Comparison of Estimated and Observed Storm Motions to Environmental Parameters

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ABSTRACT

This study explores current storm motion techniques and analyzes their accuracy with respect to different environmental parameters. Current motion estimates are compared to observed motions and different environmental parameters. The parameters investigated are the heights of the lifted condensation level (LCL) and the level of free convection (LFC), the mean relative humidity from the surface to 0°C and the storm relative helicity (SRH) from 0-3 km. Deviate estimates were seen by each storm motion estimator for the different environmental parameters. Also, it was evident that some storm motion estimators were superior to others. However, overall the observed motions in this study were dissimilar to the environmental.

1. INTRODUCTION

Storm motion estimates are widely used throughout meteorology. They are necessary to accurately predict the path a storm will take in order to correctly inform the public. Also, accurate storm motions are needed to calculate certain environmental parameters such as the storm relative helicity (SRH). The mesoscale factors that attribute to the direction of storms are not well observed. The purpose of this study is to explore current storm motion techniques and analyze their accuracy with respect to different environmental parameters. The accuracy will be judged by the distribution of the difference between the motion estimate and the observed motion.

1.1 Environmental Parameters

It is known that both thermodynamic and kinematic properties of the environment can also cause different storm motions. Recent modeling studies suggest that these variations in the thermodynamic profile need to be

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examined in greater detail (Kirkpatrick et. al 2006). For this project we will be looking at a variety of different environmental parameters. The parameters were selected with the guidance of Kirkpatrick et. al (2006) as well as some new fields. The parameters investigated are the heights of the lifted condensation level (LCL) and the level of free convection (LFC), the mean relative humidity from the surface to 0°C and the 0-3 km SRH. The SRH and RH parameters were chosen due to the rotation development and moisture needed for thunderstorm growth, respectively. However, not as well known, are the changes to the LCL and the LFC, which were found to also cause notable changes in storm structure, intensity and evolution (McCaul and Cohen 2002).

1.2 *Explanation of Estimators*

The three storm motion estimators examined are the 0-6 km mean wind speed, Johns method (Johns et. al 1993), and the Bunkers method (Bunkers et. al 2000). The mean wind method was chosen due to the fact that many storm motion estimates are derived from the 0-6 km mean wind. Maddox (1976) estimated storm motion with 75% of the 0-6 km mean wind speed and 30 degrees to the right of the mean wind direction. Davies and Johns (1993) describe storm motions as 30 degrees to the right of the 0-6 km mean wind direction at 75% of the mean wind speed if the speed is less than or equal to 15 m/s. For wind speeds greater than 15 m/s the Johns method estimate is 20 degrees to the right of the 0-6 km mean wind direction at 85% of the mean wind speed.

The Bunkers method was developed as an estimate for supercell motion. The Bunkers method is Galilean invariant; meaning its movement is independent of the ground-relative winds. Similar to the Johns method, the Bunkers motion estimate provides a deflection from the mean wind direction. The deflection from the 0-6 km mean wind is 7.5 m/s perpendicular to the direction of the 0-6 km shear vector.

1.3 *Applications*

There will most likely be a distribution of motions for a given environment instead of one definite motion. These distributions can have several applications. The first being a “sanity check” for radar tracking algorithms. Another application for motion distributions is automated warning guidance. Dance et al. (2007) created the Thunderstorm Environment Strike Probability Algorithm (THESPA) based on the distribution of accuracies in storm motion estimates. From this they were able to create automated probabilistic guidance for future storm tracks. This has implications for the warn-on-forecast concept (Stensrud et al. 2009).

2. METHODOLOGY

Severe weather days were found by using the Storm Prediction Center’s storm reports webpage. There were a variety of different weather events chosen for this study. Some storms were slow moving (5 m/s or less), others were fast moving (25 m/s or higher), some were isolated cells, and some were on tornado outbreak days. All of these were examined in different geographic areas of the U.S. Squall lines and MCSs were not investigated. A total of 12 different days were studied in this research. The storms were from 2007-2009 with four storms from each year. Once a certain day was chosen, the Warning Decision Support System -- Integrated Information (WDSS-II) was used to track a total of 93 storms over their lifetimes, creating 610 data points. Storms with at least 50 dBZ were tracked. The storm’s location was subjectively determined by the visual centroid of the composite reflectivity. The storm motion was determined by the previous storm location. Once the tracking process was completed, the environmental parameters from the 20 km Rapid Update Cycle (RUC) analysis were matched to the tracked storms.

