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

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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 for about 30km. This in turn makes it not suitable for finding the micro variations in the wind field around the radar site. To eliminate this artifacts, a newly developed and computationally simple "Advanced Cosine Neighbor Algorithm" providing true wind around a 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).

$Vr_m = ACos(\theta - \theta_m)Cos(\Phi - \Phi_n)$ (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).

$\theta = arctan2((Vr_{m+1} / Vr_m - Cos(Angle\_diff)), Sin(Angle\_diff)) + \theta_m$ (2)

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

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

$\Phi = arctan2((Vr_{n+1} / Vr_n - Cos(Angle\_diff)), Sin(Angle\_diff)) + \Phi_n$ (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 [1] in Opera hdf format has been generated, and open source python libraries WRADLIB[2] 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 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 21 November 2018 at 1230 UTC.

4. RESULT AND DISCUSSION

For the presently adopted scan-strategy of IMD radars, the algorithm performs very well for distance up to 40km. Various interpolation 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. A sample output for the simulated uniform south-westerly wind of 25m/s having tilt of 20 degrees with the horizontal and Real data acquired by Doppler Weather Radar Chennai on 21 November 2018 at 1230 UTC are shown below.

Fig 1. Simulated data - SW wind 25m/s Fig 2. Real Data - ENE wind

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.

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