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Verification of Mongolian Cyclone-Induced Snowstorm Model Forecast in Jilin Province, China

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Abstract

Situation field forecast and rainfall forecast in typical numerical forecast models including EC (The European Centre for Medium-Range Weather Forecasts), t639 (T639 Global Forecast System) and Japanese model were verified by set statistics and TS (Threat Score) scoring based on 8 cases of Mongolian cyclone-induced snowstorm in Jilin Province in this paper. As shown by the results, for the forecast of Mongolian cyclone location and intensity, EC has significantly higher accuracy than Japanese model and t639, and there is a high likelihood that it forecasts the southerly cyclone location, relatively fast movement and comparatively weak intensity within 72 hours; for snowfall forecast, Japanese model shows significantly higher accuracy than other models, especially it has obviously stronger ability to forecast the heavy rainfall above snowstorm than other models, while WRF model (The Weather Research and Forecasting Model) has strong forecast ability of normal snowfall; for normal snowfall, the 72-hour missing forecast rate is higher than false forecast rate in all the models.

Keywords

Mongolian Cyclone, Snowstorm, Numerical Forecast, Verification

1. Introduction

Snowstorm is one of the major meteorological disasters in winter in Jilin Province, which often brings serious influence on traffic, agricultural facilities and animal husbandry [1] [2]. In Jilin Province, snowstorm is usually attributed to frequently active Mongolian cyclone [3] [4], and the disastrous weather caused by it has large influence on agricultural production [5]. Numerical forecast is the basis for improving weather forecast accuracy, and the rapid development of meteorological modernization enriches numerical forecast products with each passing day [6]. Numerical forecast products provide reference for the daily forecast made by masses of forecasters, but they may cause some forecast errors [7] [8] since there are some errors in the physical process of numerical model initial values. The inspection of numerical forecast products is conducive to deepening the understanding of numerical model, so it is an effective way to use preferred numerical forecast products to improve weather forecast accuracy. Also, it can provide some reference for research on the explanative application of numerical forecast products.

Several common numerical forecast products' forecast ability was verified by setting statistics and TS scoring based on 8 cases of Mongolian cyclone-induced snowstorm in Jilin Province in this paper. In detail, situation field and rainfall forecast were verified, EC, t639 and Japanese model were verified by situation field forecast, and EC fine mesh, t639, German model, Japanese model and WRF were verified by rainfall forecast, so as to provide better reference for the application of numerical forecast products and the improvement of Mongolian cyclone-induced snowstorm forecast accuracy. T639 global mid-term numerical forecast model products with high mode resolution, reaching the global level of 30 km resolution, vertical resolution of 60 layers, the top of the model reached 0.1 hPa. The maximum temperature of the forecast for 240 hours, the elements include the pressure, the height of the potential, the temperature, the false adiabatic temperature/false equivalent bit temperature, the dew point temperature, the temperature dew point difference (or loss), the wind's u component, the wind v component, (Air pressure), relative vorticity, relative divergence, specific humidity d and so on. The EC (European Centre for Medium-Range Weather Forecasts Reanalysis) project resulted in a homogeneous data set describing the atmosphere over a time span of 15 years, from 1979 to 1993. To validate (part of) these data against independent observations we use the EC surface winds to drive the WAM wave model. The WRF model is a fully compressible, nonhydrostatic model (with a hydrostatic option). Its vertical coordinate is a terrain-following hydrostatic pressure coordinate. The grid staggering is the Arakawa C-grid. The model uses the Runge-Kutta 2nd and 3rd order time integration schemes and 2nd to 6th order advection schemes in both horizontal and vertical directions. It uses a time-split small step for acoustic and gravity-wave modes. The dynamics conserves scalar variables.

2. Result of Situation Field Verification

Mongolian cyclone location and intensity have an essential effect on precipitation region and intensity, and have great reference significance to the forecast of Mongolian cyclone-induced snowstorm. This paper verified the Mongolian cyclone location and intensity numerically forecasted by three models.

