THE ADVANCED COSINE NEIGHBOR ALGORITHM FOR TRUE WIND RETRIEVAL FROM WEATHER RADARS

Poster1-47

Ashwin Raju D K, B. Arul Malar Kannan***
India Meteorological Department

1. INTRODUCTION

Doppler weather radars are state of art instruments for the weather surveillance throughout the world. Weather radars adopt scan strategies consisting of series of typical angles that is set according to the needs. IMD's uniform scan strategy for its volume scan consists of 0.2, 1.0, 2.0, 3.0, 4.5, 6.0, 9.0, 12.0, 16.0 & 21.0 degrees. Basic moments at high spatial and temporal resolution are acquired by operating this volume scan. However Doppler Weather radars sense radial wind instead of true wind. Many algorithms like VAD, VVP, UWT etc have been developed since sixties to derive the true wind/ horizontal wind. But most of the algorithms presume uniform wind-flow; VVP gives wind at a point overhead of the radar and assumes the same wind throughout the radar at about 30km. This in turn makes it not suitable for finding the micro variations in the wind field around the radar site. To eliminate these artifacts, a newly developed and computationally simple "Advanced Cosine Neighbor Algorithm" providing true wind around Doppler weather radar is introduced in this paper. The algorithm having capabilities in capturing the wind field variations around the radar is also demonstrated using simulated synthetic and actual acquired radar data sets.

2. THE ALGORITHM

Consider a uniform wind in a small region of interest as a stream with velocity 'A' m/s, oriented at 'θ' degrees and tilted at 'Φ' degrees to the horizontal. This wind stream perceived by a scanning radar at 'θ_m' degree azimuth and elevation angle 'Φ_n' degree can be represented by equation (1).

$$Vr_m = ACos(\theta - \theta_m)Cos(\phi - \phi_n) \qquad (1)$$

Considering a neighbor ray at same elevation but at different azimuth, the orientation of wind stream can be achieved, and is represented in equation (2).

$$\theta = \text{Arctan}\,2((\frac{Vr_{m+1}}{Vr_m} - Cos(Angle\_diff)), Sin(Angle\_diff)) + \theta_m \quad (2)$$

where $Angle\_diff = \theta_{m+1} - \theta_m$

Using similar analogy the wind tilt can be derived using adjacent elevation angles as

$$\phi = \text{Arctan}\,2((\frac{Vr_{n+1}}{Vr_n} - Cos(Angle\_diff)), Sin(Angle\_diff)) + \phi_n \quad (3)$$

where *Angle_diff* is the difference between the two elevation angles under consideration.

3. DATA AND METHODOLOGY

In order to test the proposed algorithm a simulated radar data following the uniform scan-strategy having ten sweeps, adopted in IMD(Roy Bhowmik et. al, 2011) in Opera hdf format has been generated. Then open source python libraries WRADLIB(Heistermann et. al, 2013) and NUMPY were adopted for processing.

To find wind at various levels, CAPPI cuts for various heights have to be formed. However the existing algorithm for CAPPI generation in WRADLIB converts the radar data from polar to Cartesian grid. The newly proposed Cosine Neighbor Algorithm is designed to work in Polar domain. Transforming the WRADLIB generated CAPPI back to polar format from Cartesian grid introduces conversion errors making the quality of wind retrieval coarser. Hence CAPPI has been generated in Polar domain, only on the region of data interception, without intervention of adjacent rays, but to get radial smoothness Ordinary-Kriging interpolation scheme has been adopted.

This custom developed CAPPI cuts are fed to the Cosine Neighbor Algorithm. A quality control step is undertaken to filter out spurious outputs. The algorithm has also been tested on actual data acquired by Doppler Weather Radar, Chennai on 2018-11-21-1230 UTC.

As a special case study, the velocity patterns mentioned in (Brown et. al, 2007) also demonstrated in this paper.

4. RESULT AND DISCUSSION

4.1 Case Study 1:

It is simulated data of uniform South-westerly wind of 25m/s having tilt of 20 degrees with the horizontal. This wind assumed to be same throughout the scan range. The output of this case study is shown in Fig 1 for a Cappi height of 1km.

* *Corresponding author address:* Ashwin Raju D K, Doppler Weather Radar Chennai, India Meteorological Department; e-mail: ashwinraju2011@gmail.com
**B. Arul Malar Kannan, Doppler Weather Radar Chennai, India Meteorological Department; e-mail: ba.kannan@imd.gov.in

4.2 Case Study 2:

It is real data acquired by Chennai Doppler Weather Radar on 2018-11-21-1230 UTC. The output of this case study is shown in Fig 2 for a Cappi height of 1km.

