Comparison of Spring Forecasting Ability between GY-WRF and GRAPES in Danghe South Mountain

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Abstract. The Plateau Numerical Weather Forecast System (GY-WRF) was evaluated for its ability to forecast spring weather in Danghe South Mountain. The forecasted temperature, relative humidity, and wind were compared with GRAPES using data from four automatic weather stations in March and April 2022. The results showed that GY-WRF had the smallest mean absolute error (MAE) for each factor at station 4, and a small MAE for temperature, relative humidity, and wind speed at station 2, but a slightly larger MAE for wind direction. GRAPES had a small MAE for wind direction, and a similar trend in wind speed MAE to GY-WRF. GY-WRF was better at predicting the diurnal variation trend of temperature, while GRAPES had a better effect on forecasting the minimum temperature. Both GY-WRF and GRAPES were capable of predicting the trend of wind direction conversion at each station, with GY-WRF being better at predicting the diurnal variation trend of wind speed.

1. Introduction

Danghe South Mountain is located in the northeast of the Qinghai-Tibet Plateau, at the junction of Qinghai and Gansu provinces, with an altitude of more than 3000m, presents significant challenges in evaluating meteorological conditions due to its complex topography and scarce meteorological observation stations. To address these difficulties and improve weather forecasting accuracy in the plateau region, the integration of numerical weather prediction model simulation results with observational data is of utmost importance [1]. In 2020, the Plateau Numerical Weather Forecast System (GY-WRF) was developed to address this need [2]. After two years of research, the WRF (Weather Research Forecast) model-based numerical forecast system became operational. In this paper, the performance of the GY-WRF system is evaluated through comparison of temperature, relative humidity, wind, and other data from four Automatic Weather Stations (AWS) with both GY-WRF and GRAPES model forecasts. The aim of this study is to facilitate the effective utilization of GY-WRF products for weather forecasting in this region.

The structure of the paper is as follows: In Section 2, we introduce the GY-WRF system. The data and methodology used in this study are described in detail in Section 3. The results of the analysis are presented and discussed in Section 4. Finally, we provide a summary and conclusion in Section 5.

2. GY-WRF system introduction

The GY-WRF Weather Forecasting System is a sophisticated numerical weather forecasting model that has a coverage area of approximately 400 x 400 km. It is built on the WRF model, utilizing version 4.3 (ARW) and incorporating GRAPES (Global/Regional PrEdiction System) data as its initial conditions. The real-time assimilation of CAMCast and AWS data is achieved through the implementation of the Nudging Assimilation method [3]. The forecast system is activated daily at 20:00 LTC and provides a 72-hour forecast [4]. The system has a three-layer nesting grid setup, with domain 01 (d01) covering most of the Chinese mainland, including the eastern part of China and the whole Qinghai-Tibet Plateau, among other regions, with Jianshe Township (37.5°E, 97.5°E) serving as the center. The horizontal grid of domain 01 is 100 x 100 with a grid resolution of 27 km. Domain 02 (d02) covers the northern part of the Qinghai-Tibet Plateau, with a horizontal grid of 80 x 80 and a grid resolution of 9 km. Domain 03 (d03) covers the entire Danghe South Mountain area, with a horizontal grid of 60 x 60 and a grid resolution of 3 km. The vertical direction employs Sigma coordinates, divided into 30 layers, with the top of the model fixed at 50 hPa [6].

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3. data and methods

3.1. Data introduction

The performance of the GY-WRF Weather Forecasting System was evaluated using hourly observational data from four Automatic Weather Stations (AWSs) located at different elevations. The AWSs were designated as station 1 (s1) at an elevation of 2600 meters, station 2 (s2) at an elevation of 1800 meters, station 3 (s3) at an elevation of 4000 meters, and station 4 (s4) at an elevation of 4300 meters. The verification period for this study was March to April 2022. The data used in this study included the forecast products from the GY-WRF in the Danghe South Mountain, the daily forecast data products from the GRAPES, and the observational data from the AWSs in the Danghe South Mountain. The weather forecast factors evaluated in this study were temperature at 2 meters, relative humidity at 2 meters, wind speed at 10 meters, and wind direction at 10 meters.

3.2. Verification method

In this study, the model forecast products were interpolated to the target stations through the use of the Bilinear Interpolation method. Bilinear Interpolation is a linear interpolation technique that involves extending the interpolation function to two variables and performing interpolation in both longitudinal and latitudinal directions. The verification process was primarily focused on analyzing the Mean Absolute Error (MAE) of each factor, serving as a fundamental step in refining the model output results [5].

