2023 IEEE Sustainable Power and Energy Conference (iSPEC) | 979-8-3503-2269-9/23/$31.00 ©2023 IEEE | DOI: 10.1109/iSPEC58282.2023.10402898

Analysis of Forecast Bias Characteristics of Weather Model Forecast for Multiple Types of Energy Stations

Siqiu Zhang[1], Qiushi Wen[2]

***Abstract*—Forecasts of key weather elements for multi-type new energy stations are generally based on semi-daily updated regional forecast results, which are difficult to satisfy the demands of making equipment shutdown plans for multi-type stations. The author uses the hourly-updated numerical forecasting products from CMA-GD series to output fine forecasting data of each physical value for the interested weather stations. At the same time, deviations of fine forecasting data for each weather station are classified and analyzed. The results show that the deviation characteristics of fine forecasting from the terrain-following numerical model are different, and the highest bias is from wind speed forecasting, which can be considered as the key forecasting bias element. The statistical analysis results from this paper is helpful for producing fine weather forecast for a specific energy-station.**

***Index Terms*—CMA-GD model, wind speed forecast, deviation analysis**

I. INTRODUCTION

IN order to realize the national strategy of 'dual carbon peaking', in past few years, many new energy stations have been built and developed in northern area and southern coastal area in China (Zou et al., 2021). New energy resources such as photovoltaics and wind power, are abundant in Southern China due to the complicated territory. Various types of hilly areas are preferable when selecting site for many types of new energy station. Therefore, these new energy stations will need customized meteorological service, which provides fine weather forecast including interested elements for that specific energy stations (Li P , Gao X, Jiang J, 2022). However, it is difficult for conventional weather forecasting service to provide accurate and custom-made forecast for one single station while taking into account its local terrain condition. In most situation, a fine forecast for a specific station is obtained by interpolating numerical weather prediction (NWP) products. In this regard, research on merging regional Southern China NWP forecast data with the single-station forecast started many years ago. In 2006, some scholars improved the results of the regional numerical forecast by assimilating the single-station forecast data into model initial field (Ding WY, Wan QL, Min, 2006).

Forecast technology for individual station has also undergone some development and application. Wang Xue et al. used methods such as the closest method of terrain height and the closest method of terrain complexity on various numerical forecast products, to analyze forecasting bias of wind speed, temperature and humidity over selected multi-weather stations. And the results showed that different merge methods can all effectively reduce the bias of forecast attained by interpolating NWP products, but the improvement fluctuates greatly with season and valid time (Wang X, He XF, Sun ,2021). This shows that bias characteristics of element forecast of numerical model is a multi-correlation problem, and it is difficult to further reduce the model forecast bias by simply modeling the bias of the same elements. In recent years, specialized forecasting and deviation analysis have undergone great development. For example, in 2011, some scholars proposed a method of using a decision-making model to predict photovoltaic output. This method is able to directly predict the output of photovoltaic power plants, which is to build a model based on a single-type Markov chain and using historical power data of photovoltaic plants (Ming, Ding, and Ningbo, Xu, 2011). Relevant meteorological element forecast and geographical distribution elements can also be used in this kind of model.

This article analyzes the hourly forecast information of temperature and wind fields for multiple surface stations in south China Yangjiang area. The deviations of various metrological elements and of different stations are compared and analyzed, and the key deviations of meteorological element forecast are analyzed and sorted for each station. This article will be informative in developing meteorological element forecasting of multiple types of new energy station in specific terrain area.

1.Siqiu Zhang is from the Yangjiang Power Supply Bureau Guangdong Power Grid Co.,Ltd , Yangjiang, China (e-mail: 1123066187@ qq.com).

2.Qiushi Wen. is from Guangzhou Institute of Tropical and Marine Meteorology, Guangzhou, China (**corresponding author:** e-mail:wenqs@gd121.cn).

II. DATA AND METHODS

This study mainly utilizes forecasting data from February 1 to June 30, 2023 in the hourly forecasting data from the 3km-resolution South China operational NWP model (CMA-GD), and utilizes observation data corresponding to the valid time above to analyze the forecasting deviation characteristics.

CMA-GD model is a regional NWP model system independently developed by Guangzhou Institute of Tropical and Marine Meteorology, China Meteorological Administration (ITMM), and is put into operational application in the pan-South China region. First we got the hourly forecasting data for the next 72 hours, including sea level pressure, air temperature at 2 m above the earth's surface, and wind speed at 10 m the earth's surface valid. This is the first verification analysis of long term CMA-GD forecasting data in Yangjiang area. The observation data is obtained from multiple groups of national-weather-stations, representing different terrain features in the vicinity of Yangjiang power stations.

