P7.8 CORRELATION TECHNIQUE FOR NAVIGATION OF MOBILE DUAL−DOPPLER NETWORK DATA

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1. INTRODUCTION

Mobile dual−Doppler networks, like the Doppler On Wheels (DOWs) (Wurman et al. 1997, 2001), can collect high resolution data during rapid and multiple deployments, and even while moving. The retrieval of accurate dual−Doppler wind field vectors requires precise navigation of the data. Unlike stationary radars, the precise orientation of the radars at each deployment is not known. The radars do not utilize inertial navigation or similar systems, but only a lower accuracy, much less expensive, flux−gate compass system. The precise orientation of the radars must be obtained post facto through data analysis. Identification of clutter targets like power lines can provide orientation information, as can the identification of common, sharply defined, weather features. However, this process is tedious and subjective.

A correlation technique was developed to obtain the orientations of the radars more precisely and quickly. Using GPS navigation to obtain the locations of the radars, and a first guess of the radar's orientation, the reflectivity fields from both radars are overlaid on a common grid and a correlation coefficient is calculated. The orientations of the radars are perturbed around this first guess result to maximize the correlation coefficient. This technique is evaluated on several data sets including those in tornadoes and a hurricane.

2. METHODOLOGY

The basic principal of the correlation technique is to use common features in the reflectivity fields observed by two radars to calculate a correlation coefficient between them with different orientations of the radars, and find the orientation that maximizes the correlation.

First, the locations of the two radars are specified in a Cartesian coordinate system based on the GPS navigation information. First−guess orientations of the radars are then roughly estimated based on the raw reflectivity images.

In order to improve calculation efficiency, a rectangular area is specified as the target area for calculation of the correlation coefficients. This also allows one to more precisely determine the orientations by focussing on distinct features in the reflectivity field (such as holes or unique shapes) rather than broad regions of nearly uniform reflectivity which tend to result in nearly uniform correlation for many orientations.

As the orientation angle of each radar is altered in specified increments covering a searching window centered on the first guess, the reflectivity is interpolated from the radar (polar) coordinates onto a Cartesian grid using a Cressman (1959) objective analysis scheme. The correlation coefficient then is computed. This process is divided into two steps in order to improve efficiency. First, a coarse increment with a large searching window is given to find the orientations. Then these orientations are used as a better first guess to redo the calculations with a fine increment in a smaller searching window to obtain the final results. In our case studies, the coarse and fine increments usually are 1° and 0.2°, respectively.

Resolutions of both the radars and the Cartesian grid impose a limit on the precision of the navigation. For the cases considered here, the horizontal grid spacing of the Cartesian coordinate is 100m. Thus for a target 20km away from the radar, the orientation is known to within 0.2° , at best.

A spatial correlation is applied to account for the translational motion of features in the grid area. This translational motion is subjectively determined in the current study, but could be determined through autocorrelation techniques.

3. CASE STUDIES

The correlation technique is applied to several cases including two tornado cases and one hurricane case. The first case uses volumetric sector scans of a tornado observed near Bridgeport, Nebraska on 21 May 1998. Well−defined gradients in the reflectivity fields (Fig.1) provide a suitable target for the correlation

Table 1: The maximum correlation coefficients and the relevant azimuth adjustment at different heights for the Bridgeport tornado case.

Height	Max. Corr. Coeff.	DOW2 Azimuth	DOW3 Azimuth
300m	0.982	81.5°	94.4°
500m	0.987	82.0°	94.9°
700m	0.990	82.0°	94.9°
Subjective		84.2°	96.5°

**Corresponding author address*: Pengfei Zhang, Univ. of Oklahoma, School of Meteorology, Norman, OK 73019; e−mail: pzhang@ou.edu scheme. The correlation technique is applied in the plotted area in Fig.1 at three different heights; the results are displayed in Table 1. Correlation coefficients exceeding 98% are found at all levels. Since the orientations at height 500m and 700m are exactly the same, and the one at height 300m is nearly the same with lower correlation, the orientations of 82.0^o for DOW2 and 94.9^o for DOW3 are used on our dual−Doppler analysis.