4.3 Case Study 3:

This is simulated velocity patterns similar to that mentioned in (Brown et. al, 2007). Here the algorithm is applied directly over the slices rather than on Cappi under the assumption that wind has zero tilt. In real data, such assumption might give us the minimum wind velocity with correct direction. The actual wind will be slightly greater than or equal to the output. Fig 3 to Fig 6 shows the result of the algorithm over various velocity patterns.

For the presently adopted scan-strategy of IMD radars, the algorithm performs very well for distance up to 40km. Algorithm finds difficulty in deriving tilt angles if strong convective activities are present beyond 40km. Various interpolations like Linear, Nearest Neighbor, Inverse Distance Weighting and Ordinary-Kriging are tried during CAPPI generation. It is observed that Ordinary-Kriging interpolation scheme provides better result than other interpolation techniques.

The Cosine Neighbor Algorithm would give better results provided dense closely spaced scans are followed. Since close dense scans defeat the very purpose of better temporal resolution in the scanning radars; the proposed algorithm would find immediate adopt-ability in Phased Array Radars. Since Phased Array Weather radars are just being invoked and tested on research mode, the authors were not in a position to acquire those data sets in testing their algorithm; and would be the course of action for further studies.

5. ACKNOWLEDGEMENT

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6. *References*

Brown R. A and Wood V. T, 2007: A guide for interpreting doppler velocity patterns.2d ed. NOAA

Heistermann, M., Jacobi, S., and Pfaff, T., 2013: Technical Note: An open source library for processing weather radar data (wradlib). Hydrol. Earth Syst. Sci., 17, 863-871

Roy Bhowmik, S.K., Sen Roy, S., Srivastava, K. et al., 2011: Processing of Indian Doppler weather radar data for mesoscale applications. Meteorol Atmos Phys 111: 133

