P3C.12 A SOLAR ALIGNMENT TECHNIQUE FOR DETERMINING MOBILE RADAR POINTING ANGLES

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1. INTRODUCTION

In recent years, mobile Doppler radars have been used to collect data in phenomena ranging from tornadoes to hurricanes to mountain flow due to their ability to deploy close to the target of interest and thus collect data with fine resolution.

While basic editing and dual-Doppler synthesis methods are nearly identical to those used for stationary radars, mobile radars present special challenges with regard to 'navigation' of data to a common grid due to imperfect knowledge of the truck pointing angle. For example, the Doppler on Wheels (DOW) radars record data in truck-relative coordinates such that zero degrees refers to the front of the truck. Gridding of the data for use in most analyses, including dual-Doppler syntheses, requires precise knowledge of the location of each truck (available with GPS) and the actual earth-relative azimuth and range of each radar gate. Thus, an azimuth correction must be applied to all DOW data such that zero degrees consistently points north.

Previously, this reorientation has involved matching known tower locations to ground clutter or matching significant weather features observed by two or more mobile radars at known locations. These methods are not only time consuming, but their accuracy suffers from the subjective matching process. Attempts to objectively determine the pointing angles by computing a correlation coefficient or other measure of fit between the reflectivity patterns of two radars for an array of possible angles have been somewhat successful (Zhang et al., 2000), but their accuracy is difficult to quantify and likely varies depending on the sharpness of the reflectivity features present. Thus an objective method with sub-beam accuracy was desired.

During May and June, 2002, the Doppler on Wheels (DOW) mobile radars participated in the International H_2O Project (IHOP). Data were collected during convection initiation, quiescent boundary layer, and boundary layer evolution missions. During IHOP_2002, a solar alignment technique for determining the DOW radar headings was implemented.

In a solar alignment, the radar receives microwave radiation emitted by the sun and one uses the pattern of returned power to determine the truck-relative sun location. The radar pointing angle is simply the difference between the true azimuth of the sun with respect to North and its truck-relative azimuth (Fig. 1). This analysis technique is described below with examples from IHOP_2002. It will be shown that a solar alignment provides a simple, objective approach for determining a mobile radar pointing angle.

2. METHOD

2.1 Data Collection

While the solar alignment technique has previously been considered, the DOW radars are now equipped with NCAR-developed software that points the antenna toward the sun given an approximate heading, location, and time of day. This software makes the process fast and simple enough to implement in the field. A correct

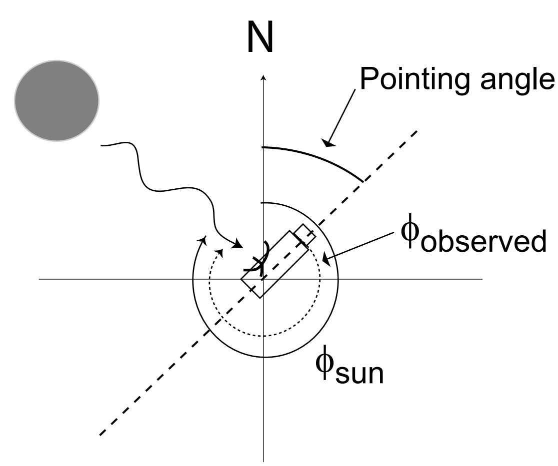

Fig. 1. Determination of the mobile radar pointing angle given the USNO azimuth ϕ_{sun} and the observed azimuth of the sun with respect to the front of the truck $\phi_{observed}$. The pointing angle is ϕ_{sun} - $\phi_{observed}$.

