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DVORAK TROPICAL CYCLONE WIND SPEED BIASES DETERMINED FROM RECONNAISSANCE-BASED "BEST TRACK" DATA (1997-2003)

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1. INTRODUCTION

For many tropical cyclones the Dvorak (1975) technique is the only operational tool available to estimate the cyclone's maximum sustained wind speed. However, when reconnaissance aircraft data are available, there are often large differences between the Dvorak satellite-based estimates and those determined from the reconnaissance data. In 1997, reconnaissance aircraft began releasing GPS dropwindsondes (Hock and Franklin, 1999) into the maximum wind band of tropical cyclones. As a result of these new observations, National Hurricane Center (NHC) "best-track" estimates of maximum sustained surface wind have likely become more accurate in recent years.

Brown and Franklin (2002) compared Dvorak satellite intensity estimates with recent reconnaissance-based best track data. It was determined that 25% of the satellite intensity estimates had apparent errors of 14 kt or greater. This study represents a continuation of the Brown and Franklin study, and attempts to quantify some of the likely sources of error in the Dvorak estimates.

2. DATA

In this study, Dvorak satellite intensity estimates from the Tropical Analysis and Forecast Branch (TAFB), the Satellite Analysis Branch, and the Air Force Weather Agency were examined for times when they were within 1 h of a best track time and within 1 h of a reconnaissance aircraft "fix". During the period 1997-2003, 1482 Dvorak satellite intensity estimates satisfied these criteria. The best track data were then interpolated to the time of the Dvorak satellite estimate to obtain a "verifying" intensity. The 1482 verifying best track intensity and Dvorak maximum sustained surface wind (MSSW) estimates were then compared. In the discussion below, the difference between the Dvorak estimate and the interpolated best track intensity is defined to be the Dvorak estimate error.

3. RESULTS

The RMS error of the Dvorak estimates is slightly lower than that reported by Brown and Franklin (2002). The RMS error of Dvorak satellite estimates over the period 1997-2003 is 11.0 kt. The correlation coefficient of the linear fit is 0.93 (87% variance explained). The new error distribution indicates that 50% of the intensity estimates are within 5 kt of the best-track intensity, while 75% are within 12 kt and 90% are within 18 kt.

The satellite intensity estimates were examined as a function of a cyclones forward speed. The results show that for storms moving slower than 3 kt the satellite intensity estimates are on average about 2-3 kt too high. For storms moving 12 to 15 kt the average intensity estimate is about 2-3 kt too low. For storms moving 20 kt or more Dvorak estimates averaged about 5 kt too low.

Dvorak satellite intensity estimates exhibited a slight overestimate at lower latitudes and a slight underestimate at higher latitudes. Storms at latitudes below 15°N, have a Dvorak intensity high bias of about 4-5 kt. Storms between 27°N-31°N have a Dvorak intensity low bias of about 3-4 kt. Dvorak estimates of storms at latitudes 35°N or higher are 5-7 kt too low.

Brown and Franklin (2002) noted that at intensities of 100 kt or more, Dvorak estimates were frequently too high. It was speculated that Dvorak weakening constraints cause the intensity of weakening tropical cyclones to be overestimated. In order to verify this the 1482 best track-Dvorak wind estimates were stratified by weakening or strengthening trends. The trends were determined by comparing the verifying best track intensity with the best track intensity 12 h prior to the time of the fix.

Figure 1 is a scatter diagram of the Dvorak intensity estimates versus the interpolated best track data for weakening and strengthening tropical cyclones. The data

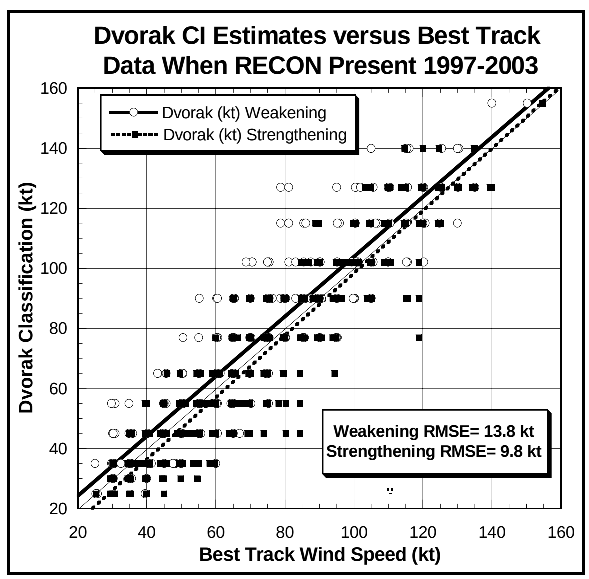

Figure 1. Scatter Diagram of best track intensities vs. Dvorak MSSW estimates. The dark solid (dashed) line indicates the best-fit linear relationship of weakening (strengthening) tropical cyclones. The thin solid line represents a perfect (y=x) relationship.