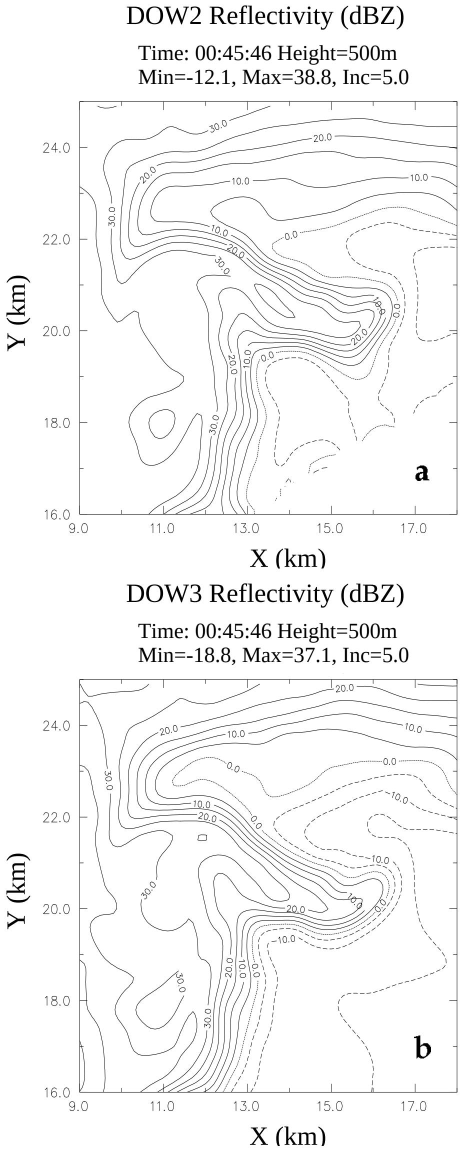

Fig.1 The reflectivity fields of DOW2 (a) and DOW3 (b) for the Bridgeport case.

The correlation coefficient contours in the azimuth window from 78.5^o to 86.0^o for DOW2 and 91.4^o to 98.9^o for DOW3 at 500m are shown in Fig.2. It shows that the correlation coefficients converge to the maximum value 0.987 at adjusted azimuth 82.0^o for DOW2 and 94.9^o for DOW3.

Hurricane Georges was observed on 28 September 1998 around Biloxi, Mississippi in a range of 25km. The reflectivity fields of two pairs of single−level

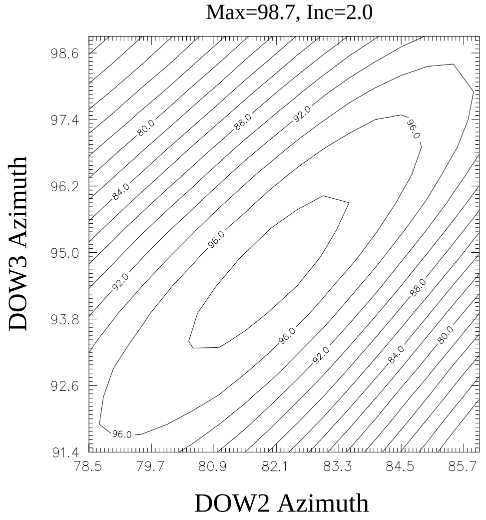

Fig.2 The correlation coefficient (%) contours for the Bridgeport case at h=500m.The maximum is at DOW2 82.0^o and DOW3 94.9^o.

Table 2: The maximum correlation coefficients and the relevant azimuth adjustments in different volume for the Hurricane George case.