Error of forecasting data is measured by RMSE, which is defined as:

$$X_{RMSE} = \sqrt{\frac{\sum_{i=1}^{N}(X_{obs,i} - X_{model,i})^2}{N}}$$

That is, the square root of the mean value of the sum of squared deviations corresponding to the forecast and observation points. It usually is used to describe the overall deviation of forecasting quantity in a certain period of time. And at the same time, use RMSE/MEAN to expressed The ratio of the deviation in the physical dimension, and the comprehensive analysis of the above characteristics can be used to understand the most key forecast bias elements.

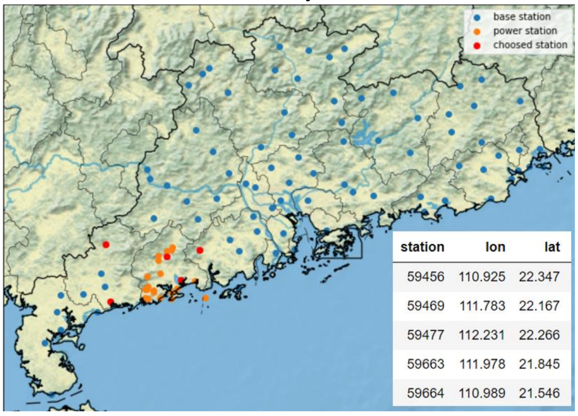

Figure 1 Geographical distribution of weather stations (red) and new energy stations (orange)

Figure 1 shows the distribution of national-level surface observation stations in Guangdong Province (blue dots), new energy stations in Yangjiang area(orange dots), and five high-quality and representative national-level surface observation stations (red dots) selected for this research. Stations numbered 59456, 59469, and 59477 represent a relatively flat terrain area, a narrow valley area, and a windward slope area at the foot of mountains respectively, so they are characterized by a more pronounced mountain climate; while stations numbered 59663 and 59664 are closest to the Yangjiang energy station area and judging from the map distribution these two stations are characterized by a pronounced coastal climate.

III. FORECAST DEVIATION ANALYSIS

	2023.2	2023.3	2023.4	2023.5	2023.6
TEMP.2M (RMSE/MEAN)	1.88 (0.64%)	2.24 (0.76%)	2.53 (0.85%)	2.16 (0.72%)	2.05 (0.68%)
WIND.10M (RMSE/MEAN)	1.32 (43.69%)	1.27 (47.44%)	1.54 (48.58%)	1.88 (47.89%)	1.89 (55.91%)
PRES.SEA (RMSE/MEAN)	1.13 (0.11%)	0.94 (0.09%)	1.06 (0.13%)	1.34 (0.11%)	0.97 (0.09%)

Table 1 Statistics forecast RMSE of 2 m temperature, 10 m wind speed and sea level pressure at all stations monthly averaged from February to June 2023

Table 1 shows the monthly average forecast RMSE of five stations in the Yangjiang area. RMSE slightly increases each month. Dividing the RMSE by the climate average, we can see that the 10 m wind speed RMSE of 1.5 - 1.6m/s has the highest proportion, reaching more than 43%, while the RMSE of 2 m temperature and sea level pressure both account for less than 1%, and the RMSE of sea level pressure is only about 0.1% of the forecast values.

Figure 2 shows the distribution of 2 m temperature observations and corresponding forecast trends by date on the horizontal axis. It can be clearly seen that during the period of February 13th -15th, there was an overall cooling process caused by an obvious strong cold wave intrusion at each station, and forecasts within 72 hours of the cooling trend of this process was very stable. The predicted cooling ranges are very close to the actual conditions, which shows that the model has a good performance in capturing such sharp changes in weather. At the same time, it can also be seen that the 72-hour forecasts of the warming process after 15th, are significantly earlier, and this causes a forecast bias for a period of time. The daily average forecast deviation gradually decreased since the weather background became stable after February 17th. Judging from the distribution of forecast data after April in the coastal stations 59663 and 59664, the temperature fluctuation trend is basically consistent with the observation. However, the forecast has a larger oscillation range than observations around daily cycle mean values. Forecast results vary insignificantly of the 24, 48, and 72 valid time forecast, but from mid-May to early June where part of daily lowest temperature forecast values are significantly lower than observations.

Overall, the model has good ability in forecasting temperature in each forecast period. Within the threshold of physical values fluctuating from 15 to 30 degrees Celsius, the average RMSE value remains below 1.6 degrees, which means the proportion of RMSE/MEAN is only about 3% .

