A SIMPLE ALGORITHM FOR ELIMINATING DOPPLER VELOCITY ALIASING

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1 Introduction

Now the Doppler radars have become one of the most important instruments for short time weather forecast, and for meso-scale weather research.

Doppler velocity alaising occurs when the radial component of the target's velocity is greater than the Nyquist velocity ($V_{\max} = \pm \frac{PRF\lambda}{4}$). Even with the implementation of dual-PRT techniques to drastically improve the Nyquist velocity, velocity aliasing cannot be avoided in intense tropical cyclones and tornados.

Dealiasing of the Doppler radar velocity filed must be performed before the data can be used in operational meteorology and in research. Dealiasing must be achieved automatically because of the vast quantity of radar data received in a given time interval.

Many dealiasing algorithms have been progressed significantly in recent years (Ray et al. 1977; Bargan et al. 1980; Eilts et al. 1990;Hennington 1981; Merritt 1984; Bergen 1988; Jing et al. 1993;Tao 1993; Yamada et al. 1999;James et al. 2001). But existing automatic unfolding algorithms mostly require correctly identify the aliased data as a priori, and some assumptions and additional manual work are required generally; otherwise, unsatisfactory results may occur. However, to identify automatically folding gates is not easy. In addition, data gaps and noise in the Doppler radar data cause problems for the automatic unfolding algorithms. As a result, Doppler velocity unfolding remains as one of the outstanding problems in radar meteorology.

Considering these questions existed in previous algorithms, a new dealiasing algorithm for Doppler velocity is put forward in this paper based on the characteristics that the wind field is continuous along a ring centered at the radar and the unfolded Doppler velocity-azimuth curve is close to a first-order harmonic curve. The procedures of the new method are first removes the discontinuities in the VAD curve, then adjust the entire velocity data into the proper Nyquist velocity interval. Unlike most existing Doppler velocity dealiasing algorithms, it does not require the knowledge of auxiliary wind measurement and interactively identify aliasing velocities. The Doppler velocity data with multi-aliasing collected from a tropical cyclone was used to test the new method.

2 Description about new dealiasing algorithm

An ideal VAD curve with maximum velocities of ±28 m/s is shown in Fig. 1a. Fig. 1b illustrates the measured Doppler velocity pattern when the Nyquist velocity of the radar is 15 m/s, hence, folding occurs.

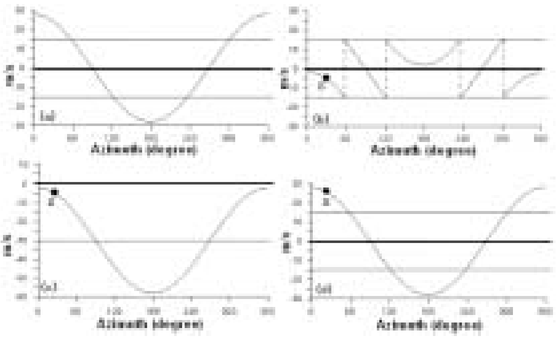

Fig.1 principle sketch map

(a) unfolding velocity-azimuth curve (b) folding velocity-azimuth curve(c) velocity-azimuth curve after the first step (d) velocity-azimuth curve after second and third steps.

It can be seen that the VAD pattern shown in Fig. 1a can be recovered by moving the aliased segment of the Doppler velocities up or down as Fig.1c by two

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times of Nyquist interval (e.g., $\pm 2V_{max}$), and then adjust the entire velocity data into the proper Nyquist velocity interval as Fig.1d by $\pm n * V_{max}$. So a new dealiasing algorithm is designed that there is no need to determine the folding area.

Prior to dealiasing, it is necessary to remove noise while preserving meteorological velocity information. First, all radial velocity gates with low signal to noise ratio (reflectivity <0 dBZ) are removed as suggested in Bargen et al. (1980). Second, using a 3×3 window to filter some noise data as suggested in Bergen et al. (1988). If more than three of eight neighboring gates around a point with a valid value are missing, this point is assigned a missing flag.

The dealiasing algorithm has two steps for each PPI scan.