2.1. Mongolian Cyclone Location Verification

Figure 1 shows the verification result of the Mongolian cyclone location numerically forecasted by EC, Japanese model and t639. The three models show high accuracy for the 24-hour numerical forecast of cyclone location. In the longitudinal direction, Japanese model and t639 show a slightly higher accuracy than EC, and the accuracy is greater than 70%. In case of forecast bias, all of the three models put forward the location by a degree of longitude; in the latitudinal direction, the three models show an accuracy of less than 60%. In case of forecast bias, the models basically show southward deflection, but most errors are within a degree of latitude. For 48-hour cyclone location forecast, the three models show a higher accuracy in the longitudinal direction than in the latitudinal direction, and EC is obviously better than the rest two models since it shows a higher accuracy. In the longitudinal direction, in case of forecast bias, all of the three models show relative fastness, but most errors are within a degree of longitude;

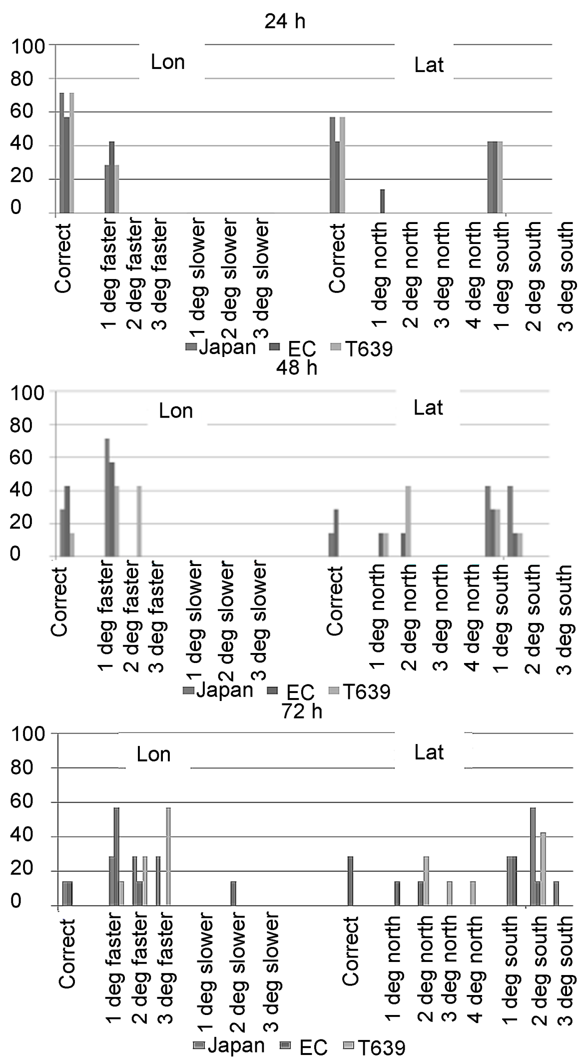

Figure 1. Verification results of the Mongolian cyclone location by numerical forecast.

in the latitudinal direction, the three models show that Mongolian cyclone is southerly. For 72-hour forecast of cyclone location, the models show an obviously lower accuracy compared to 48-hour forecast. In particular, EC shows an obviously higher forecast accuracy than Japanese model and t639, Mongolian cyclone significantly moves fast, the most obviously erroneous location is southerly by 3 degrees of longitude, southward deflection is forecasted highly possibly, and the maximum error expands to 3 degrees of longitude.

2.2. Mongolian Cyclone Intensity Verification

Figure 2 shows the verification result of the Mongolian cyclone intensity numerically forecasted by the models. The result shows that among the three time

