Forecast of the Ice Disaster in Hunan Power Grid in Late January 2022 Using a High Resolution Global NWP Model

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Abstract. The icing of power grid has great influence on the safe and stable operation of power grid. Under the background of global warming, the frequency and duration of grid line icing events have increased. Under the influence of warm and humid air flow and special terrain in winter, it is very easy to have ice cover in Hunan Province. From the winter of 2021 to the spring of 2022, Hunan experienced five rounds of grid line icing, and the icing event lasted for more than three days totally. In this study, a global numeric weather forecast model with a resolution of 10 km is used to explore its prediction performance for the ice events at the end of January 2022 (27–29th January). The results show that it has a good prediction performance for the ice cover in Hunan, and the spatial distribution characteristics of the ice cover can be predicted 6 days in advance, although the intensity is slightly weak. A test also shows that the ability to predict heavy icing events can be improved by fusing icing observation information at the initial time of icing prediction, which emphasizes the importance of icing observation to icing prediction.

Keywords: grid line icing · numeric weather forecast model · prediction performance

1 Introduction

The safe and stable operation of power grid is an important foundation for high-quality life and economic development. In winter, due to the influence of cold and warm air, the wire icing events often occur. The cold air affecting China is mainly controlled by the Arctic polar vortex. Under the background of global warming, the polar vortex becomes unstable making it easier for the cold air to move southward, forming a cooling rain and snow freezing event in China. Due to the special horseshoe shaped geographical characteristics of Hunan province, which is surrounded by mountains in the East, South and West, the cold air in winter is easy to drive in from the flat area of Dongting Lake, bringing about a large-scale freezing disaster process. In recent years, Hunan Province has experienced many severe rain and snow freezing events, which have brought

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serious damage to the power grid [1, 2]. From late January to February 2022, Hunan was continuously affected by multiple rounds of grid line icing due to cold and warm air. The earliest two occurred from January 24–25th to January 27–29th.

Numerical weather forecasting model is an important tool for forecasting weather and extreme events. Numerical weather forecasting needs a lot of computing and storage resources. In recent years, with the development of supercomputers, the resolution of numerical models has increased from hundreds of kilometers to ten kilometers or even higher, and the prediction ability of numerical models has been gradually improved [3–5]. The numerical prediction model includes a variety of physical parameterization schemes that can describe the atmospheric movement process, and forecasts the temperature, precipitation, cloud water content, etc., which provides the possibility for the prediction of transmission line icing.

In this study, we evaluated the forecast performance of the ice disaster in Hunan power grid in late January 2022 using a high resolution global NWP model with a 10-km resolution. The remainder of the paper is organized as follows: Sect. 2 describes the ECMWF model used in this study. Section 3 describes the key features if grid line icing in late January 2022 in Hunan. Section 4 analysis the prediction performance for the ice disaster in Hunan power grid in late January 2022. A summary of our key findings and further discussion are provided in Sect. 5.

2 Model and Datasets

2.1 Model

The model data used in this study is from European Centre for Medium-Range Weather Forecasts (ECMWF) Integrated Forecasting System (IFS) High-Resolution Operational Forecasts [6]. The ECMWF Integrated Forecasting System (IFS) consists of several components, which include an atmospheric model, an ocean wave model, an ocean model, a land surface model, a data analysis system, and perturbation techniques for generation of the ensembles. Many studies show that ECMWF IFS has good prediction ability for some key weather systems (e.g. Arctic polar vortex and subtropical high), thus has been widely used in many Weather Forecast Department. The resolution of the ECMWF IFS datasets is about 10-km used in this study.

2.2 Datasets

To compare the model's results of the ice disaster in Hunan power grid in January 2022, the observed line icing data are collected from the intelligent analysis and control platform for power grid operation inspection of Hunan, with a daily frequency. To analysis the model's results of the precipitation and temperature, the observed precipitation data and temperature data from China Meteorological Administration (CMA) are used in our study.

