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QUALITY CONTROL OF SINGLE DOPPLER RADAR DATA AND RETRIEVAL OF HORIZONTAL WIND FOR A LANDING TYPHOON

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Abstract: The removal of noise and velocity ambiguity and retrieval and verification of horizontal wind field is a prerequisite to make the best and fullest use of Doppler radar measurements. This approach was applied to the Doppler radar data collected during August 2005 for a landing typhoon Matsa (0509) in Yantai, Shangdong Province, and the verified result shows that the quality control for this dataset was successful. The horizontal wind field was retrieved and then verified by studying the characteristics of the radar radial velocity and large-scale wind field and the vertical cross section of the radial velocity determined with the typhoon center as the circle center and comparing it with satellite imagery. The results show that the meso- and small-scale systems in Matsa and its horizontal and vertical structure could be clearly retrieved using the dataset collected by single Doppler radar, and a shear or a convergence was corresponding with a band of severe storm around Matsa. At the same time, the retrieved wind field from single Doppler radar is proved to be a reliable and high-resolution dataset in analyzing the inner meso-scale structure of Matsa. It is also proved that the method for removing the velocity ambiguity could be an effective approach for preliminary quality control of the Doppler radar data, and the VAP method could also be a reasonable solution for the analysis of mesoscale wind field.

Key words: Doppler radar; horizontal wind; retrieval; velocity ambiguity; landing typhoon

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1 INTRODUCTION

Forming over tropical oceans, the typhoon is an intense cyclonic vortex with a warm-core structure. During landfall, it often causes casualties and huge economic losses in the area it passes through, due to the immense amount of energy and water vapor it has accumulated. One of the key issues in the forecast and research of summertime weather is the track, intensity, sustaining mechanisms and consequent weather changes associated with a post-landfall typhoon that has the potential of causing severe disasters. Some encouraging findings have been obtained in large-scale numerical simulation and observational analysis using conventional observations and satellite cloud imagery [1 - 4]. In contrast, little effort has been made in the analysis of the meso- and small-scale structure within typhoons. Due to the limitation of resolution for the observations available, little work has been done to study the mesoscale observations for the interior of post-landfall tropical cyclones and relevant numerical simulation has not been conducted the way it should due to the lack of verification with observed data. The absence of observation and analysis of the wind field structure of mesoscale convective cells inside typhoons has limited the understanding of detailed structure of the typhoon, the study of its mechanism and the forecast of the accompanying destructive weather and track. The successful applications of Doppler radar with high resolution and satellite observations have now become keys to the problems.

Since the application of Doppler radar in meteorological measurement, high-resolution data have been offered to the meso- and small-scale analysis and forecast of a variety of systems [5 - 6]. With the increasing improvement of radar hardware techniques, velocity ambiguity has been scarcely found in

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measuring usual weather systems but it is still inevitable when it comes to systems developing very intensely. It is then necessary to remove the ambiguity and noise. Moreover, as what the radar measures directly is the radial velocity, which sets some degree of limitation to the analysis, the retrieval of horizontal wind fields will only serve the research and forecast better. The removal of noise and velocity ambiguity and the retrieval of the horizontal wind field is an important step prior to the use of the velocity measurements by Doppler radar. Meanwhile, as every existing retrieval technique involves assumptions of varying extent [7 - 12], a series of verifications have to be done when retrievals are completed with conclusions to demonstrate the reliability of the results retrieved. They are the prerequisites for accurate and sufficient use of the measurements by Doppler radar.

To provide reliable data for the analysis of landing tropical cyclones using singular Doppler radar measurements, specific Doppler data for Typhoon Matsa (0509) for 03:00 August 6, 2005, was processed to deliase noise and velocity ambiguity and the horizontal wind field was retrieved. Then, the retrieved wind field was verified from a number of aspects.

2 BRIEF SUMMARY OF THE WEATHER PROCESS AND ASSOCIATED LARGE-SCALE ENVIRONMENTAL FIELD

At 08:00 August 1st, STS Matsa intensified into a typhoon and made its first landfall on the province of Zhejiang 03:40 August 6th before keeping moving to the northwest (Fig.1). Its impacts on Shandong province began from 07:00 August 7th to the early morning of August 9th. During this period, Shandong received an average rainfall of 42.9 mm with Yantai having the most, 164.9 mm. The precipitation concentrated from 20:00 August 7th to 06:00 August 8th. During this time, Yantai was always in the northeast part of Matsa’s center. It is known from the upper circulation at 500 hPa (Fig.2) that Matsa was moving with a southerly airflow at the periphery of the subtropical high where the upper westerly had been weak. Yantai was in an area where southeasterly and southerly flows were transforming into a northeasterly flow in the northeastern portion of the tropical cyclone.

