A Simulating Method of Polarimetric Weather Radar Data for Typhoon Detection

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1.Introduction

Typhoon is a kind of severe weather that seriously affects the production and life of human society. The typhoon landing process is mainly observed by the ground-based weather radar. However, it is difficult to monitor the whole process of such meteorological disasters from generation to development to extinction which mostly occur on the sea. The main reason is the lack of sufficient detection means (such as airborne polarimetric weather radar) to obtain the three-dimensional structure inside such a strong convective system and the meteorological parameters related to the micro-physical process. To develop the required typhoon monitoring equipment, polarimetric data of typhoons is in urgent need to assist in the research of system design and subsequent verification of signal processing algorithms.

At present, the simulation methods of meteorological target polarimetric data has been made a series of developments. In 2011, Li et al. used Advanced Regional Prediction System(ARPS) to simulate a supercell storm polarimetric characteristics according to its microphysical characteristics[1]. In 2014, Lischi et al. used the microphysical properties of high-resolution Weather Research and Forecasting(WRF) output to simulate polarimetric data for complex meteorological targets based on ground-based radar[2]; In 2015, Brown et al. compared polarimetric radar reflectivity and differential reflectivity simulated by WRF with real radar observations of Hurricanes Arthur and Ana [3]. In 2016, Liu Xia et al. proposed a simulation method for the polarimetric characteristics of rainfall targets based on WRF[4].

2.Methodology and Results

In the current study, we propose a method for simulating ‘realistic’ X band polarimetric data of typhoons based on WRF outputs. The T matrix method[5] is used to calculate the electromagnetic scattering matrix, and the polarimetric data simulation of typhoon by coherent superposition is realized. The specific implementation steps are as follows:

Step 1: Use WRF to simulate typhoon and obtain weather scene data.

Step 2: Read the weather scene data from WRF outputs, and obtain the mixing ratio and the particle number concentration data of the typhoon precipitation in one of the grids;

Step 3: Calculate the microphysical characteristics of typhoon precipitation by combining physical parameters such as density, radius and minimum mass of precipitation type with meteorological data such as mixture ratio and particle number concentration;

Step 4: Based on the microphysical properties, the electromagnetic scattering characteristics are calculated by the T matrix method to obtain a polarimetric scattering matrix;

Step 5: Select the next grid to be calculated and return to step 1 to re-execute until all grid data in the simulation area is calculated.

Typhoon Meranti(2016) was simulated to assess the performance of our method.. Impacting the Batanes in the Philippines, Taiwan, as well as Fujian, China in September 2016, Meranti formed as a tropical depression on September 8 near the island of Guam. The simulation was initialized at 0600 UTC on 14 September 2016 and then run for 12 hours. Observations of Meranti were taken by weather radars in Taiwan. We chose 3 hours of observations to capture Typhoon Meranti at its closest passes to either set of radars, which ranged from 1300 UTC on 14 September to 1500 UTC on 14 September.

3.Conclusions

Figure 1 shows the simulated reflectivity Z, Zh and Zdr at 5 km height as compared with observations. The

times shown are 1300, 1400, 1500 UTC 14 September 2016 for the three rows, respectively.
From the comparisons between observations and our simulation results, we can indicate that our simulation method is able to adequately capture the major features such as overall precipitation asymmetry of Typhoon Meranti during the observation hours. Some fundamental differences between observed and simulated Zh and Zdr could be shown from a more detailed comparison. From the results we could assume that the conclusions may be more generally applicable to other typhoons. However, some discrepancies with the polarimetric radar observations have been shown from our simulations, and most had a high bias in both intensity and rainfall compared with observations.
This analysis will be extended to more detailed comparisons between simulated and observed radar reflectivity in the future work, which also includeThe radar variables simulations of other bands such as Ku, C or S band, and other polarimetric variables, such as the specific differential phase and correlation coefficient, with the goal of providing a reliable dataset of the typhoon polarimetric data. We can use the simulated polarimetric data to analyze the relationship between Zh and Zdr, and compare with the observations to provide a reliable data set for the precipitation classification algorithm and better improve the precipitation classification algorithm. Better typhoon forecasts and valuable insights into the mechanisms of typhoon intensification and heavy rainfall production could be made from further study into the microphysical processes and comparison with polarimetric radar data of typhoon.