Volume	Height	Max. Corr. Coeff.	DOW2 Azimuth	DOW3 Azimuth
1	750m	0.979	128.0^o	41.6^o
2	750m	0.980	128.8^o	42.0^o

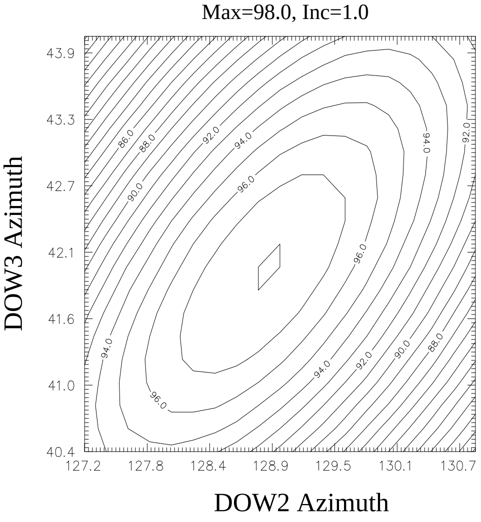

Fig.3 The correlation coefficient (%) contours for the second volume scan of the Hurricane Georges case. The maximum is at DOW2 128.8^o and DOW3 42.0^o.

scans were used to determine the radar orientations. The fine−scale structure in the hurricane eye in the volume scans provides an excellent feature for our technique. The results of two volume scan are consistent (Table 2). Fig.3 clearly displays that the correlation coefficient of the second volume scan converges on the 128.8^{o} for DOW2 and 42.0^{o} for DOW3 .

The third case uses a pair of single−level observations of a tornado near Kiefer, Oklahoma on 27 May 1997. Due to the lack of distinct reflectivity features, the correlation does not show a strong maximum value when evaluated near the tornado. A more distinct reflectivity feature farther from the tornado gives results consistent with those determined subjectively using this same feature. However, the subjective results are somewhat different when using the radial velocity couplet centers as the target. The reasons for this discrepancy are being investigated.

In the fourth cases, three pairs of sweeps are selected to determine the orientations of the DOWs in an observation of a tornado near Almena, Kansas on 3 June 1999. The region around the low reflectivity eye of the tornado is specified as the target area, which is 13km and 2.5km away from DOW2 and DOW3, respectively. The results from these three sweeps agree with each other(Table 3). Since the distance between the tornado and DOW3 is much shorter than between it and DOW2, the result for DOW3 is more sensitive than DOW2. Comparing Fig.4 with Fig.2 and Fig.3, the correlation coefficient contours are oriented more vertically instead of diagonally. It also indicates the sensitivity of the results on DOW3 azimuth adjustment.

Table 3: The maximum correlation coefficients and the relevant azimuth adjustments of different sweeps for the Almena tornado case.

Height	Max. Corr. Coeff.	DOW2 Azimuth	DOW3 Azimuth
210m	0.958	176.4^{o}	91.0^{o}
500m	0.957	176.6^{o}	90.8^{o}
900m	0.962	176.2^{o}	89.4^{o}
Subjective		176.4^{o}	88.0^{o}

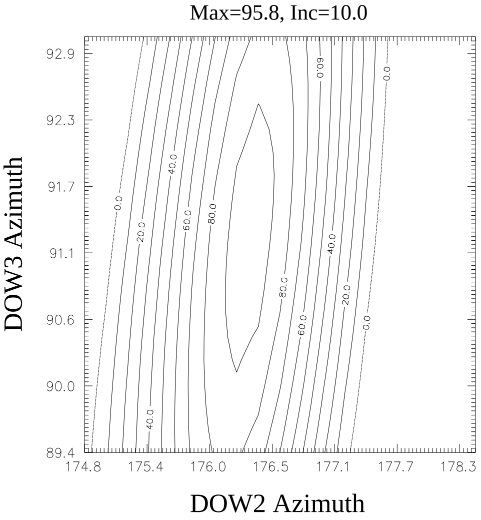

Fig.4 The correlation coefficient (%) contours for the Almena case. The maximum is at DOW2 176.4^{o} and DOW3 91.0^{o}.

4. CONCLUSIONS

The above case studies demonstrate that the correlation technique is quite feasible for the precise navigation of mobile dual− or multiple−Doppler radar networks for different weather phenomena. We found that it is critical to have sharply defined features in the reflectivity fields to serve as targets. This suggests that a common weather feature, with strong gradient in reflectivity sampled by all radars, is very helpful for post−observation dual−Doppler radar data analysis. We also found that our technique gives higher correlation and more precise navigation on single sweep data rather than a whole volume scan.

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