1. INTRODUCTION

The Hurricane-customized Extension of the VAD (HEVAD - Harasti and List, 2001) method is a single-Doppler radar technique that estimates the earth-relative, horizontal wind field (hereafter referred to as the total wind) of hurricanes in the lower troposphere (LT - up to 3 km altitude). The HEVAD method has recently been improved in two ways. First, the data processing methodology has been refined. Second, the procedure for synthesizing the estimated wind components has been modified. This paper presents a summary of the latter along with new results from a case study of Hurricane Bret (1999).

2. MODIFICATIONS TO THE HEVAD METHOD

The HEVAD method is an extension of the VAD method, customized for hurricanes that are predominantly axisymmetric. The primary circulation is approximated by a modified, Rankine vortex

\[ V_\ell(\zeta, z) = V_\ell(R, z) \left( \frac{R}{\zeta} \right)^{V_\ell}, \]

where \( V_\ell \) is the tangential wind measured at the radial distance \( \zeta \) from the vorticity center and at the altitude \( z \) within the LT. The radar is located at \( \zeta = R \). \( X_\ell \) is a constant exponent that is calculated explicitly in the region \( \zeta > \zeta_m \), where \( \zeta_m \) is the radius of maximum wind. The radial wind \( (V_r) \) is modeled and calculated in a similar way. The Cartesian components of the mean asymmetric wind \( (U_m, V_m) \) are also estimated within the vicinity of the radar (the radar-local environmental current (EC)) throughout the LT. Vertical profiles of \( V_r, V_\ell, U_m \), and \( V_m \) are constructed for the LT directly above the radar. These profiles are extrapolated and/or combined to yield total wind estimates throughout the entire domain.

Three modifications to the HEVAD method are recommended: (1) \( V_r(\zeta_m, z) \) calculated from equation (1) may be extrapolated into the region \( \zeta < \zeta_m \), using the typically observed value of \( X_\ell = -1 \). (2) \( V_\ell \) should only be extrapolated out to horizontal distances of \( \sim R - \zeta_m \) from the radar since \( V_\ell \) typically changes sign from one side of the hurricane to the other. For the same reason, an extrapolated estimate of \( V_r \) should not be included in the estimate of the total wind speed across the entire hurricane. Omitting \( V_r \) from the estimate of the total wind speed results in a negligible bias, typically of \( -1 \) ms\(^{-1} \). (3) **Background:** The total asymmetric wind is comprised of the EC and an asymmetric perturbation. If the asymmetric perturbation is small relative to the axisymmetric components \( (V_r \) and \( V_\ell \)), and if it varies linearly throughout the horizontal domain sampled by the radar, then it averages out in the mean (Caya and Zawadski, 1992), yielding unbiased estimates of \( U_m \) and \( V_m \). If the deviations are small but vary in a nonlinear fashion, then the estimates of \( U_m \) and \( V_m \) are biased by an unknown, but likely small amount. Holland (1983) points out that the EC can vary greatly across the hurricane’s domain. **Conclusion:** An estimate of the total wind speed over the entire domain should not include \( U_m \) and \( V_m \). Rather, the storm motion should be used instead since it is likely to be a better proxy for the domain-averaged EC.

3. RESULTS AND DISCUSSION

Hurricane Bret was observed simultaneously by two WSR-88D radars (KBRO and KCRP) along the Texas coast as it made landfall on August 22, 1999 near 23:42 UTC. Fig. 2c shows that KCRP was located in a region of convective precipitation whereas KBRO was located in a region of shallow stratiform precipitation (below KCRP’s radar beam). The polar coordinates \( (\zeta, \beta) \) of KBRO and KCRP relative to the vorticity center were \( (R, \beta) = (105 \) km, \( 184^\circ) \) and \( (R, \beta) = (102 \) km, \( 351^\circ) \), respectively.

Fig. 1 shows the vertical profiles of the retrieved HEVAD wind components derived from the KBRO (solid curves) and KCRP (dashed curves) VAD data. There is a very striking similarity in the trends along the profiles shown in Fig. 1a-c despite the ~200 km separation of the radars. The \( V_\ell(R) \) profiles shown on the left side of Fig. 1a agree to within ~1 ms\(^{-1} \), thus verifying the near axisymmetry of Bret, given the similar values of \( R \). The \( V_r(R) \) profiles shown in Fig. 1b depict outflow and inflow over KBRO and KCRP, respectively. This radial flow from north to south across the hurricane is in agreement with the radial wind results obtained from Peter Dodge, NOAA/AOML/HRD (see Dodge et al., 2002 for a description of their method - similarly obtained estimates are hereafter referred to as “Dodge”).

The profiles in Fig. 1c-d show how greatly the EC can vary over the hurricane’s domain. The averages of these curves are consistent with a net west-northwestward motion of the storm whose velocity was...
Such an asymmetric flow pattern of eastward moving air in the north-west quadrant and westward moving air in the south-west quadrant agrees qualitatively with previous observational studies of hurricanes with similar trajectories and wind shear patterns (deduced from Dodge); e.g., Fig. 13a of Marks et al. (1992), adjusted to an earth-relative frame of reference, and the wind vectors inferred from Fig. 13b plus Fig. 13c of Willoughby et al. (1984).

The calculated estimates of \( \dot{X} \) were in near-perfect agreement for KBRO and KCRP: 0.29 ± 0.02 and 0.28 ± 0.02, respectively. The \( \dot{V} \) profiles were extrapolated to all values of \( \zeta \) using equation (1). The right side of Fig. 1a shows the vertical profiles for \( \dot{V}(\zeta_m) \), which agree to within ~2 ms\(^{-1}\) of Dodge. These curves reveal at least two altitudes where \( \dot{V}(\zeta_m) \) was a local maximum: \( z_m = 0.78 \) and 2.04 km over KBRO and \( z_m = 0.95 \) and 1.88 km over KCRP. Fig. 2a-b show the estimates of the total wind speed at the lowest \( z_m \) values for KBRO and KCRP, respectively. The total wind was computed as the vector sum of \( \dot{V} \), evaluated at all values of \( \zeta \), plus the storm translational velocity. Fig. 2a-b agree well with each other, and with the wind speeds near the same altitude shown in Fig. 4 of Dodge et al. (2002). The 100 x 100 km region shown in Fig. 2a-b was chosen to facilitate this comparison; the HEVAD estimates actually extend well beyond this area. Also, the HEVAD estimates of the total wind speed at higher altitudes (not shown) agree very well with the GBVTD and TREC wind speed results for the same altitudes; e.g., Fig. 1 of Harasti et al. (2002). Besides its ability to estimate \( \dot{U}_m \) and \( \dot{V}_m \), the advantage that the HEVAD method has over these other methods is that the estimate of the total wind speed can be estimated at hurricane radii \( \zeta > R \) where GBVTD is unable to obtain wind estimates, and where there may be insufficient radar echo for TREC to be applied (e.g., the lack of echo beyond KBRO in Fig. 2c).

REFERENCES


Dodge et al., 2002: See paper 16A.3 of these preprints.

Harasti et al., 2002: See paper 12A.8 of these preprints.