3 PROCESSING OF THE NOISE AND VELOCITY AMBIGUITY IN RADAR DATA

Located at 37.5°N, 121.38°E, the weather radar at Yantai is 0.41 km above sea level. Every six minutes, it takes volume scans that contain nine elevation angles each. The azimuth resolution is 1°. The radial resolution is 0.25 km for velocity, with a measuring

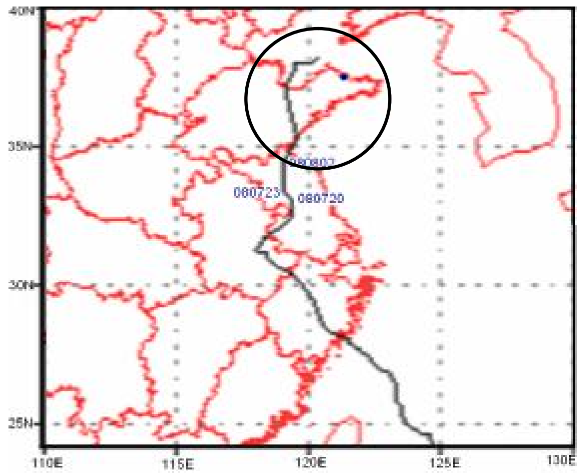

Fig.1 The track of Typhoon Matsa and range of measurement by the Doppler radar in Yantai.

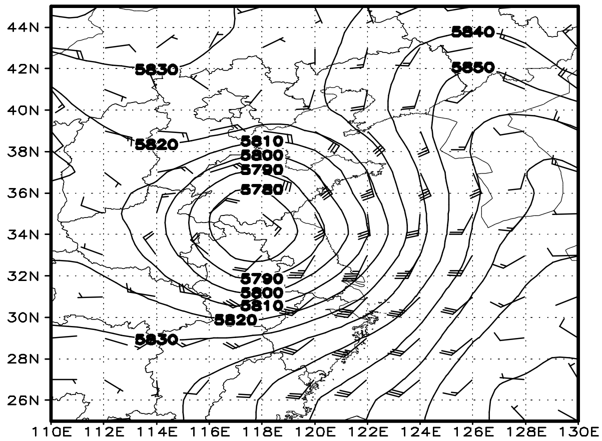

Fig.2 500-hPa wind field and geopotential field at 02:00 August 8, 2005.

radius of 115 km; the radial resolution is 1.0 km for intensity with the radius being 230 km (Fig.1). For the radial wind, the direction tends to be negative when it comes near the radar but positive when it is away from it, with the maximum ambiguous velocity being 27 m/s. The ambiguity exists in data of almost all levels of time. It is therefore necessary to remove noise and dealiase velocity ambiguity from the data.

Following the experimental results by Bergen et al.[13], a 3×3 window is used to dealiase substantial noise. To remove isolated points with values or without measurements, follow the method by Liu [11], the details of which will be omitted here.

It is known from our analysis (omitted) that the processing of radial velocity data as shown above has dealiaseed the part of the ambiguous velocity and substantial noise that would otherwise hamper further analysis while retaining useful information on the mesoscale wind field.

4 RETRIEVAL AND VERIFICATION OF THE WIND FIELD

With the VAP (Velocity Azimuth Processing) method proposed in 1994 by Tao [12], Liu et al.[14] performed a series of error analysis and verification which showed that the method could be applicable in studying the wind field structure of β-scale systems.

To verify whether the retrieved horizontal wind should be applied to the analysis of the mesoscale structure of landing typhoons, this study compares the characteristics of radar-based radial velocity, large-scale environmental wind field, vertical cross section of mean wind and satellite cloud imagery and echoes of rain belts to show that the retrieved wind field is accurate and useful, for it not only agrees with large-scale environmental wind field and large-scale structure of the vertical and horizontal wind field known to date about tropical cyclones, but also gives reasonable analysis of cloud imagery and rainfall echoes in terms of mesoscale structure. It has shown that the retrieved wind field can be used as vigorous observations in mesoscale analysis of the tropical cyclones making landfall. See the Chinese edition of the journal for more details.

5 CONCLUSIONS

(1) Under the condition that the analysis of mesoscale information is not adversely affected, the radial velocity is processed with a filter to eliminate the noise; then the ambiguous velocity is dealiaseed to a significant extent. The verification of this particular case further proves that Liu's method is effective in automatic dealiasing of velocity ambiguity for complete dataset.

(2) As discussed above, the VAP method has been shown to be useful in analyzing the mesoscale structure of tropical cyclones.

(3) Intense mesoscale echoes are well corresponding with the convergence and divergence of the meso- and small-scale wind field and cyclonic wind shear. The retrieved wind field clearly reveals the distribution of mesoscale horizontal and vertical structures existing in the horizontal wind field inside a landing typhoon and provides high-resolution observations for the study of mesoscale structure inside landing typhoons by means of further utilization of singular Doppler observations.

For the next step, detailed analysis of meso- and small-scale structures in the spiral rain belts of the typhoon will be conducted using the aforementioned results in conjunction with numerical simulations.

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