3 Observed of Grid Line Icing Features in Hunan Province During Late January 2022

The grid line ice cover in Hunan province mainly began at the late of January 2022. As shown in Table 1, the line ice cover was observed at 70 stations during January 24–25th. Among them, about 59 sites (88% of total) were lightly (icing thickness less than 10 mm) covered with ice, 8 sites (12% of total) were moderately (icing thickness less than 20 mm while higher than 10 mm) covered with ice, and no sites are severe (icing thickness higher than 20 mm) icing. The icing became more severe on January 27–29th. The line ice cover was observed at 461 stations during January 27–29th. Among them, about 375 sites (81% of total) were lightly (icing thickness less than 10 mm) covered with ice, 76 sites (16% of total) were moderately (icing thickness less than 20 mm while higher than 10 mm) covered with ice, and 10 sites (3% of total) are severe (icing thickness higher than 20 mm) icing.

Table 1. The grid line icing sites in Hunan province during 24–25th and 27–29th January 2022.

Icing thickness	Number of sites (24–25th January)	Number of sites (27–29th January)
$0.1 \leq x < 2$	26	133
$2 \leq x < 5$	29	162
$5 \leq x < 10$	4	80
$10 \leq x < 20$	8	76
$20 \leq x < 30$	0	10
total	67	461

Figure 1 shows geographical distribution characteristics of minimum temperature, precipitation as well as grid line icing in Hunan Province on 24–25th January and 27–29th January of 2022 in observation data. During 24–25th January, the minimum temperature is lower in the north of Hunan Province, which is about 2–4 °C, while higher in the south of Hunan Province, which is higher than 4 °C and can up to 10 °C (south of Yongzhou and Chenzhou city).One thing to keep in mind is that the meteorological observation stations are usually located in urban or suburban areas, while the grid lines prone to icing are mainly concentrated in mountainous areas, of which the temperature is often 3–4 °C lower than that in urban or suburban areas. Thus, the temperature in mountainous areas may be below 0 °C when the temperature is 2–4 °C in urban or suburban areas. A lower temperature will make it more likely to freeze in the north of Hunan Province. As is show in Fig. 1, the icing area are mainly locate in the center and northwest of Hunan province 24–25th January.

With the activity of cold air, Hunan province experienced further cooling. Compared with that on 24–25th January, the temperature in much low on 27–29th January. The minimum temperature is lower in the north of Hunan Province, which is less than 0 °C, while higher in the south of Hunan Province, which is about 2–6 °C. The icing area

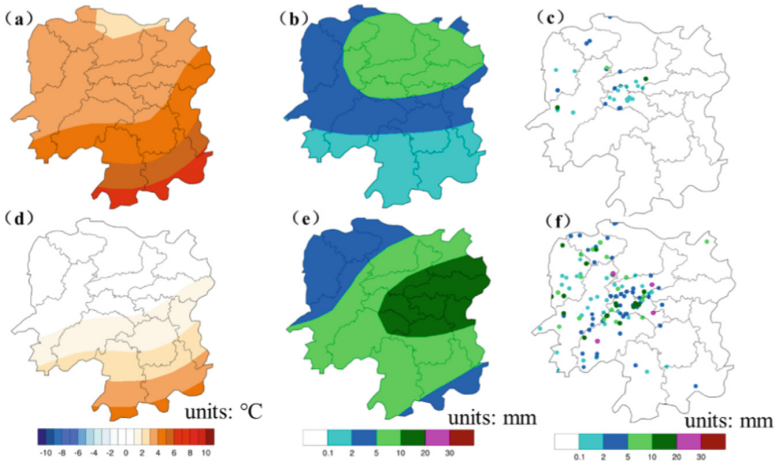

Fig. 1. Geographical distribution characteristics of minimum temperature (a and d), precipitation (b and e) as well as grid line icing (c and f) in Hunan Province on 24–25th (up row) and 27–29th (down row) January of 2022 in observation data.

extend to the southwest of Hunan province on 27–29th January. Also, some sites in the center (Yiyang city) and southwest (Hengyang city) of Hunan Province occurs severe icing.

4 Forecast of Grid Line Icing Using a 10-km NWP Model

This study is mainly aimed at the assessment of the icing process on 27–29th January, because the icing is more serious compared with that on 24–25th January. In order to comprehensively evaluate the performance of ECMWF IFS model, temperature, precipitation and icing are evaluated in this study. The temperature and precipitation are directly predicted by the model, while the icing are diagnosed by the meteorological parameters. Since ECMWF IFS can provide the forecast data of the next 10 days at the longest, we have given the results of icing process with different leading time in this study. For example, L1D is the forecast one day in advance, which means the forecast of January 29th is made on January 28th; L2D is the forecast two day in advance, which means the forecast of January 29th is made on January 27th, and the like.