The first step is to make the piecewise folded velocity-azimuth curve (e.g., Fig.1b) to be a continuous curve (e.g., Fig. 1c). A start point S, which has a valid value (preferred not be zero), must be identified in a particular VAD curve. Taking a folded point S in the Fig. 1b as an example. Its value will be compared with those velocities within a 3×3 window surrounding this point to find the neighboring discontinuous piece. Then, the value of this discontinuous piece will be added $\pm 2 * N * V_{max}$ to make the discontinuous VAD curve becomes a continuous curve as Fig. 1c. This process is done on the next circle until all velocity-azimuth curves become continuous.

The second step is to determine whether the continuous velocity-azimuth curve is on the correct level based on the character of a unfolded velocity-azimuth curve always has a maximal away-speed and a maximal toward-speed approximately equal value. If not (such as the curve of Fig.1c,) the velocity-azimuth curve should be adjusted to the correct level according to the number n, which

$$n = \lfloor (V_{r\min} + V_{r\max}) / V_{\max} \rfloor .$$

Where $V_{r\max}$ is the maximum value and $V_{r\min}$ is the minimun value in the VAD curve. That is

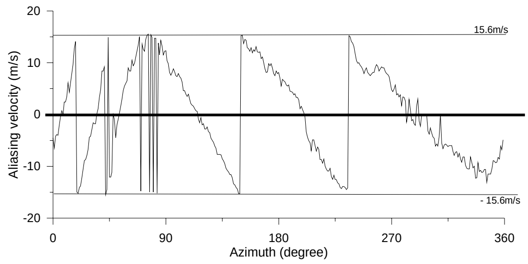
$$V_r^* = V_r + n * V_{\max}$$

for all points of the velocity-azimuth curve. After the second step, the velocity-azimuth curve will been adjusted to the reasonable velocity interval as the curve shown in Fig.1d.

For get better result of dealiasing, the above steps can be repeated one or two times.

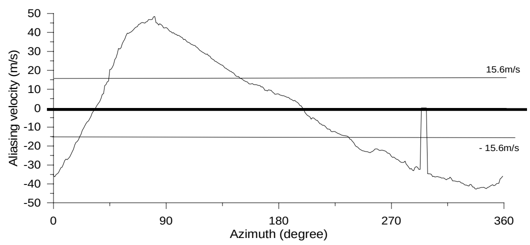
3 Test

The Doppler velocity data with multi-aliasing collected from Typhoon OTTO observed by LuDao Doppler Radar at southeastern Taiwan on 4th August in 1998 was used to test this dealiasing algorithm. The Nyquist velocity ($V_{\max}$) of radar scan mode is 15.6 m/s, the gates width is 0.5 km and $R_{\max}$ is 120 km.



(a) raw

(a) after the first step



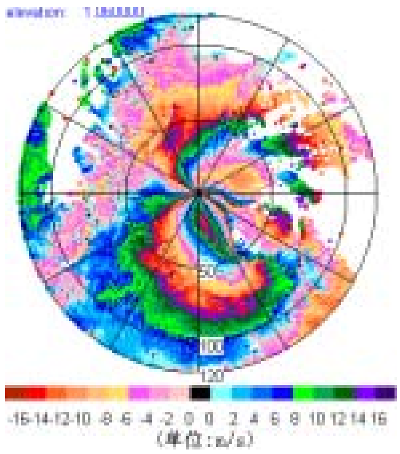
(c) after the second step

Fig. 2 Doppler velocity-azimuth curve on the 50th gates circle at 1.06° elevation

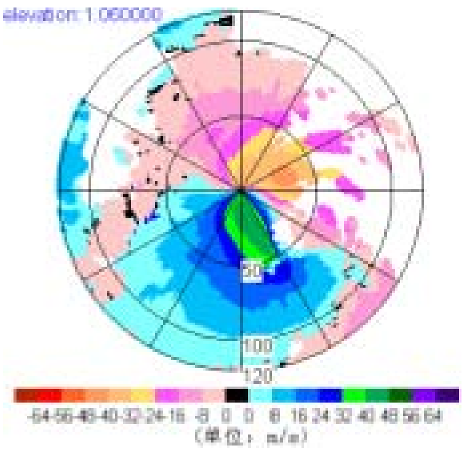
The velocity-azimuth profile of Fig. 2a shows there are two times folding in the scan of 1.06°

elevation at 01UTC 4 August 1998; After first step, the folding curve has become a continuous curve as shown in Fig. 2b, but the velocity value of most gates are positive. After step 2, the curve of velocity-azimuth profile was adjusted to the proper velocity interval with a maximal away-speed and a maximal toward-speed as shown in Fig. 2c, and the range of velocity has increased from 15.6 m/s to about 50 m/s.

