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THE EFFECTS OF VERTICAL WIND SHEAR AS DIAGNOSED BY THE NCEP/NCAR REANALYSIS DATA ON NORTHEAST PACIFIC HURRICANE INTENSITY

Cynthia K. Palmer* and Gary M. Barnes*
University of Hawaii, Honolulu, Hawaii

1. INTRODUCTION

Although forecasting tropical cyclone tracks has improved over the last five years, the intensity errors remain large. Operationally, forecasters at the Joint Typhoon Warning Center depend on the Dvorak technique to estimate the intensity values. They use the intensity estimate, the intensity trend, and the large-scale flow to help forecast the intensity over the next 72 hours. How useful are these large-scale fields to the forecast process? In particular, are the estimates of the vertical wind shear of the horizontal wind derived from the large scale fields useful for predicting intensity change? How close must high vertical wind shear be to affect a tropical cyclone? Can we develop a technique to improve the intensity forecast?

The general consensus in the previous literature is that vertical wind shear of a given threshold is detrimental to hurricane intensity. Gray (1968) found that most tropical cyclones form on the poleward side of the equatorial troughs in the region where the vertical wind shear was small. McBride and Zehr (1981) compared developing and nondeveloping systems, where they found that the vertical wind shear was greater over the nondeveloping systems, inhibiting their development. Zehr (1992) found that in the Western North Pacific, tropical cyclones did not form in a vertical wind shear of a threshold 12.5 ms^{-1}. DeMaria and Kaplan (1994) found that a vertical wind shear of 8 ms^{-1} affects the tropical cyclone core, causing the system to weaken. Frank and Ritchie (2001) modeled a tropical cyclone under 5 ms^{-1}, 10 ms^{-1}, and 15 ms^{-1}. They found that a shear of 5 ms^{-1} will cause a storm to decay within 36 hours. A vertical wind shear of 10 ms^{-1} causes the tropical cyclone to decay within 24 hours, while a shear of 15 ms^{-1} started the decay process immediately.

* *Corresponding author address:* Cynthia K. Palmer, NOAA/NWS, 2001 NW 56th Drive, Pendleton, OR 97801; email: Cynthia.Palmer@noaa.gov.
Gary M. Barnes; Univ. of Hawaii, Dept. of Meteorology, Honolulu, HI 96822; email: garyb@soest.hawaii.edu

2. DATA AND TECHNIQUES

Using the Northeast Pacific best track data (from the coast of North America to 180°) and the NCEP/NCAR Reanalysis data for the period of 1975 - 1999, the effects of vertical wind shear on hurricane intensity are examined. On a 2.5° x 2.5° grid, the reanalysis data use satellite-derived winds from the water vapor and the visible channels to represent the large-scale flow at the upper and lower levels, respectively. The vertical wind shear was therefore calculated between 200 mb and 850 mb. To isolate the effects of the vertical wind shear, we have stratified the data. In our sample, hurricanes were limited to westward or west-northwest tracks to minimize thermodynamic effects since the sea surface temperature isotherms run essentially east to west in the Northeast Pacific between approximately 5°N and 20°N. This stratification revealed that during the 25-year period, 100 hurricanes move westward or west-northwestward for either part of or their entire life cycle. Of these 100 hurricanes, 45 were randomly chosen for examination. Using the intensity from the best track data, the hurricanes' life cycles were divided into intensifying, steady state, and decaying stages. Multiple regions around the hurricanes were examined to determine which regions and what shear magnitudes have the greatest affect on the hurricane's intensity during the various stages. These regions include the 5º, 10º, and 15º boxes centered on the circulation center, and the 10º box halves (north, east, south, and west). The vertical wind shear was examined two different ways for each region. First, the shear was averaged over the entire region, and compared to the intensity. Second, the single maximum vertical wind shear occurring in a given region was examined and compared to the intensity, since climatologically, a southwest-northeast oriented upper level jet is positioned over Hawaii during the summer months. As the hurricanes progress westward, they eventually move under this jet maximum. This causes the high vertical wind shear values to creep into the northwest corner of the regions. After analyzing these regions around the hurricane circulation, two regions were singled out for further examination: the western half and the northern half of the 10° box.

3. RESULTS

Throughout the intensifying stage, the intensity typically increases approximately 70 knots for a three day period. During this time, the average vertical wind shear hovers around 16 knots, and changes minimally in the western and northern halves. The maximum vertical wind shear values show a slight increase of 2.5 knots in the western half and up to 5 knots in the northern half. While the intensity is steady, the average vertical wind shear shows a slight increase of 2 and 4 knots for the western and northern halves, respectively. Meanwhile, the maximum vertical wind shear increases 6 and 8 knots in the western and northern halves, respectively.

As the intensity decreases (approximately 70 knots over 3 days), the average vertical wind shear does not change in the western half, and continues to slightly increase in the northern half by 3 knots. The maximum vertical wind shear values also increases roughly 3 knots in both the western and northern halves. Although these values seem relatively small, the question arises: what is the shear value at the point of decay, or the point when the intensity begins to weaken? The average vertical wind shear is 21 knots in the western half and 24 knots in the northern half. The maximum vertical wind shear value is 40 knots in the western half and 38 knots in the northern half. Therefore, is there a time lag between when high shear values are first detected and the following intensity decrease?

The vertical wind shear time series show that the vertical wind shear tends to remain under or around 16 knots, while the intensity is intensifying or steady, and then it eventually begins to increase. The average vertical wind shear increases 17 knots in the western half and 20 knots in the northern half over a 48-hour period, while the maximum vertical wind shear value increases 31 knots in the western half and 28 knots in the northern half. However, the critical segment of the vertical wind shear increase occurs between the initial shear increase and the intensity's decay point, which represents the lag. Preliminary results suggest that as the vertical wind shear begins to increase, we see a lag occurring between 12 and 24 hours before the intensity's decay point.

Does the average vertical wind shear in a given region have more effect on the intensity than the maximum value of shear for that region? Results suggest that the hurricanes are able to maintain their intensity with single maximum shear values of 20 to 30 knots within 7º of the circulation center, while 35 and 40 knots shear can trigger the decay stage within 12 to 24 hours. However, when the average vertical wind shear in the western and northern halves exceeds 20 knots, then the hurricane begins to decay within 12 hours. Both the maximum and average vertical wind shears yield useful information. Of the 45 hurricanes analyzed, 40 storms showed a decrease in intensity as the vertical wind shear increased. These results suggest shear diagnosed from the large-scale fields does have an impact on a hurricane's intensity.

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