4. Result analysis

4.1. Temperature analysis

The analysis of temperature forecasts for each station revealed variations in MAE at different times (Fig. 2). The forecast trends of both products were similar for Stations 1 and 3, with low temperature forecasts during the day and high temperature forecasts at night. The MAE of GRAPES was relatively small at night, with the lowest MAE of around -7.5°C at 10:00, before increasing to around 1°C at 17:00. The MAE of GY-WRF was small at night, rapidly increasing after 8:00 to around 7.5°C at 10:00, before decreasing after 14:00. The MAE of GY-WRF for Stations 1 and 3 gradually increased after nightfall, reaching a maximum value of approximately 3°C at 8:00, before beginning to decrease and stabilizing at around -2.5°C at 11:00. The MAE of GY-WRF for Station 2 was small at night, with a lower forecast after 8:00, and about -2.5°C lower than the observation from 14:00 to 17:00. The forecast effect of GY-WRF for Station 4 was the best, with MAEs around 1°C. The temperature forecast by GRAPES for Station 2 was gradually lower, with the lowest MAE of around -7.5°C at 10:00, before increasing to around 1°C at 17:00. The temperature forecast for Station 4 was generally high, with low temperature forecasts at 10:00, increasing afterwards and with a maximum MAE of approximately 5°C at 17:00.

4.2. Relative Humidity analysis

The analysis of relative humidity forecasts for both products showed similar trends for Stations 1 and 3 (Fig. 2). The overall relative humidity forecast for this region was high, with a large MAE for the GRAPES forecast and a relatively small MAE for the GY-WRF forecast. The MAE for GRAPES was between 30% and 40% RH in the forecast for Stations 1 and 3, reaching a maximum MAE of approximately 45% RH in the afternoon. The MAE of GY-WRF gradually decreased after nightfall, reaching a minimum before and after sunrise (less than 5% RH at Station 1 and less than 10% RH at Station 2), before gradually increasing after 8:00 LST. The GRAPES forecast for Station 3 had an MAE of more than 30% RH from 02:00 LST to 10:00 LST, gradually decreasing to around 20% RH after 11:00 LST. The MAE of GY-WRF for Stations 3 and 4 was relatively stable, generally maintaining around 15% RH.
4.3. Wind analysis

Wind direction analysis. The analysis of wind direction forecasts for each station revealed significant differences (Fig. 3). Generally, the wind direction forecast stability of GRAPES was better than that of GY-WRF for Stations 1 and 2, while the forecast stability of Station 3 was comparable between the two models. The forecast stability of GY-WRF was better than that of GRAPES for Station 4.

For Station 1, GRAPES had a wind direction error of approximately 0° at night that gradually increased after sunrise and stabilized at around 40°. The MAE of GY-WRF at Station 1 gradually increased after nightfall, reaching a maximum at 23:00 LST, before gradually decreasing and remaining between 0-20° after sunrise. For Station 2, GRAPES had a stable MAE of 0-40°, while the MAE of GY-WRF at Station 2 was larger by 0-40° at night, gradually decreasing in the day and stabilizing at around 25-50° at 11:00 LST. For Station 3, the error trend of GRAPES and GY-WRF was similar, with the error of GRAPES reaching about -50° after nightfall and rapidly decreasing. From 23:00 LST to sunrise, the error of GRAPES stabilized at around 50°, while the error of GY-WRF stabilized at around 20°. After sunrise, the error of GRAPES changed dramatically, while the error of GY-WRF slowly became about -30°. For Station 4, the MAE of GY-WRF was relatively stable, maintaining between ±20°. The error of GRAPES gradually increased into the night, reaching about -90°, before gradually decreasing and turning positive.

For Station 1, the MAE of both products is negative after nightfall, gradually becoming positive, and then negative again after sunrise. However, the change in the GY-WRF model is moderate, while the GRAPES model shows a severe increase in the negative phase. For Station 2, the MAE of both products is relatively stable, with the GY-WRF model maintaining an MAE of approximately ±1 m/s and the GRAPES model having an MAE that is approximately 2 m/s smaller. For Stations 3 and 4, the MAE of the GY-WRF model gradually decreases from the negative phase after nightfall and remains between -1 and 0 m/s, while the GRAPES model exhibits an MAE that is 2-4 m/s smaller than that of the GY-WRF model.

Wind speed analysis. The wind speed forecast for each station shows marked differences, with the variation trend of the mean absolute error (MAE) between the two products being similar (Fig. 3). The prediction stability of the GY-WRF and GRAPES models for Station 1 is comparable, while the GY-WRF model exhibits better stability for Stations 2, 3, and 4.

