of vertical wind shear vs. TC intensity was conducted. In our study, TC intensity change was defined in multiple ways from best-track data to determine time-lag relationships. Our analysis attempted to account for other environmental variables by also introducing the TC potential intensity. The Maximum Potential Intensity (MPI) estimates were provided by Greg Holland. The MPI helps account for TC intensity changes unrelated to the effects from environmental vertical shear.

From our statistical analysis we have learned, in a quantitative matter, how shear affects TC intensity. We are hopeful this information can be incorporated into statistically-based shear models that can be used by JTWC and/or other naval operational forecasters. Chris Velden, PI and Gregg Gallina, an MS student, were involved in this project.

WORK COMPLETED

The databases (shear analyses and coincident TC best tracks) for the Western Atlantic, and Eastern/Western Pacific basins were assembled (described in previous reports). Statistical tests were performed to determine correlations between the shear and TC intensity. The data were also analyzed by categories based on variables such as MPI, current storm mean sea-level pressure (MSLP), and various shear magnitudes.

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14. ABSTRACT

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RESULTS

Our results show a strong correlation between the calculated shear magnitude and average TC pressure changes (see Fig.1) for storms in the western North Pacific (WPAC). Each time interval represents the total mean pressure change after the shear observation. For example, the +24 is the total 24-hour pressure change after the original shear observation, expressed for selected shear bins. Note the general linear stepping nature associated with each of the time differential bins. These linear relationships have R^2 values of .95 or greater. The lower (higher) the shear magnitude, the more likely the subsequent TC central pressure was going to fall (rise). These findings are consistent with intuitive reasoning, and recent observational and theoretical studies.

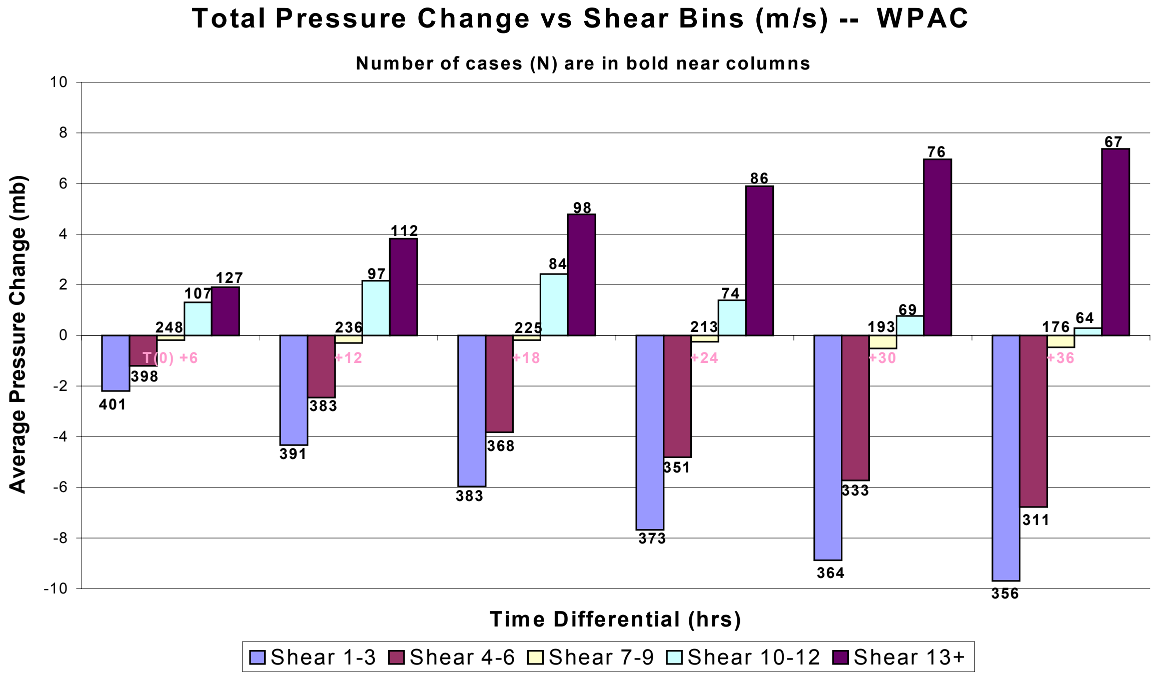

Figure 1. The average subsequent TC pressure change (total) for each shear magnitude bin (m/sec) at six different times. # of cases for each shear bin is shown.

Our study points directly to the generalized effects of deep-layer shear on TC intensity, and this is quantified by the statistical analysis shown in Fig. 1. For example, a TC in a weak vertical wind shear environment (1-3 m/s) will lead (in the mean) to a ~10mb pressure fall in the subsequent 36 hours. By contrast, a TC in strong shear (> 13 m/s) will lead to a ~8mb pressure rise over the same time period. This is a general result that does not yet take into account the effects from other possible influences on TC intensity change (discussed later).