References

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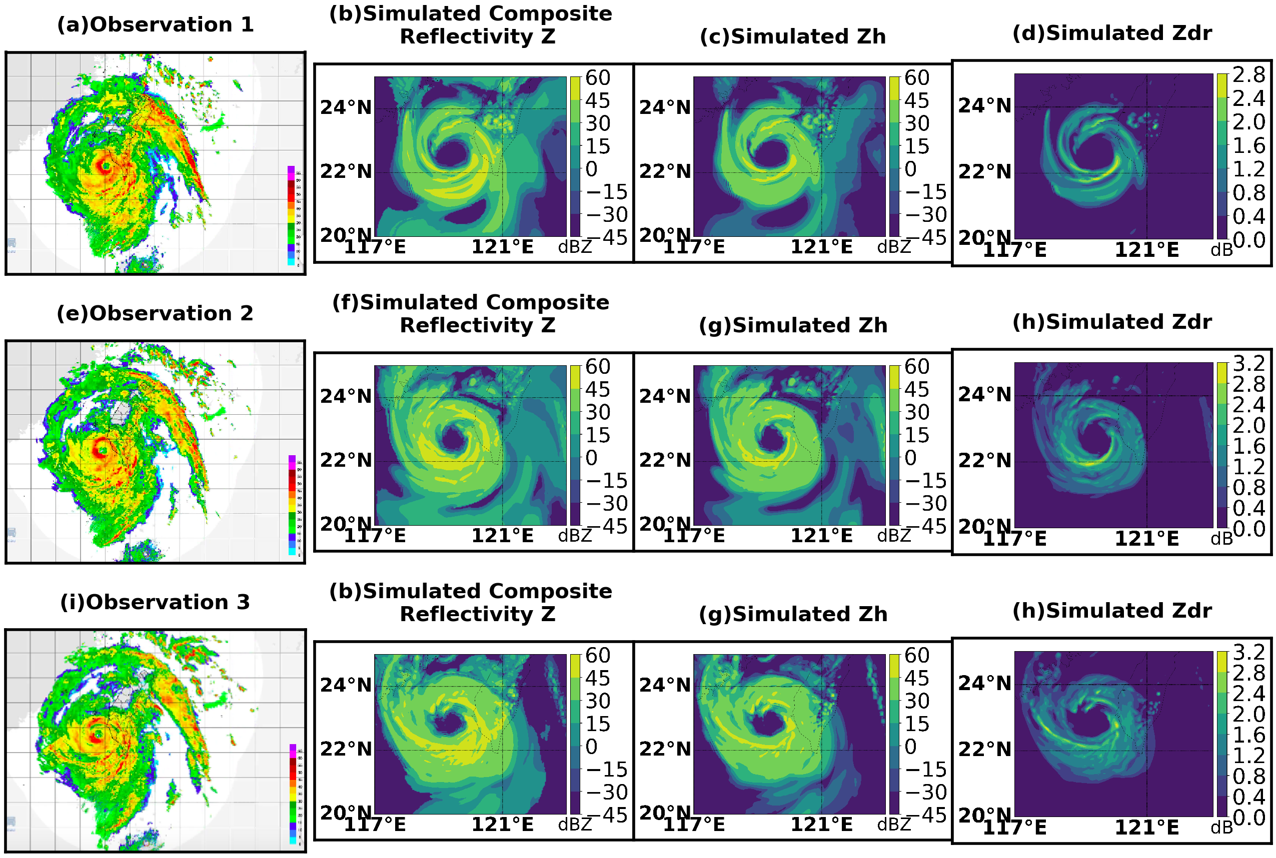
(a)Observation 1
(b)Simulated Composite Reflectivity Z
(c)Simulated Zh
(d)Simulated Zdr
(e)Observation 2
(f)Simulated Composite Reflectivity Z
(g)Simulated Zh
(h)Simulated Zdr
(i)Observation 3
(b)Simulated Composite Reflectivity Z
(g)Simulated Zh
(h)Simulated Zdr
24°N
22°N
20°N
117°E
121°E
dBZ
60
45
30
15
0
−15
−30
−45
dB
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0