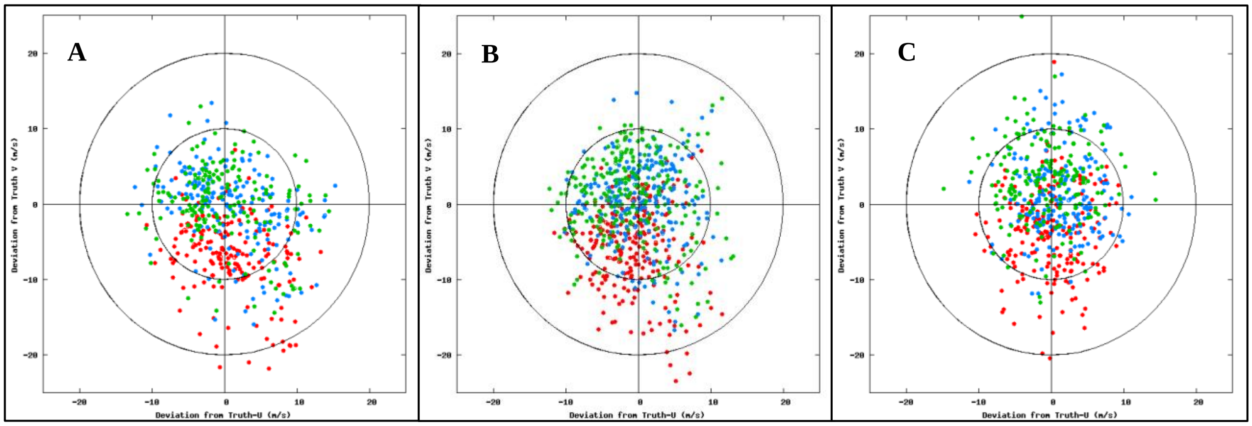
Distributions were created to look at the deviation of the three motion estimators from the observed truth with respect to different environmental parameters. These distributions give an idea of storm motion deflections due to the dependence of certain environments as well as the overall distribution of the estimates with respect to the observed motions.

3. RESULTS

None of the investigated environmental parameters stratified the differences between the different storm motion estimates and the observed storm motion. However, different thresholds of observed environmental parameters did show narrower or broader spread in the overall distribution of differences between the estimated and observed storm motions.

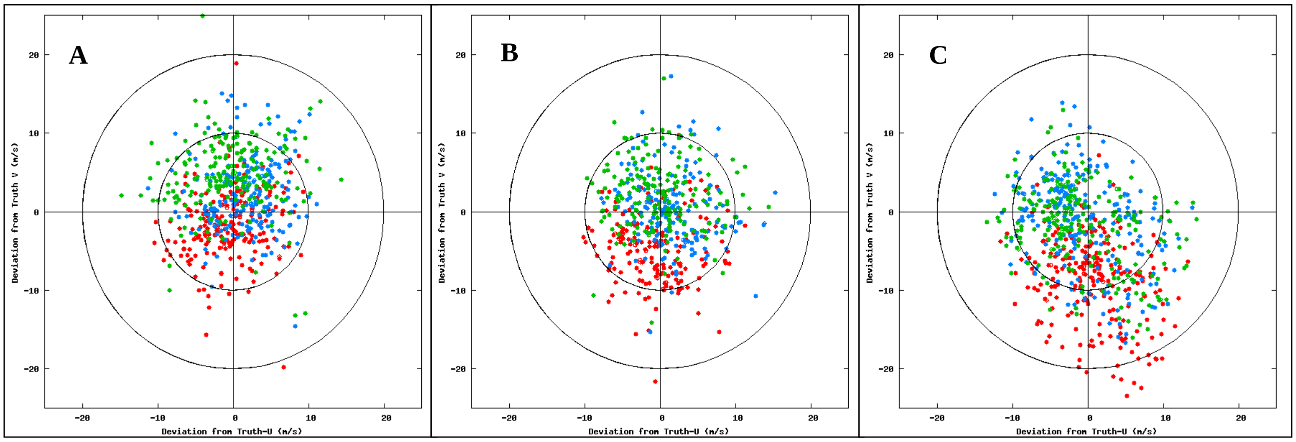
Figure 1 shows LCL thresholds with the deviations of each storm motion estimate. The graphs illustrate that the LCL does not have an impact on the overall spread of storm motions. The mean wind in every graph favors a southerly deviation. This does mean that the mean winds predicted motion is always more southerly of the true values whether in direction or speed. Overall, the Bunkers and Johns estimates seem centered on the origin (i.e. the true motion).