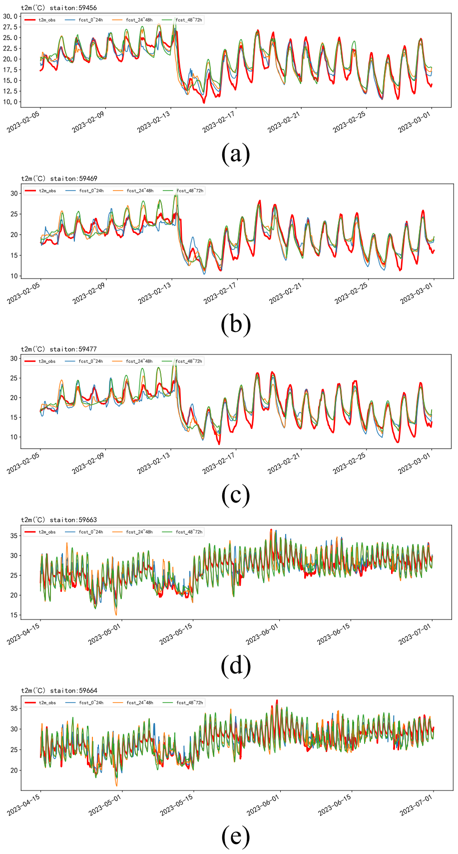

Figure 2 The 2 m temperature observation and forecast in dalliy cycle (unit: ℃)

However, the deviation characteristics of different physical values are different. Judging from the 10 m wind speed in Figure 3, the cooling process on February 13th did not bring about a sudden change in wind fields, and no obvious trend change in the forecast and observation distributions was detected. Higher wind speed forecasts are observed at the three mountain climatic stations in mid-February, especially the 24-hour forecast wind speed at station 59456 to most significant. The changing trends of wind speed forecasts at the other two coastal stations are much more stable due to the stable sea-land breeze circulation.

Sudden fluctuations in the extreme values of 10 m wind speed was observed 3 times at the 2 coastal stations, on April 28th, May 8th, and May 25th respectively, all due to largest typhoon wind circles passing by. But the model forecasts had no obvious response or lags greatly. This failure indicates that the model's forecast of near-surface wind speed lags behind when encountering large-scale weather systems like typhoon.

Generally speaking, the wind speed forecast deviation is greater than the temperature forecast deviation. Although the RMSE has been controlled to be around 1.6m/s, the average wind speed is about 2.5 -3.0m/s. In regard of observation, the deviation accounts for about ±45%, which is a relatively prominent key forecast deviation physical values. Forecast trend shows that the wind speed forecast is slightly over forecasted in some periods, and a few sudden changes in wind speed is lagging behind observation. Such deviation characteristics could be partly due to the modelling systematic deviation. Further research of effective deviation correction could be carried out in the future.

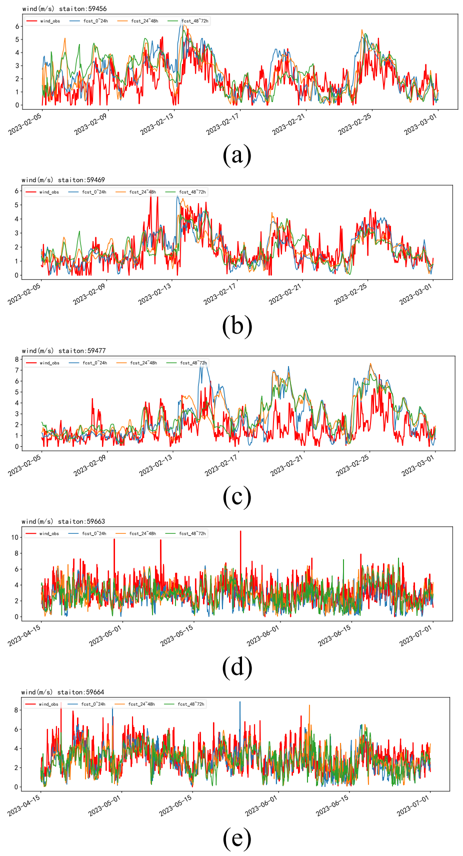

Figure 3 10 m wind speed observation and forecast in dalliy cycle (unit: m/s)

Next is the analysis of multiple types of RMSE distribution for wind speed. It can be seen from the figure 4 that the RMSE of the 3 stations 59456, 59469, and 59477 in the mountainous area is higher than these 2 stations near the coast. At the same time, the RMSE/MEAN curve also changes greatly with different stations. This shows that the uncertainty in wind speed and the difficulty of forecasting increases during season changing from spring to summer. However this phenomenon is not evident at the 2 coastal stations 59663 and 59664, indicating that the change of season in coastal area is relatively weaker than that in the mountainous area. Therefore wind speed forecast in coastal areas is more stable.