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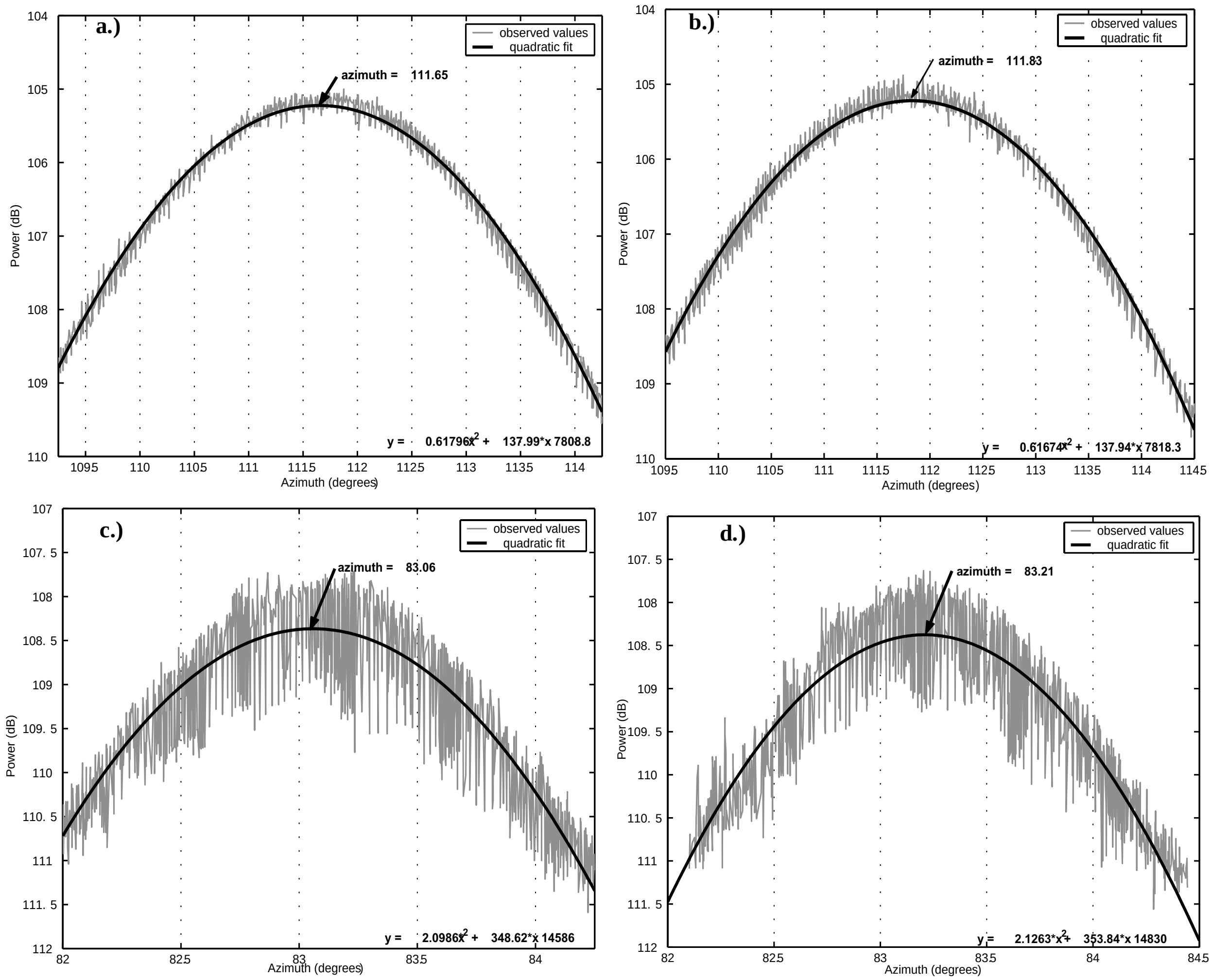

Fig. 2. Returned power versus azimuth plots for DOW2 (a) clockwise (b) counterclockwise and DOW3 (c) clockwise (d) counterclockwise on 10 June 2002. Arrows point to the azimuth of maximum power determined by the quadratic fit.

alignment requires the current time input to be accurate, which is assured using the GPS in the DOWs. The radar operator then centers the sun within a narrow sector of azimuths. Without transmitting radiation, the antenna measures the incoming power while the antenna slowly sweeps the narrow sector encompassing the sun. The slow antenna rotation rate ensures that difference between stamping the azimuth of each ray at the end of the transmitting/receiving period versus the center is negligable (Arnott et al. 2003). The azimuth at which the maximum power occurs corresponds to the azimuth of the sun at that location and time. This process takes about one minute to complete and is performed for each deployment. It should be noted, however, that the accuracy of the alignment decreases as the sun elevation increases because the sun occupies a larger portion of the scanned azimuths.