An alternative way of viewing this relationship is given in Figure 2. From this presentation, it can be clearly seen that the cross-over point (or critical value) of the shear magnitude is ~7-9 m/s. As a general rule, below (above) these shear values, WPAC TCs (in the mean) will intensify (weaken). Within the Atlantic basin (not shown), the critical value is closer to ~7 m/s. We speculate that the difference between the basins may be related to higher MPI values and effects within the Western Pacific basin.

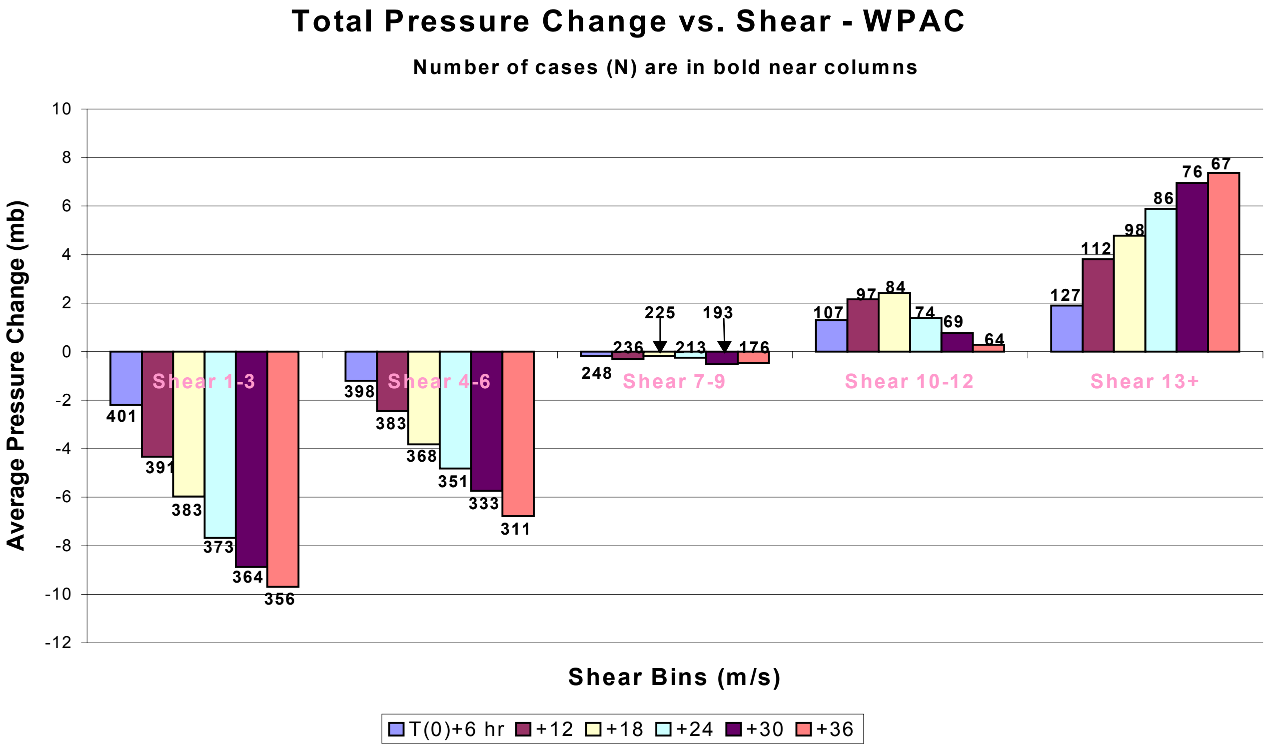

Figure 2. Same as in Fig. 1, except average pressure change as a function of selected shear bins.

It is of interest to examine the relationships found above, but for TCs of different strengths. For example, Figure 3 shows a comparison of shear magnitude and total pressure change in the same manner as Fig.1, except only for storms between 960 and 980 mb (weak typhoons) in the WPAC. The results suggest that, on average, the critical shear value is similar to Figures 1 and 2, but the overall magnitude of the intensity changes are much greater. Storms in this category typically intensify at a greater rate in weak to moderate shear, but cannot withstand stronger shear as well as their more intense counterparts (i.e. supertyphoons). An explanation for this is that weak storms are far from their MPI, so there is enough instability to withstand weak/moderate shear flows and intensify. On the other hand, strong shear is more likely to disrupt their circulations. Both the Atlantic and WPAC had similar results.