Figure 2 shows the geographical distribution characteristics of minimum temperature in Hunan Province on 29th January of 2022 predicted by ECMWF IFS with different leading time. The result shows that ECMWF IFS has good simulation ability for temperature and can reproduce the characteristics of low temperature in the north and high temperature in the south, expect that the predicted temperature is lower than that in observations. The minimum temperature is lower in the north of Hunan Province, which is less than 0 °C (and less than −2 °C in northwest of Hunan Province), while higher in the south of Hunan Province, which is about 2–3 °C. Also, the temperature prediction results of the numerical model have high similarity 1–4 days in advance (the spatial correlation coefficient of which exceeds 0.83), and the similarity can be maintained 6 days in advance.

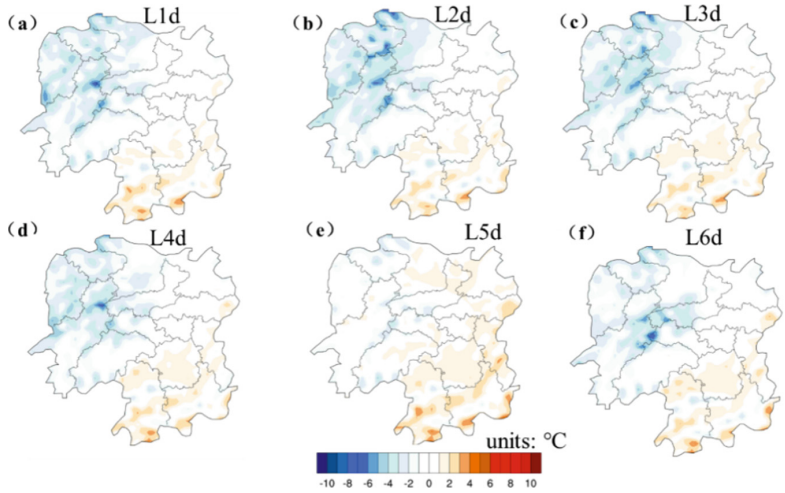

Fig. 2. Geographical distribution characteristics of minimum temperature in Hunan Province on 29th January of 2022 predicted by ECMWF IFS with different leading time.

Figure 3 shows the geographical distribution characteristics of precipitation in Hunan Province on 29th January of 2022 predicted by ECMWF IFS with different leading time. The result shows that The predicted precipitation amount in ECMWF IFS is larger southwest to northeast of Hunan province, which is larger than 20 mm, while smaller in the northwest and southeast of Hunan province, which is smaller than 10 mm. Also, the precipitation prediction results of the numerical model have high similarity 1–4 days in advance (the spatial correlation coefficient of which exceeds 0.8), and the similarity can be maintained 6 days in advance. Compared with that in observation, the intensity of precipitation is relatively strong. The maximum precipitation intensity during observation is less than 10 mm, which is about half of the predicted precipitation amount.

Figure 4 shows the geographical distribution characteristics of grid line icing in Hunan Province on 29th January of 2022 predicted by ECMWF IFS with different leading time. The result shows that ECMWF IFS has good simulation ability for grid line icing prediction and can reproduce the geographical characteristics of icing. For example, the icing is more serious in Southwest Hunan and central Hunan, of which the maximum ice thickness is more than 10 mm. While the ice thickness in southern Hunan is less than 5mm, which is consistent with the observation. Also, the grid line icing prediction results of the numerical model have high similarity 1–4 days in advance (the spatial correlation coefficient of which exceeds 0.83), and the similarity can be maintained 6 days in advance.

Compared with that in observation, the maximum icing thickness is relatively small. The maximum icing thickness is larger than 20 mm (Yiyang city and Hengyang city), which are all missed in all 6 day forecast. This is because that the precipitation in the numerical model is cumulative precipitation. At the beginning of all the forecast, the precipitation in the numerical model is zero, so the ice thickness calculated at the initial time is zero, which may be different from the actual observations. In order to improve