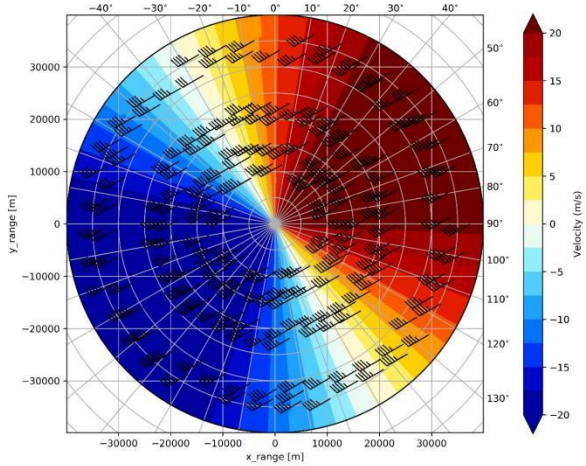

Fig 1. Simulated data - SW wind 25m/s

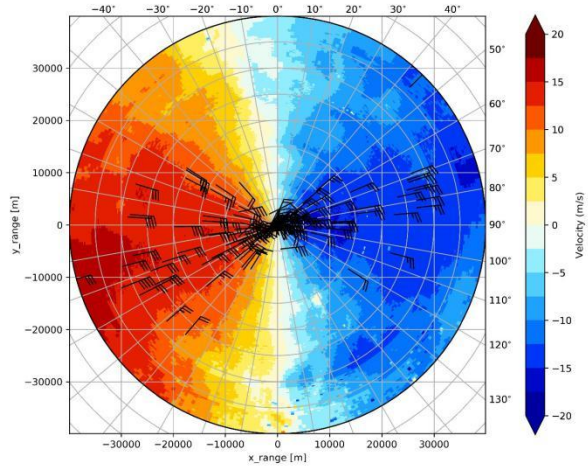

Fig 2. Real Data - ENE wind

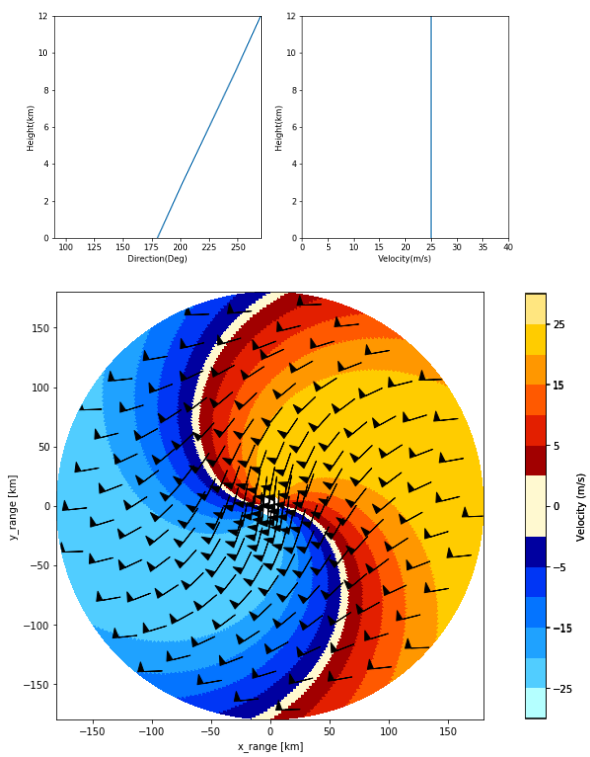

Fig 3. Constant velocity and varying direction

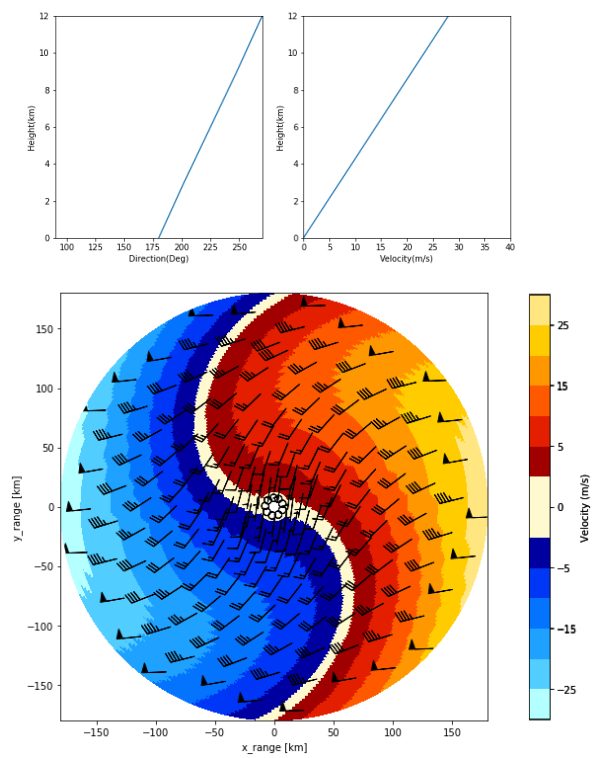

Fig 4. Varying velocity and direction

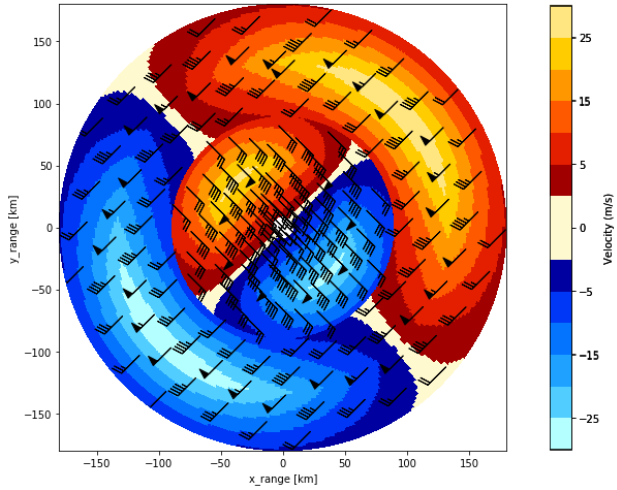

Fig 5. Varying velocity and abrupt direction change

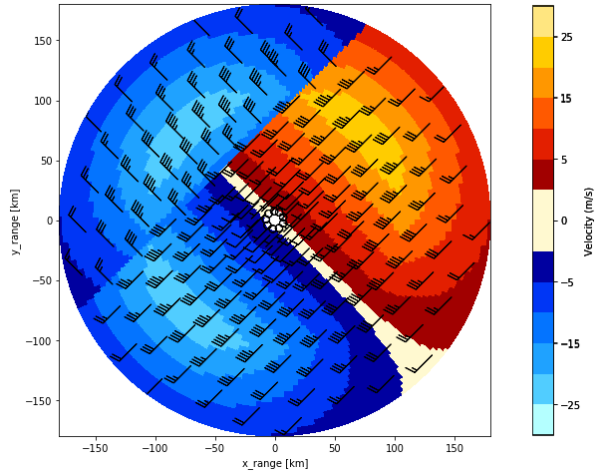

Fig 6. Frontal approach