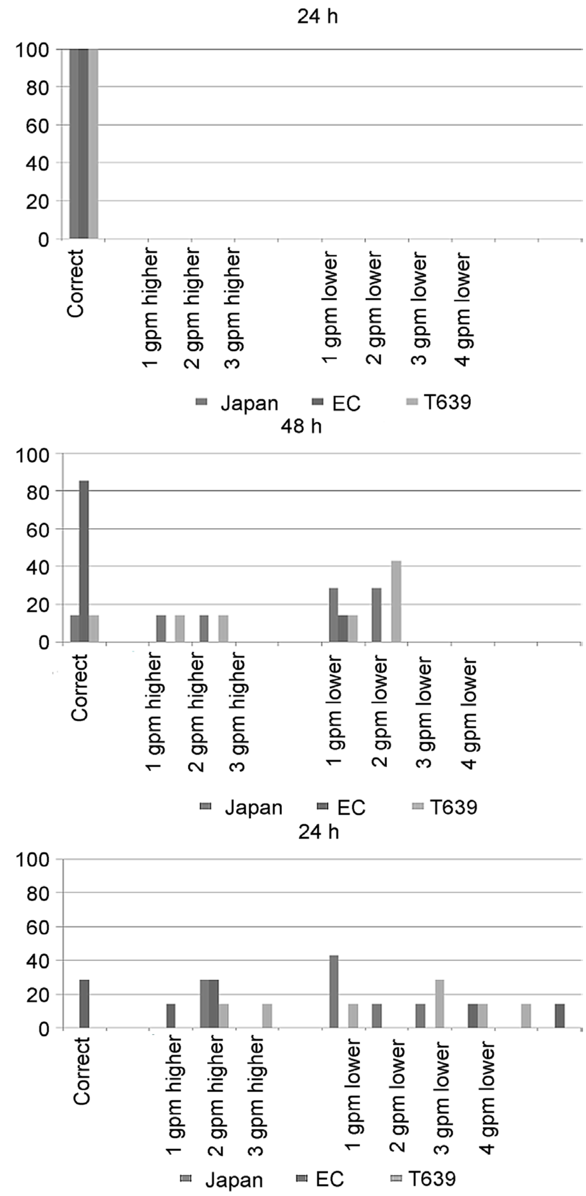

Figure 2. The verification results of the Mongolian cyclone intensity by numerical forecast.

levels, 24-hour forecast accuracy is obviously higher than the rest two and achieves the best forecast effect, with all the three models showing an accuracy of 100%, followed by 48-hour forecast accuracy which equals 85.7% in EC, while less than 15% in T639 and Japanese model, and 72-hour forecast accuracy is lowest, which only equals 28.6% in EC, while 0 in the rest two models; among the three models, EC achieves the best forecast effect, the 48 and 72-hour forecast accuracy in this model is obviously higher than in the rest two, and the reference significance is greatest. In Japanese model and T639, the lower the time level is, the higher the forecast accuracy is. In other words, 24-hour forecast accuracy has the greatest reference significance, while 48 and 72-hour forecast accuracy basically has no reference significance; for 48 and 72-hour forecast, EC foretells high intensity in 72 hours, while the rest models foretell low intensity, showing a weak regularity.

3. Snow Forecast Verification

3.1. Snow Forecast Grading Accuracy Verification and Rain or Shine Accuracy Verification

In snow forecast, the snowfall forecast by all the numerical models plays an important reference role. This paper verified a few common numerical forecast models of snowfall, including t639, EC fine mesh, German model, Japanese model and provincial WRF.

Figure 3 shows the verification result of the snow forecast accuracy of the models. The result shows that for the forecast accuracy of Mongolian cyclone-induced snowstorm, especially the rainfall more violent than snowstorm, Japanese model is obviously better than other models.

For 24-hour rainfall forecast, WRF shows the highest accuracy of common snowfall forecast, followed by Japan, but the accuracy is greater than 80% in both models; the accuracy is lowest in German model, which is less than 40%. Japanese model shows the highest forecast accuracy of snowstorm and above, which is greater than 50%, and has a very high reference value; the accuracy is less than 10% in other models, showing a big difference. WRF shows the highest forecast accuracy of rain or shine, which is greater than 90%, followed by Japanese model, which is nearly 90%; German model shows the lowest forecast accuracy, which is roughly 50%. For 24-hour forecast of rain or shine and common snowfall, WRF has stronger ability than other models; EC fine mesh does not have the ability to forecast any rainfall more violent than snowstorm.

For 48-hour rainfall forecast, Japanese model shows the highest forecast accuracy of common snowfall, followed by WRF, and the accuracy is greater than 80% in both models. Especially, Japanese model shows accuracy higher than that in 24 hours; German model shows the lowest accuracy, which is roughly 30%. Japan shows the highest accuracy of forecast of the rainfall above snowstorm, which is 48% or so, and has a high reference value to forecast. Other models show accuracy of below 5%. For the forecast of rain and shine, Japan shows the

