Postprint: TS Score Analysis of WRF Cloud Microphysics Parameterization Schemes for Heavy Rain Simulation in Xinjiang

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Abstract

In mesoscale numerical models, the selection of different parameterization schemes exerts a significant influence on precipitation simulation and prediction performance, and a judicious choice of parameterization schemes can enhance forecast accuracy. To this end, this study employs the Weather Research and Forecasting (WRF) model version 3.8, adopts a two-layer nested grid configuration of 3 km and 9 km, and utilizes ECMWF (European Centre for Medium-Range Weather Forecasts) reanalysis data as initial and boundary conditions to simulate four heavy rainfall events in the Xinjiang region. The TS (Threat Score) metric is used to evaluate the applicability of four cloud microphysics parameterization schemes—the Lin scheme, WSM6 scheme, Thompson scheme, and WDM6 scheme—for heavy rainfall simulation in Xinjiang. The results demonstrate that the Thompson scheme exhibits advantages in forecasting station rainfall for light rain (0.1–5.0 mm) and moderate rain (5.1–10.0 mm), whereas the other three cloud microphysics parameterization schemes show varying degrees of missed forecasts. Based on correlation coefficient analysis, the Thompson scheme' s simulation performance is marginally superior to the other schemes and is suitable for Xinjiang, a region characterized by frequent light and moderate rainfall. However, all four cloud microphysics parameterization schemes display poor forecast performance for heavy to torrential rain precipitation categories, which represents a specific area requiring improvement in the WRF model for the Xinjiang region.

Full Text

Evaluation of Cloud Microphysical Parameterization Schemes in WRF for Precipitation Simulation in Xinjiang

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Abstract: In weather research and forecasting models, different parameterization schemes significantly affect precipitation prediction. Selecting appropriate parameterization schemes can improve prediction accuracy. This study utilized version 3.8 of the Weather Research and Forecasting (WRF) model to simulate four precipitation cases in Xinjiang using two-layer nested grids at 3 km and 9 km resolutions, with ECMWF (European Centre for Medium-Range Weather Forecasts) reanalysis data as initial and boundary conditions. The applicability of the Lin, WSM6, Thompson, and WDM6 schemes for precipitation simulation in Xinjiang was evaluated using threat scores (TS). Results showed that the Thompson scheme demonstrated advantages in predicting light rain (0.1-5.0 mm) and moderate rain (5.1-10.0 mm), while the other three cloud microphysical parameterization schemes exhibited missed forecasts for these categories. Based on correlation coefficient analysis, the simulation accuracy of the Thompson scheme was slightly higher than that of the other schemes, making it more suitable for Xinjiang. However, all four schemes showed limited capability in forecasting heavy precipitation, indicating that the schemes require further improvement for application in Xinjiang.

Keywords: WRF; threat score; cloud microphysics; parameterization scheme; precipitation; simulation capability; Xinjiang

1. Introduction

Precipitation forecasting accuracy in numerical weather prediction models is highly sensitive to the choice of cloud microphysical parameterization schemes. The Weather Research and Forecasting (WRF) model offers multiple microphysics options that can substantially influence simulated precipitation characteristics. This study systematically evaluates four commonly used parameterization schemes—Lin, WSM6, Thompson, and WDM6—for their applicability to precipitation events in the Xinjiang region.

2. Methodology

The WRF model version 3.8 was employed to simulate four distinct precipitation cases occurring in Xinjiang. The experimental design utilized a two-layer nested grid configuration with horizontal resolutions of 3 km and 9 km. Initial and boundary conditions were derived from ECMWF reanalysis data. The four microphysical parameterization schemes evaluated were: the Lin scheme, the WSM6 (WRF Single-Moment 6-class) scheme, the Thompson scheme, and the WDM6 (WRF Double-Moment 6-class) scheme.

Model performance was quantitatively assessed using threat scores (TS) and correlation coefficients computed between simulated and observed precipitation values from automatic weather stations. The TS metric provides an objective measure of forecast skill across different precipitation intensity thresholds.

3. Results

3.1 Precipitation Time Series Analysis

[Figure 3: see original paper] presents the time series of hourly precipitation from automatic station observations and the four microphysical parameterization schemes for all cases. The Thompson scheme showed the closest agreement with observed precipitation patterns for light and moderate rainfall events, while the other three schemes tended to underestimate or miss precipitation episodes entirely.

3.2 Statistical Verification

summarizes the correlation coefficients between simulated and observed precipitation values for each scheme at both grid resolutions. The Thompson scheme consistently achieved the highest correlation coefficients across the four cases, though the improvement over other schemes was modest. At 3 km resolution, correlation coefficients for the Thompson scheme ranged from 0.42 to 0.78, while at 9 km resolution they ranged from 0.05 to 0.76. The WDM6 scheme showed comparable performance in some cases but exhibited greater variability.

The TS verification revealed that the Thompson scheme maintained superior skill for light rain (0.1–5.0 mm) and moderate rain (5.1–10.0 mm) thresholds. However, all four schemes demonstrated limited capability in forecasting heavy precipitation events, with TS scores generally below 0.3 for rainfall exceeding 10 mm.

4. Discussion and Conclusion

The evaluation results indicate that the Thompson microphysical scheme provides the most reliable precipitation forecasts for Xinjiang among the four tested options, particularly for light to moderate rainfall events. Its advantage stems from its more sophisticated treatment of ice-phase processes and raindrop size distributions, which appears better suited to the region' s precipitation characteristics.

Nevertheless, the generally poor performance of all schemes in predicting heavy precipitation highlights a critical limitation. This deficiency likely relates to inadequate representation of convective processes and cloud-aerosol interactions at the mesoscale. The comparable performance between 3 km and 9 km resolutions suggests that microphysical parameterizations may be more influential than horizontal grid spacing for these cases.

Future work should focus on customizing microphysical parameters for the arid and semi-arid climate of Xinjiang, particularly for improving heavy precipitation forecasts. The development of regional-specific parameterizations or data assimilation of local observations may enhance model performance.

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