As mentioned earlier, the effects of shear are not the only determinant of TC intensity change. In an attempt to account for this, our analysis also categorized the relationships by MPI differential (difference between the TC MPI pressure and actual TC pressure). The MPI takes into account many of the environmental variables outside of wind shear that control TC intensity. Our results showed that in low MPI differential (<20mb), the effect of shear was minimal. In high MPI differential (60mb+)

storms tend to strengthen at all shear values, although much less so at high shear magnitudes. Higher shear values typically have a stronger filling effect on storms with low MPI differential.

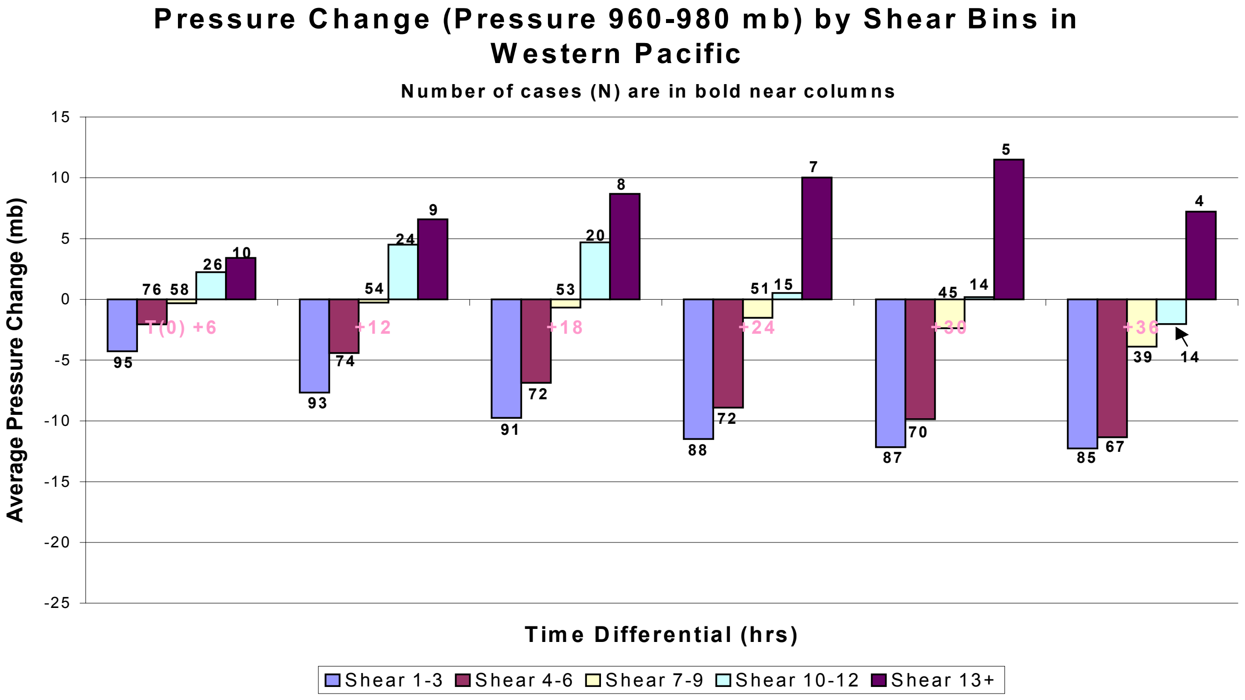

Figure 3. Same as in Fig. 1, except only for TCs with MSLP between 960 and 980 mb.