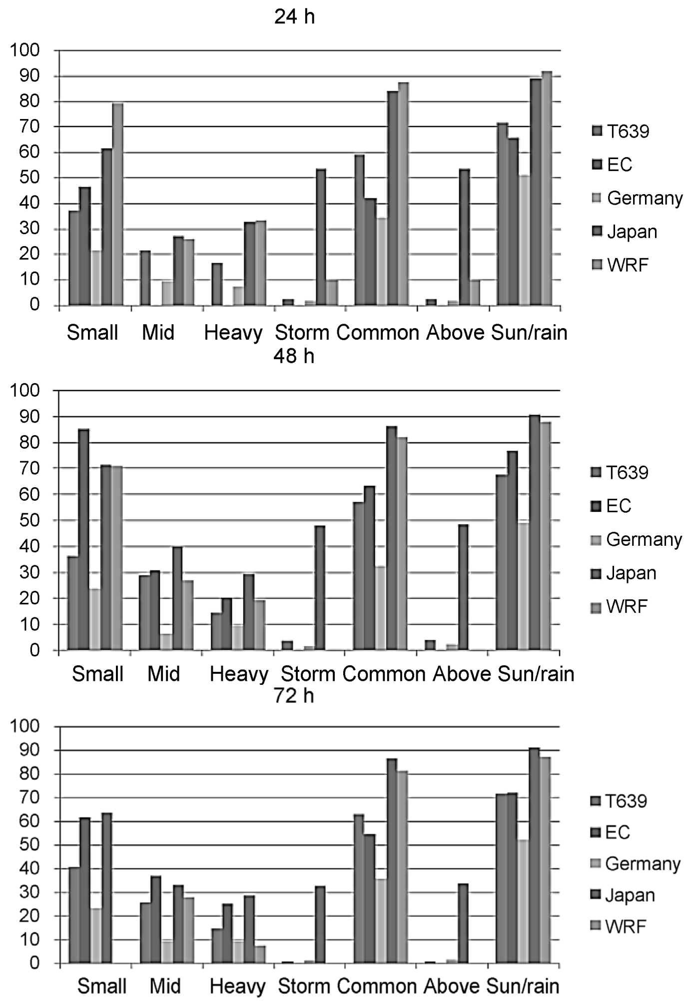

Figure 3. The verification results of the snow forecast accuracy of the models.

highest accuracy which is greater than 90% and higher than in 24 hours, followed by WRF, which show accuracy of nearly 90%. German model shows the lowest accuracy, which is merely around 50%. Japan has better ability to forecast rain or shine, common snowfall and snowstorm in 48 hours than other models, so it has a high reference value to forecast. Particularly, the 48-hour forecast of rain or shine and common snowfall in this model is even more accurate than 24-hour forecast; WRF's ability to forecast rain or shine and common snowfall is next only to Japanese model's, so it also has a certain reference value to forecast; but WRF and EC fine mesh do not have the ability to forecast the rainfalls above snowstorm.

For 72-hour rainfall forecast, Japanese model shows the highest accuracy of forecast of common snowfall, followed by WRF, and the accuracy is greater than 80% in both models. Particularly, Japanese model shows accuracy higher than in 24 and 48 hours; German model shows the lowest accuracy which is roughly 35%, but higher than in 24 and 48 hours; for the forecast of the rainfalls above snowstorm, Japan shows the highest accuracy which is around 35%, and this has a high reference value to forecast; other models show accuracy below 5%. For the forecast of rain or shine, Japanese model shows the highest accuracy which is greater than 90% and higher than in 24 hours, followed by WRF, which shows accuracy approximately equal to 90%; German model shows the lowest accuracy, which is just around 50%. In 72 hours, Japanese model has better ability to forecast rain or shine, common snowfall and snowstorm than other models, and thereby has a high reference value to forecast. Particularly, the forecast of rain or shine and common snowfall is even more accurate than the 24 and 48-hour forecast, so it should be used more frequently in future; in terms of rain or shine and common snowfall forecast, WRF's ability is next only to Japanese model's, so it also has a reference value to forecast; but WRF and EC fine mesh do not have the ability to forecast any rainfall above snowstorm.

3.2. Verification of False Rainfall Forecast Ratio

Figure 4 shows the verification result of false snowfall forecast ratio under various