The RMSE of wind speed only increases slightly with forecast lead time within 0~72 hours. This yields that the incremental effect of systematic deviation in the model within this lead time period is not evident. However, the mean RMSE of wind speed forecast varies with different sites. RMSEs of wind speed at the 2 coastal stations remain under 1.5m/s, while in mountainous area, only station 59469 yields a small wind speed RMSE, which locates in a narrow valley area.

In general, the ratio of predicted wind speed RMSE to the climate mean in coastal area has remained below 50% for a long time, and the absolute value of RMSE has remained less than 1.5m/s, which yields that the numerical model has advantages in predicting near-surface wind speed in coastal areas compared with other areas, and its forecast results can provide effective information for the actual energy power generating work. It can be concluded that wind speed forecasting product in coastal area has broad application prospect.

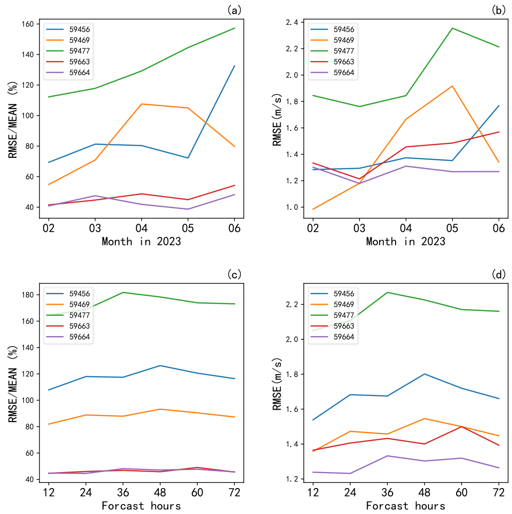

Figure 4 The RMSE/MEAN curve (first column) and the absolute RMSE values (second column) of the 10 m wind speed forecast with the monthly average (first row) and forecast hours (second row)

Conclusion

In this study, the CMA-GD regional NWP model data in the Yangjiang area from February to June 2023 are used to analyze and compare the characteristics of different forecast products:

1. The deviation of 10 m wind speed forecast has the largest proportion in the comparison with other physical values such as temperature and seal level pressure. And its proportion of RMSE over climate means may appear above 40%, which shows that wind speed can still be considered as the key forecast deviation of the numerical forecast model in Yangjiang area, even though the absolute value of the 10 m wind speed forecast deviation is only ±1.6m/s.

2. The forecast deviations of 2 m temperature and 10 m wind speed have a tendency to increase with each month, which reflects the natural feature of seasonal changes increasing the difficulty of model forecast. Meanwhile the model forecast has a relatively stable systematic deviation from 0 to 72 hours lead time.

3. Compared with stations in the mountainous area, the 2 stations along the coastal area are characterized by more stable forecast deviations with the month or forecast time, indicating that the seasonal changes in coastal area is weaker than that in mountainous area. So it can be considered that wind speed forecast product has broad application prospects in coastal areas.

Acknowledgment

This comparative study cannot be successfully carried out without the detailed observation data provided by the relevant staff of the new energy station in Yangjiang area, and the long-term operational forecast data from the CMA-GD model provided by relevant researchers, for which we would like to express our gratitude.

References

[1] Zou C N, Xiong B, Xue H, et al. The role of new energy in carbon neutral[J]. Petroleum Exploration and Development, 2021, 48(2): 411–420.
[2] Li P ,Gao X ,Jiang J , et al.Spatial and temporal patterns of solar radiation in China from 1957 to 2016[J].Sciences in Cold and Arid Regions,2022,14(01):68-78.
[3] Ding WY,Wan QL, Min JH et al.Variational Assimilation of Automatic Weather Stations Rainfall in Convective Systems and its impact on Rain Forecast [J]. Journal of Atmospheric science,2006(02):317-326.
[4] Wang X,He XF,Sun YH et al. Research on Refined Station Forecasting Technology Based on Numerical Prediction and Muti-method Integration [J]. Meteorological and Environmental Sciences,2021,44(05):87-95.DOI:10.16765/j.cnki.1673-7148.2021.05.012.
[5] Le, Ge, and Wenwei, Lu, and Xiaodong, Yuan, et al. (2018) “Power prediction of photovoltaic power station based on improved similarity day and BC-SVM.” Journal of Solar Energy 39 (3): 775-782.
[6] Ming, Ding, and Ningzhou, Xu. (2011) “A method to forecast short-term output power of photovoltaic generation system based on Markov chain.” Power System Technology 35 (1): 152-157.
[7] Wang XJ,Shi GP, Zou ZQ et al.Revision of solar radiation product ERA5 based on forest algorithm [J]. Journal of Remote Sensing of Natural Resources,2022,34(02):105-111.