The raw PPI of Doppler velocity (Fig. 3a) shows that there is serious aliasing. After dealiasing, the PPI shows that all the aliasing areas have been removed and the maximum radial velocity increased from 15.6 m/s to 55.2 m/s as shown in Fig.3b.



(a) raw



(b) after automatic dealiasing

Fig. 3 Doppler velocity-azimuth curve

and Doppler velocity in a conical scan at 1.06^{o} elevation

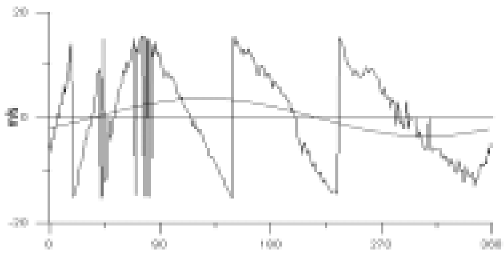
There are obvious folding in the scan area in the fig. 3a. All the aliasing areas have been removed including some dispersed isolated echoes in fig.3b. The maximum radial velocity has been increased from 15.6 m/s to 55.2 m/s in this curve。

4 Check

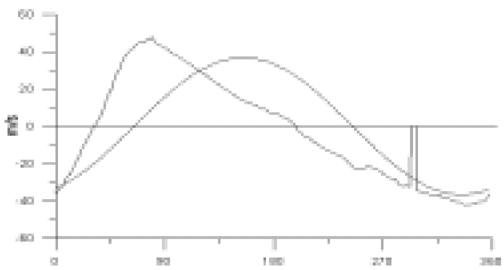
The relationship between amplitude (A) of first-order harmonic curve(V= Asin(θ))and the averaged absolute value of the curve

$$|\overline{V}| = \frac{1}{2\pi}\int_0^{2\pi} A\sin(\theta)d\theta$$

is A=1.57$*|\overline{V}|$.



(a)



(b)

Fig.4 velocity-azimuth curve and , its first-order harmonic curve. (a) before dealiasing, (b) after dealiasing

For a folding velocity-azimuth curve, the amplitude A of first-order harmonic curve of VAD profile is very small as shown in Fig.4a, and the ratio

$$R = A/|\overline{V}|$$

will be <<1.57. If no folding, the VAD curve is approximate to a first-order harmonic curve as shown in Fig. 4b, and the ratio R must be close to 1.57. So, the ratio R can be used to check the results of dealiasing,

numbers of distance circle	1-39	40-79	80-119	120-159	160-199	200-239
R before dealiasing	0.49	0.29	0.29	0.47	1.39	1.207
R after dealiasing	1.52	1.50	1.53	1.48	1.53	1.26
Number of data gaps	0-2	0-63	49-74	44-113	117-198	151-206

Table 1 comparision of R before and after dealiasing

The comparision of R before and after dealiasing is given in table 1. It can be seen that before dealiasing the value of most of R are less than 0.5. It shows that there are serious velocity folding of this scan. But, after dealiasing, the value of R larger than 1.48, except on the scan edge. So it can be said that the dealiasing test of the new algorithm is successful.

5 Summary

A new dealiasing algorithm is presented based on the continuity and the first-order harmonic feature of the Doppler velocity-azimuth curve. This algorithm does not require the knowledge of an auxiliary wind field and manual judgement about aliased area. A test of multi-aliasing velocity data collected from a typhoon case showed this algorithm can effectively dealias multiple folds of Doppler velocities once the low signal to noise ratio data have been thresholded. This algorithm is easy to use, can be performed automatically on a computer, and has potential to be implemented in operational environment.

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