The next parameter investigated was the 0-3 km SRH. Figure 2 shows SRH thresholds with the deviations of each storm motion estimate. For low SRH the mean wind is centered on the origin. This is expected, because storms within low helicity environments typically have very weak or no rotation. As the SRH increases the spread of storm motion deviations expands. For the highest threshold of SRH the distribution of the deviations is no longer centered on the origin. This could be due to the fact that environments with higher values of SRH are associated with supercells. When storms split, the difference in motions between the left and right split would create a large spread in the deviations. The Bunkers estimation used in



Red: Mean Wind Blue: Johns Method Green: Bunkers Method

Figure 1: Deviations of storm motion estimates from the observed storm motions for different thresholds of the LCL. A) LCL height less than 1000 m; B) LCL height greater than or equal to 1000 m and less than 1750 m; C) LCL height greater than or equal to 1750 m.



Red: Mean Wind Blue: Johns Method Green: Bunkers Method

Figure 2: Deviations of storm motion estimates from the observed storm motions for different thresholds of the SRH. A) SRH values less than 75 ; B) SRH values greater than or equal to 75 and less than 200 ; C) SRH values greater than or equal to than 200 .

this study was for a right moving storm. Thus, left moving storms would have large deviations compared to the Bunkers estimate. This is most likely contributing to the biased distribution.

Figure 3 shows a composite graph of the deviations of the three storm motion estimators from the observed motion. The mean wind shows a southerly deviation from the truth. The Johns method seems to be the best centered on the origin. This could be due to the fact that Johns focuses on all storm types and not just supercells. The Bunkers estimation shows a similar distribution to Johns, however, it favors the northwest quadrant. Regardless of the slight biases of the motion estimators, most of the data points are within the 10 m/s deviation circle.

4. SUMMARY

None of the storm motion estimators proved to be successful at predicting storm motion when discriminating by environmental parameters. There were some deviate motions exhibited by each storm motion estimate for certain parameters (e.g. SRH). It was evident that some storm motion estimates were superior to others. Johns method seemed to

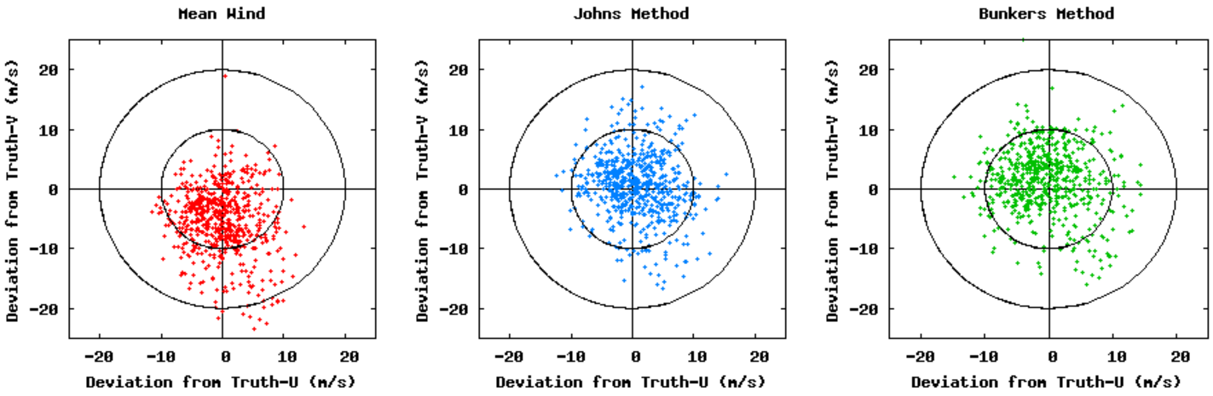


Figure 3: Deviations of storm motion estimates from the observed storm motions for the three different estimators, for every data point.

perform the best, while the 0-6 km mean wind was the most biased estimate, regardless of environment.

One factor contributing to uncertainty in this study is the quality of the RUC analysis. This is due to the poor resolution and unknown accuracy of the analysis. Future studies may consider storm type before stratifying storm estimate deviations by environment.

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