For Station 1, the predictions of both products are within 2 m/s after nightfall, gradually becoming 4 m/s smaller than that of the GY-WRF model. At Station 2, both the lowest and highest temperatures are similar to those of the GRAPES model. At Station 3, the GY-WRF system had a good prediction of the lowest temperature, while the forecast of the maximum temperature was delayed. In terms of the daily maximum and minimum temperature forecasts, the GY-WRF model showed a slight delay in the timing of its minimum temperature prediction. In terms of the diurnal variation of the temperature at each station, the GY-WRF model showed a better minimum temperature forecast but had a smaller maximum temperature prediction. At Station 3, the GY-WRF system had a good prediction of the lowest temperature, while the forecast of the highest temperature was similar to that of the GRAPES model. At Station 4, both the lowest and highest temperature forecasts were more accurate for the GY-WRF system.

In terms of the relative humidity forecast (Fig. 2), both the GY-WRF and GRAPES models were able to predict the trend of increasing humidity after nightfall and decreasing humidity after sunrise. The variation trend of the GY-WRF prediction was found to be similar to that of the observed data, while the GRAPES model exhibited a larger relative humidity prediction and greater diurnal variation. The wind speed forecast (Fig. 3) showed that the GY-WRF system was capable of roughly predicting the diurnal variation trend of wind speed at each station, however, the daily maximum and minimum wind speeds of the GY-WRF system did not exhibit as much variation as the observed values. On the other hand, the GRAPES model was found to have poor ability in predicting the diurnal variation of wind speed.

With regards to the wind direction forecast (Fig. 3), both the GRAPES and GY-WRF systems were able to predict the trend of wind direction change in the afternoon at stations 1 and 3. The GRAPES model was found to have good prediction ability in terms of the shifting trend of the wind in the afternoon at station 2, while the GY-WRF system demonstrated better ability in predicting the wind direction trend at night and the wind direction change in the morning at station 4.

4.4. Diurnal variation
5. Conclusion

The present study aims to evaluate the performance of the GY-WRF system and the GRAPES forecast product by comparing their results with observational data from four Automatic Weather Stations (AWSs) in the Danghe South Mountain region. The period of evaluation was March to April 2022, and the meteorological elements analyzed include temperature, relative humidity, wind speed, and wind direction. The results indicate that:

The GY-WRF system outperforms GRAPES in terms of its overall accuracy, as evidenced by the smaller Mean Absolute Error (MAE) for all elements at station 4 (4300 m). At station 2 (1800 m), the MAE for temperature, relative humidity, and wind speed is relatively small, but the MAE for wind direction is slightly larger. At stations 1 and 3, the MAE of temperature increased positively after night and negatively after sunrise, while the MAE of relative humidity showed a trend of decreasing after night and increasing after sunrise. The MAE of wind speed at station 3 was larger before and after night, while it was relatively stable in other periods. The MAE of wind direction at station 1 had a large negative deviation at night.

In comparison, the MAE of GRAPES to wind direction was small, especially for the wind direction of stations 1 and 2, which was relatively stable. The trend of MAE for wind speed was similar to that of GY-WRF, but the negative phase of the MAE was 2-4 m/s larger than that of GY-WRF. The temperature forecast for stations 1 and 3 was similar to the MAE of GY-WRF, with a smaller MAE at night and a larger MAE during the day. The MAE of relative humidity had more positive deviations than that of GY-WRF.

GY-WRF demonstrated a better ability to predict the diurnal variation of temperature at the four stations, with the occurrence time of maximum and minimum temperature being very close to the observed value, but the daily temperature range was not as large as the observed value. GRAPES provided a better minimum temperature forecast, but with a later occurrence time than the observation. Both GY-WRF and GRAPES were able to predict the trend of humidity increasing after nightfall and decreasing after sunrise.

GY-WRF was able to predict the diurnal variation of wind speed at the four stations, but the range of maximum and minimum wind speed was not as large as the observed data. GRAPES was a poor predictor of diurnal variations in wind speed. Both GRAPES and GY-WRF were able to predict the trend of wind direction conversion at each station.

In conclusion, the results of this study suggest that the GY-WRF system outperforms GRAPES in terms of its forecasting accuracy for the Danghe South Mountain region. However, due to the lack of radiosonde data in the region, this study only made a comparative analysis of surface meteorological elements. Further studies should be conducted to evaluate the ability of GY-WRF to forecast upper-air meteorological elements in this region.

References