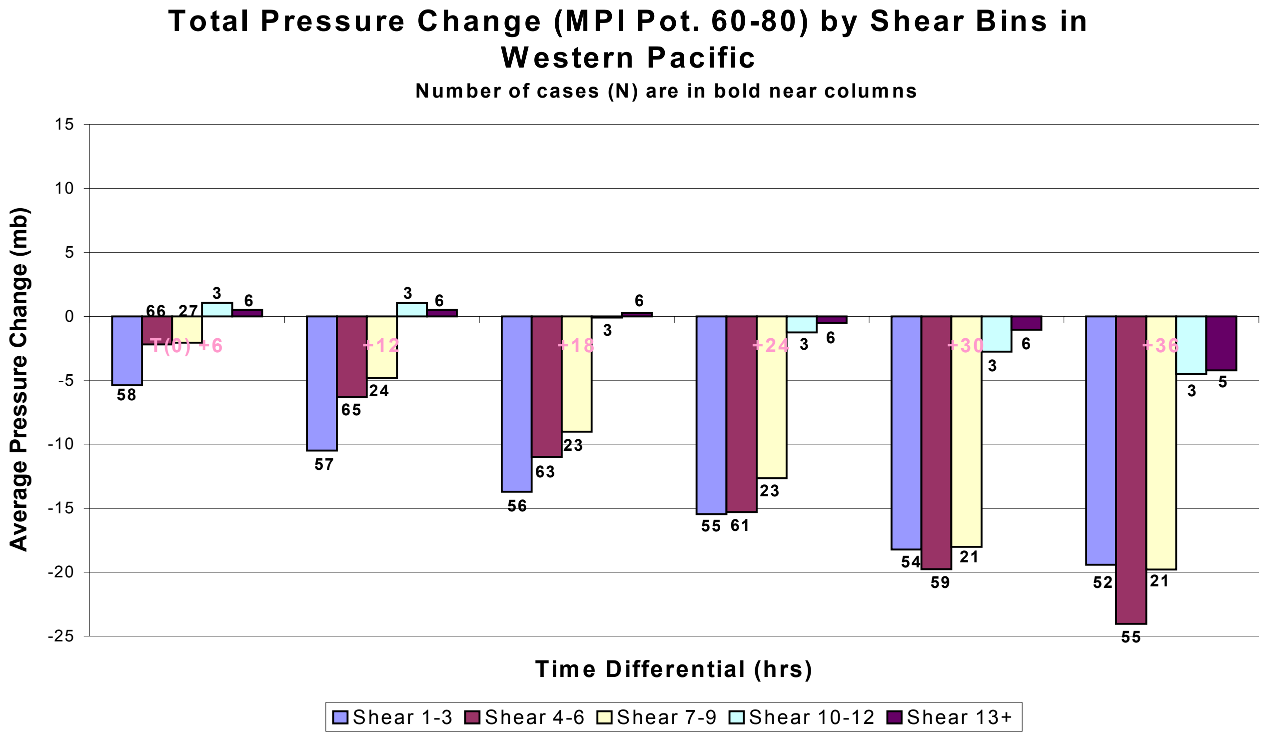

Figure 4. Same as in Fig. 1, except only for TCs with MPI differential between 60 and 80mb. MPI differential. = MPI pressure – Best Track Pressure.

Figure 4 shows an example of our dataset stratified into a bin with high MPI differential (60-80 mb). Again, both WPAC and Atlantic basin cases showed similar results.

The message from our results is that the effects of vertical shear are shown to be detrimental to TC intensity, and are dependent on its current intensity, and MPI. Weak storms in low MPI differential will not survive shear as well as stronger storms in higher MPI differential.

Our analysis also looked at the time response of the TC to changing shear environments. Case studies indicated many instances where a storm entered a hostile (favorable) shear environment and subsequently began to weaken (strengthen). But how soon does it typically take for the shear to lead to intensity changes? For intensity prediction purposes, it is important to try and diagnose the TC intensity response timing, relative to the shear magnitude. We found that in general, for a storm entering high shear environments (>13m/s) the response time is short, ~12hrs, while a moderate shear environment (8-12 m/s) is typically 18 to 24 hours. There is some dependence of this relationship on storm intensity (and probably size/structure).

IMPACT/APPLICATIONS

Applications of this research will result in a quantitative understanding of the relationship between TC intensity and shear, which can be used by JTWC/naval forecasters as objective guidance from real-time satellite-derived shear fields.

TRANSITIONS

Real-time fields of vertical wind shear and tendency are already being disseminated from CIMSS to JTWC for qualitative use and evaluation. Initial feedback has been very positive. The results of this study will be communicated to the operational navy forecast units through a Masters thesis by Gregg Gallina, to be delivered by the end of calendar year 2001.

RELATED PROJECTS

The UW-CIMSS shear fields have been tested for impact in the operational SHIPS model, which is an intensity prediction scheme developed by Mark DeMaria of NESDIS. The initial tests did not show conclusive impact on the SHIPS forecast accuracy. Further collaboration with DeMaria is underway.

SUMMARY

This observational study has defined the general effects of vertical wind shear on the intensity of tropical cyclones. Results can be used as guidance by the TC prediction community, as well as input for statistical TC intensity forecast models. This ONR-funded initiative has created a better understanding of the shear/intensity relationship, which can be used in our further studies of tropical cyclones at UW-CIMSS.

REFERENCES

Pasch, R.J., and C.S.Velden, 1999: Operational use of UWISC/CIMSS vertical wind shear fields for TC forecasting at the TPC/NHC. Abstracts of the 23rd AMS Conf. On Hurricanes, Dallas, TX, 571-574.

Gallina, G., C.S. Velden, 2000: A quantitative look at the relationship between environmental vertical wind shear and tropical cyclone intensity change utilizing enhanced satellite derived wind information. Abstracts of the 24th AMS Conf. On Hurricanes, Ft. Lauderdale, FL, 256-257.