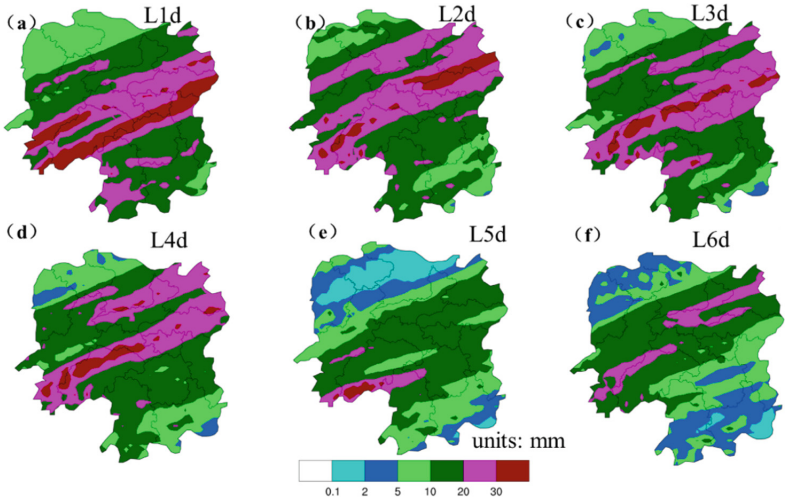

Fig. 3. Geographical distribution characteristics of precipitation in Hunan Province on 29th January of 2022 predicted by ECMWF IFS with different leading time.

the prediction performance of the model, we try to combine the observed ice thickness into the initial predicted icing value of the numerical model to make it consistent with the observation. As the icing observation on January 25th is relatively complete, we use the prediction on January 25th for analysis. As is shown in Fig. 5, the maximum icing thickness is larger than 20 mm in Yiyang city of Hunan province, which is consistent as that in observations. This indicates that the fusion of observed icing information in the prediction can help to improve the prediction of severe icing events.

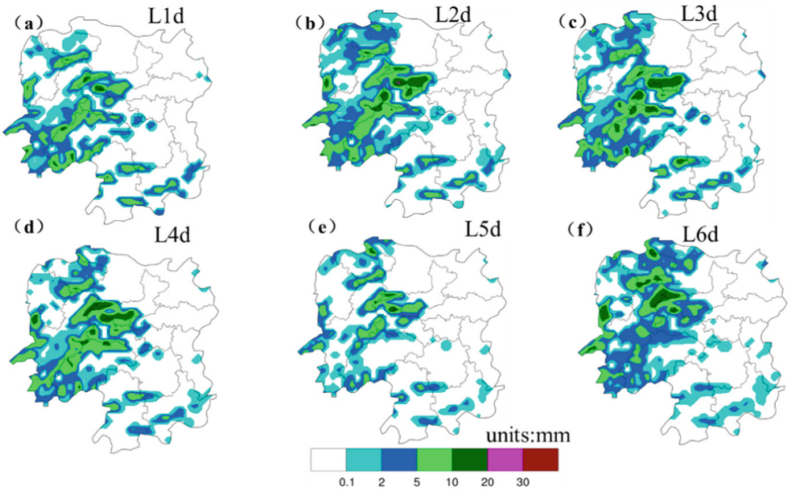

Fig. 4. Geographical distribution characteristics of icing in Hunan Province on 29th January of 2022 predicted by ECMWF IFS with different leading time.

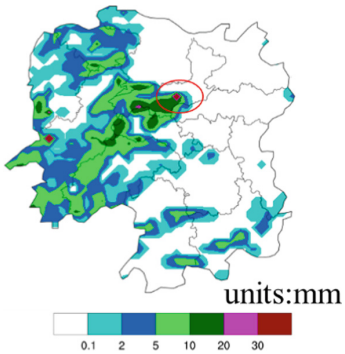

Fig. 5. Geographical distribution characteristics of icing in Hunan Province on 29th January of 2022 predicted by ECMWF IFS from 25th January of 2022 with observed icing data combined.

5 Conclusions and Discussions

In this study, ECMWF IFS data with a resolution of 10km is used to explore its prediction performance for the ice events at the end of January 2022 (27–29thJanuare). The results show that it has a good prediction performance for the ice cover in Hunan, and the spatial distribution characteristics of the ice cover can be predicted 6 days in advance, although the intensity is slightly weak. A test also shows that the ability to predict heavy icing events can be improved by fusing icing observation information at the initial time of icing prediction, which emphasizes the importance of icing observation to icing prediction. The prediction of grid line icing on a longer time scale means that we can have enough time to carry out anti-ice preparation. Therefore, we will evaluate the prediction ability of the numerical model for grid line icing on a longer time scale (such as sub-seasonal to seasonal prediction) in the future.

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