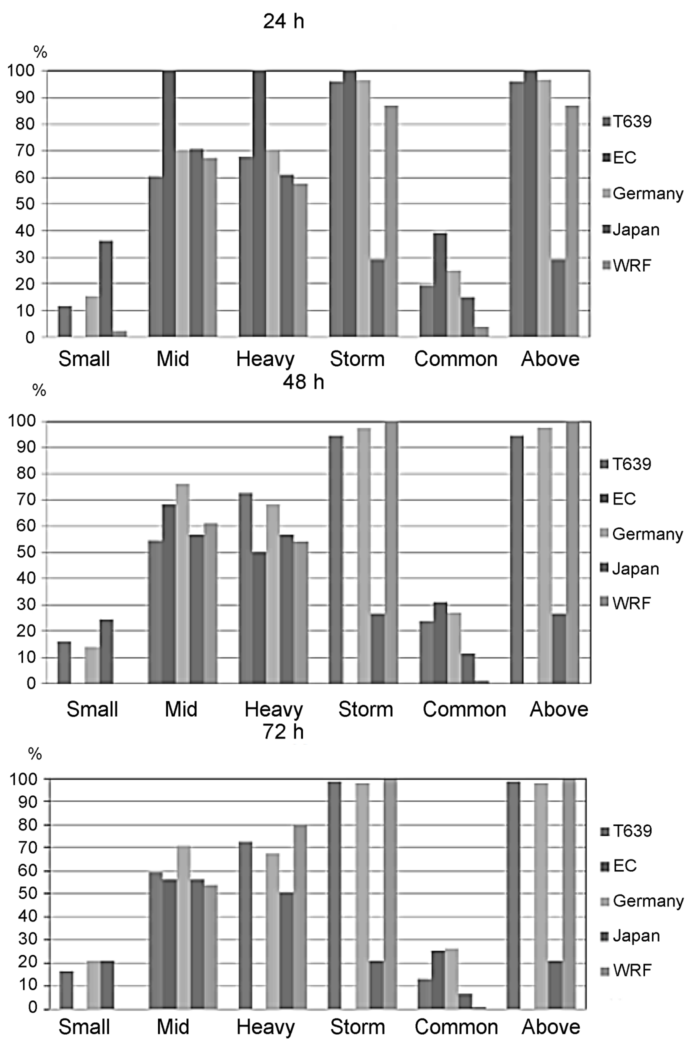

Figure 4. The verification result of false snowfall forecast ratio of models.

models. The result shows that for 24-hour forecast, EC fine mesh shows the highest false forecast ratio of common snowfall, which equals 40% or so, followed by German model, which shows a false forecast ratio of roughly 25%; WRF shows the lowest false forecast ratio, which is less than 5%. For the rainfalls above snowstorm, Japanese model shows a false forecast ratio of around 30%, while other models show a false forecast ratio of over 85%. For 24-hour forecast of common snowfall, WRF shows a false forecast ratio obviously lower than other models; for the forecast of the rainfalls above snowstorm, Japanese model shows the lowest false forecast ratio.

For 48-hour forecast of common snowfall, WRF shows the lowest false forecast ratio, which is only around 1%, followed by Japanese model, which shows false forecast ratio of around 10%; there isn't big difference between other models, which show a false forecast ratio ranging from 24% to 31%. For the forecast of the rainfalls above snowstorm, Japanese model shows a false forecast ratio of around 30%, while other models show a false forecast ratio of over 95%. For 48-hour forecast of common snowfall, WRF shows a false forecast ratio obviously lower than other models; Japanese model shows the lowest false forecast ratio when used to forecast the rainfalls above snowstorm.

For 72-hour forecast of common snowfall, WRF shows the lowest false forecast ratio, which is merely around 1%, followed by Japanese model, which shows a false forecast ratio of around 7%, and T639 shows a false forecast ratio of around 13%, while EC fine mesh and German model show a relatively high false forecast ratio, which is around 25%; for the forecast of the rainfalls above snowstorm, Japanese model shows the lowest false forecast ratio, which is around 20%, while other models show a false forecast ratio of over 95%. For 72-hour forecast of common snowfall, WRF shows a false forecast ratio obviously lower than other models, while Japanese model shows the lowest false forecast ratio for forecast of the rainfalls above snowstorm.

3.3. Verification of Missing Rainfall Forecast Ratio

Figure 5 shows the verification result of missing snowfall forecast ratio under various models. The result shows that for 24-hour forecast of common snowfall, Japanese model shows the lowest missing forecast ratio, which is around 1%, followed by WRF, which shows a missing forecast ratio of around 10%, while other models show a missing forecast ratio of over 30%, particularly German model shows a missing forecast ratio of over 60%. For the forecast of the rainfalls above snowstorm, Japanese model shows a missing forecast ratio of around 30%, while other models show a missing forecast ratio of over 70%. For 24-hour forecast of both common snowfall and snowstorm, Japanese model shows the lowest missing forecast ratio, followed by WRF, while German model shows the highest missing forecast ratio.