2.2 Data Analysis

To determine the truck-relative azimuth of the sun, we first compute the average received power along each ray, ignoring the first and last five gates. We then apply the following correction to the original azimuths ($\phi_{original}$). to account for the change in sun position (ϕ_{sun}) during the time of the scan, effectively moving all rays such that they are valid at the central time of the collection period.

$$\phi_{corrected} = \phi_{original} + \frac{\partial \phi_{sun}}{\partial t}(t_{center} - t_{ray}) \qquad (1)$$

The change of azimuth of the sun in time is then determined using data from the USNO records.

Due to gear backlash, the same point in space will have a slightly different assigned azimuth depending on whether the antenna is moving in a clockwise or counterclockwise direction. Thus, we separate the clockwise and counterclockwise sweeps of the sun when determining the azimuth of the maximum power and use the difference between them to quantify the gear backlash error (section 3).

To determine the azimuth of maximum power, a quadratic curve (power as a function of azimuth) is fit to the data within the azimuths subtended by the sun and the azimuth giving a zero derivative in the function is determined. The clockwise and counterclockwise scans are done separately and their resulting azimuths are averaged to obtain the azimuth of the sun with respect to the front of the radar truck. This is then subtracted from the azimuth of the sun with respect to true North to give the pointing angle of the radar (Fig. 1.)

3. RESULTS

Example solar alignments from DOW 2 and DOW 3 are shown in Fig. 2. (The DOW3 solar alignments scans for this case were done at several different elevation angles for other purposes and thus have a wider range of received power at each azimuth.) The observed sun azimuths, actual sun azimuths, and resultant pointing angles are summarized in Table1.

Comparisons with the ground clutter method were conducted for several deployments (Ziegler, personal communication) by overlaying the lowest elevation radar sweeps on a map that includes tower locations. The pointing angle is determined by computing the angle through which the radar data was rotated such that the ground clutter coincided with the tower locations. When the pointing angle determined by the solar alignment is used to rotate the data, the tower locations and ground clutter coincide. The two methods yield similar results, but the solar alignment requires less user interaction and also provides sub-beam accuracy.

	Sun azimuth with respect to true North	Sun azimuth with respect to the front of the truck	Pointing angle
DOW2	199.3	111.74	87.56
DOW3	263.6	83.14	180.46

Table 1: Pointing angles for 10 June 2002

Additional comparisons were made between the solar alignment technique and the correlation method of Zhang et al . (2001). For the comparisons made, both methods yielded the same results.

In addition to determining the pointing angles of the radar, the “jitter” due to gear backlash between clockwise and counterclockwise scans was also quantified for each deployment with an offset of .2 degrees on average. The jitter error can be corrected (by subtracting half the offset from azimuths in the counterclockwise scans and adding half the offset in the clockwise scans (if the offset between counterclockwise and clockwise is positive)) prior to data analysis. The solar alignments are therefore useful in providing information about the mechanics of the radar and can be used to apply corrections to the data.

4. CONCLUSIONS

The solar alignment method correctly determines the pointing angle of a mobile radar. The DOWs are equipped with new software that points the antenna automatically towards the sun given and approximate heading, making the data collection process fast and simple. The subsequent analysis is also much faster and more accurate than former methods of determining the pointing angle when analyzing radar data. Thus, the solar alignment provides a straight-forward objective approach in determining a radar pointing angle and should be of great use for future mobile radar data analysis.

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