Nonlinear Three-dimensional Wind Field Retrieval of Typhoon Based on Modified VAD Analysis

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1. Introduction

Three-dimensional (3D) wind field retrieval is important in the numeric weather forecast. The Doppler weather radar commonly used in weather systems can only detect the radial velocity of the precipitation particle along the line of sight of radar. So it needs to develop 3D wind field retrieval algorithms using the radial Doppler velocity data.

In the traditional ground-based radar system, the 3D wind field retrieval method represented by the velocity azimuth display (VAD) analysis is to express the radial Doppler velocity as a Fourier series with azimuth angle[1]. Under the assumption of constant or linear horizontal wind distribution, the Fourier coefficients obtained by least-squares fit represent the average wind field information in the VAD circle, and the vertical wind field profile information can be obtained by processing the data of VAD circles with different elevation angles.

The height of typhoon is about 15km, and the Doppler weather radar onboard near space platform is located at a height of about 5 km above the typhoon, which can perform the look-down cone-scanning. However, due to the differences of the ground-based radar, there are some problems to be considered when detecting. Firstly, when the platform is measured close to the typhoon, the beam footprint will be spiral due to the motion of platform. Secondly, for far-range detection requirements, the beam may sweep through the typhoon, eye wall and spiral rain-band in sequence during the detection, where the wind field cannot be assumed to be constant or linear. Finally, for a VAD circle, some singular point caused by the random factors needs to be eliminated, which will cause the lack of measurements.

In order to more accurately reproduce the 3D wind field, the VAD analysis in the Doppler radar onboard near space platform scanning geometry mode is proposed. Using the extend velocity azimuth display (EVAD) analysis[2], the nonlinear 3D wind field can be retrieved. Compared with the traditional VAD analysis, the modified VAD analysis can retrieve the more realistic atmospheric wind field, which have better precision and wider application.

2. Methodology

2.1 Traditional VAD analysis

The traditional ground-based radar VAD analysis obtains the wind field information by 360° omnidirectional circumferential scanning at a fixed elevation angle to obtain the radial Doppler velocity V_r, as shown in Figure A.

In Figure A, the X axis points to east, the Y axis points to north and the Z axis points to zenith. V_r is the radial doppler velocity, θ is azimuthal angle, u,v and w are the wind field pointing to X,Y and Z, respectively. α is elevation angle, R is the range from platform to particle. Assuming that the horizontal wind is linear and the vertical wind is constant, the Fourier expansion of the radial Doppler velocity V_r as a function of azimuth angle θ can be obtained and the expressions of wind field information can be

calculated by least-squares fit.

2.2 The modified VAD analysis

The system geometry of the look-down cone-scanning Doppler radar is shown in Figure B. When the beam is scanned by the cone, the beam footprint will be spiral due to the platform motion. V_a is the platform velocity, θ is the azimuthal angle, $-\pi/2-\alpha$ is the elevation angle, R is the range from platform to particle and r is the scanning radius.

When the platform approaches the typhoon, the wind field cannot be assumed to be constant or linear. In this paper, firstly, the horizontal wind field is assumed nonlinear, that is, u and v perform N-order Taylor expansion at the scanning center point O. Secondly, considering the motion of the platform, the error caused by the spiral beam scanning trajectory is compensated and corrected. Thirdly, the EVAD analysis is used to retrieve the wind field in the missing area. Finally, the retrieval effects of traditional linear VAD and modified VAD are compared.

When the wind field is nonlinear, the data has 10% missing area and the input nonlinear wind field is shown Figure C (a), the horizontal wind field error from the traditional linear VAD method is shown in Figure C (b). Figure C (c) is the horizontal wind field error from the modified VAD method. It can be found that the modified VAD method has a better retrieval accuracy.

3.Conclusions

When the wind field changes greatly and the data has a missing measurement area, the traditional VAD technique will cause a large error under the assumption of linear wind field. In the case of linear changes and lack of measurement points, the modified VAD technology applied to the look-doswn conical-scanning motion platform can be used to obtain the wind field information, and the accuracy is better than the traditional VAD method.

References

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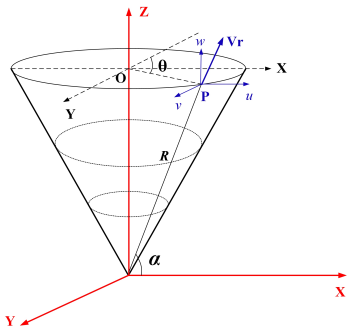
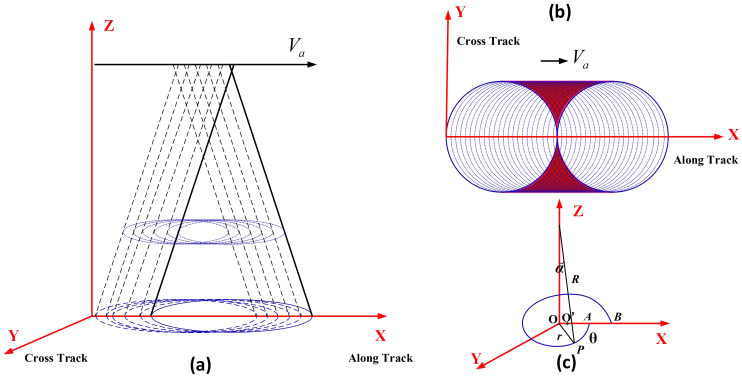
[2] T. Matejka and R. C. Srivastava, "An improved version of the extended velocity-azimuth display analysis of single-Doppler radar data," *Journal of Atmospheric & Oceanic Technology,* vol. 8, no. 4, pp. 453-466, 1991.

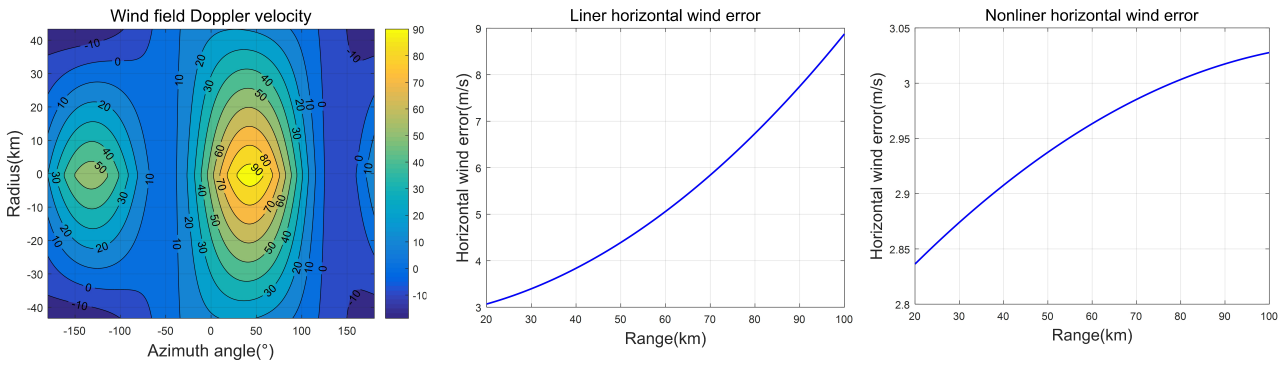
Keywords: Three-dimensional retrieval, VAD Analysis, Nonlinear wind field



A. Traditional VAD schematic diagram



B. Modified VAD schematic diagram



（a） （b） （c）

C. Simulation results.(a)Input wind field; (b)Linear horizontal wind error; (c)Nonlinear horizontal wind error