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indicate that the intensities of weakening storms are overestimated by the Dvorak technique. The figure shows that for weakening storms a high bias of 5 to 6 kt exists across the full intensity range. In contrast, strengthening storms show a low bias of about 3 to 5 kt for tropical cyclones with maximum winds of 65 kt or less.

The error distributions of weakening versus strengthening storms show that 50% of the Dvorak errors of strengthening storms are within 5 kt of the best-track intensity, but for weakening storms, 50% of the errors are only within 9 kt. The 70th percentile error values were 10 and 15 kt respectively, while the 90 kt percentile errors were 15 and 25 kt, respectively. These results suggest that Dvorak CI constraints tend to be too limiting during a storm's weakening phase, producing an overestimate of a storm's maximum sustained wind.

A second comparison to the best track was done for weakening storms using the wind-equivalent of the Dvorak T number. The T number is not subject to the same constraints as the CI number, and could respond to weakening trends more quickly. These results produce a low bias of about 3 to 5 kt for storms less than 65 kt. The low bias increases to 10 kt for category 3 hurricanes and to 15 kt for category 5 storms.

Finally, an intensity was derived from an average of the T and CI numbers for weakening storms. Figure 2 shows how this intensity estimate compares with the best track intensity. This estimate shows minimal bias for intensities less than 80 kt. At higher intensities, there is a slight high bias of about 3 kt for category 3 storms, and roughly 5 kt for category 5. In the absence of other information, NHC has begun to consider the T/CI average in its estimates of a tropical cyclone's MSSW for weakening systems.

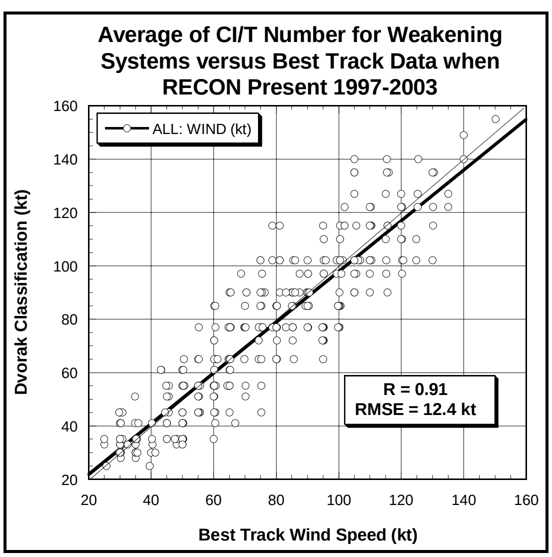

Figure 2. Scatter Diagram of Dvorak intensities (based on an average of the T and CI numbers) vs. best track intensities for weakening tropical cyclones during the period 1997-2003. The thin dashed line represents a perfect (y=x) relationship.

Based on these results, it was concluded that Dvorak rules that hold the CI number for 12 h during initial weakening are too restrictive. A retrospective analysis of TAFB fixes using a 6-h, rather than 12-h criteria was performed. The results showed virtually no bias for storms with best track intensities greater than 65 kt. For weaker tropical cyclones there was a slight underestimate of 2-3 kt. These results showed less bias than the intensity corresponding to the T/CI average. These results suggest that a change to the Dvorak rules should be considered.

4. CONCLUSIONS

Recent reconnaissance-based NHC best track data have been used to validate Dvorak satellite intensity estimates. These results indicate that there is a slight high bias of Dvorak estimates of slow moving storms and low bias for fast moving storms. For storms at higher latitudes (north of 30°N) there is a slight low bias of satellite based intensity estimates.

For weakening tropical cyclones the Dvorak estimates are about 5 to 6 kt too high. Determining an intensity from the average of Dvorak T and CI numbers the bias becomes much less. Alternatively, use of a 6-h constraint on the CI number completely removes the bias. These results indicate that Dvorak weakening rules should likely be amended. These results are consistent with the findings of Lushine (1977). Further studies should be completed to determine how weakening rules should be applied.

5. REFERENCES

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