For 48-hour forecast of common snowfall, there is a big difference in missing forecast ratio. Japanese model shows the lowest missing forecast ratio, which is

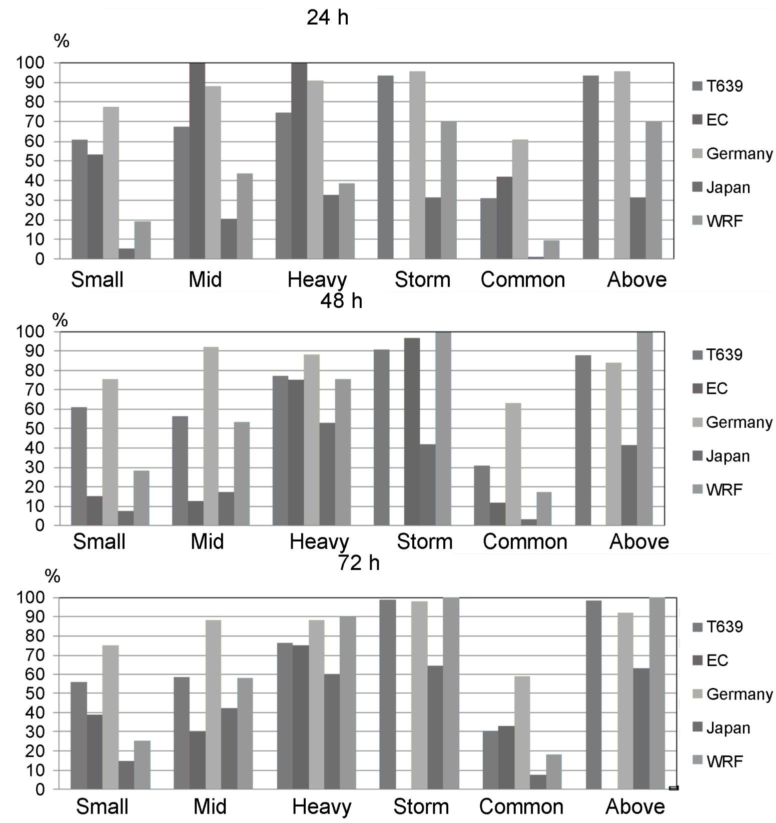

Figure 5. The verification result of missing snowfall forecast ratio of models.

around 3%, followed by European fine mesh, which is around 12%, while other models show a missing forecast ratio of over 17%, and German model shows a missing forecast of over 63%. For the forecast of snowstorm and above, Japanese model shows a missing forecast ratio of around 40%, while other models show a ratio of over 80%, particularly WRF show a ratio as high as 100%. For 48-hour forecast of common snowfall and snowstorm, Japanese model shows the lowest missing forecast ratio, while WRF shows a missing forecast ratio as high as 100%.

For 72-hour forecast of common snowfall, Japanese model shows the lowest missing forecast ratio of around 8%, followed by WRF, which shows a missing forecast ratio of around 18%, while other models show a missing forecast ratio of over 40%, particularly German model shows a ratio of around 60%. For the forecast of snowstorm and above, Japanese model shows a missing forecast ratio of around 63%, while other models show a missing forecast ratio of over 90%, particularly shows a missing forecast ratio as high as 100%. For 72-hour forecast of common snowfall and snowstorm, Japanese model shows the lowest missing forecast ratio, while WRF shows a ratio as high as 100%.

4. Summary

For the forecast of Mongolian cyclone location, overall, there is a great likelihood that the cyclone is forecasted to be south-deflected and moving fast. The accuracy is higher as model correction approaches, and 24-hour forecast is relatively accurate.

For the forecast of Mongolian cyclone intensity, overall, EC has obviously higher accuracy than Japanese model and t639, and that Japanese model and t639 have relatively low forecast accuracy in 72 hours, while EC has relatively high forecast accuracy. Now-casting is highly accurate in these three models, and 24-hour forecast is basically accurate.

For the forecast of snowfall, particularly snowstorm and above, Japanese model shows obviously higher accuracy than other models, and this has important reference significance to snowstorm falling area forecast and quantitative forecast.

For 72-hour forecast of common snowfall, all the models show a missing forecast ratio greater than the false forecast ratio, and for the forecast of snowstorm or above, all the models show a high false forecast ratio and missing forecast ratio. Overall, Japanese model shows the lowest false forecast ratio and missing forecast ratio for heavy rainfall forecast.

In conclusion, for different situations, the numerical forecast model shows different advantages and disadvantages. Therefore, we should select the appropriate numerical forecasting model for the specific situation, so as to provide a reference for the application of numerical forecasting products to improve the accuracy of Mongolian cyclone snowstorm forecasting.

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