Response to reviewer comments

Dear Editor and Reviewer,

We are very grateful for your time and valuable comments, which we found very helpful. We have addressed questions and comments raised by the reviewer in the revised manuscript with tracked changes. Please find our point-by-point response (in blue font) to the comments below. We hope our revisions have properly addressed your concerns.

Thanks again for your time.

Sincerely,
The authors

Reviewer 4

General comments

The manuscript "A robust error correction method for numerical weather prediction wind speed based on Bayesian optimization, Variational Mode Decomposition, Principal Component Analysis, and Random Forest: VMD-PCA-RF (version 1.0.0)" by Zhou et al. introduces a hybrid method for correcting 10-meter wind speed predicted by WRF. The authors compare the performance of two sets of experiments with different predictors and report the best model for wind speed correction during December 2021 to January 2022. In general, this manuscript fits the scope of the Geoscientific Model Development. However, after reading the manuscript, I find it still has a few major flaws. Firstly, the descriptions for the observation data and methods are unclear and ambiguous, and some citations should be implemented in the main text. Secondly, the information in the main text, figures, and tables is repeated. For example, the authors just simply report many statistics for model validation and comparison in Section 3, which are also showed in the tables. I would suggest the authors to summarize the key points and analyze the potential reasons for the differences in the main text rather than listing the statistics, which can be better for readers' understanding. Finally, the writing and figures should be improved. Some figures should be combined, e.g., Figure 1 and 2. The captions for some figures are very simple, e.g., Figure 5, Figure6, and Figure 10. The labels and legends might be enlarged for a better readability. This reviewer requests major revisions listed below.
Response: Thank you very much for your recognition and encouragement of our work, we will further modify it according to your comments.

Specific comments

1. P5, Section 2.1: The description of the observation data is unclear. I would suggest the authors to give more details on this dataset. What are the data sources for the ground and satellite data? How do the authors process the data? How do the authors

interpolate the data across 410 sites? Please cite the data sources and related techniques.

Response: Thank you very much for pointing this out.

The observed data comes from the China Meteorological Administration land data assimilation system (CLDAS-V2.0) real-time product data set (https://data.cma.cn/data/cdcdetail/dataCode/NAFP_CLDAS2.0_RT.html).

These data are processed by the China Meteorological Public Service Center to equivalent latitude and longitude grid scale, covering a geographical range of 15-32.97°N and 94-120.97°E. The spatial resolution of the grid is 0.03° × 0.03° (3km by 3km) and the temporal resolution is 1 hour. China Meteorological Public Service Center applied the nearest neighbor interpolation for precipitation, and bilinear interpolation for the other four meteorological elements with downscaling from 3km to 410 sites.

"Combining the surface observations with satellite data" and "exhibits superior quality compared to other products" are CLDAS-V2.0 official website documentation description results.

To clarify this and we have rewritten the Data part into the following text:

"*The observed data comes from the China Meteorological Administration land data assimilation system (CLDAS-V2.0) real-time product data set (https://data.cma.cn/data/cdcdetail/dataCode/NAFP_CLDAS2.0_RT.html).*
According to the description of the documents on the official website, The dataset is constructed through the integration of multiple sources, including ground and satellite data, and is refined using advanced techniques such as multi-grid variational assimilation, physical inversion, and terrain correction. This dataset exhibits superior quality in comparison to other products, offering higher spatial and temporal resolutions.

The target observation data includes 2-m air temperature, 2-m specific humidity, 10-meter wind speed, surface pressure, and precipitation. These data are processed by the China Meteorological Public Service Center to equivalent latitude and longitude grid scale, covering a geographical range of 15-32.97°N and 94-120.97°E. The spatial resolution of the grid is 0.03° × 0.03° (3km by 3km) and the temporal resolution is 1 hour.

China Meteorological Public Service Center applied the nearest neighbor interpolation for precipitation, and bilinear interpolation for the other four meteorological elements with downscaling from 3km to 410 sites. We select the 10-meter wind speed data of 410 sites, as illustrated in Fig. 1."

2. P6, Line 155: Do the authors consider the spin-up time for WRF simulations?

Response: Thank you very much for pointing this out.

Using the WRF model in combination with daily GFS data resolution of 0.25° × 0.25°, the GFS data updates at 06:00 UTC and generates forecasting every 3 hours for a total duration of 90 hours. We selected the 24-h forecasting data from the WRF-resulted file after a spin-up time of 18 hours.

We've updated section 2.2.1 to the following text:

"*The WRF 4.2 model (Skamarock et al., 2021), developed by the National Center for Atmospheric Research (NCAR), represents a new generation of mesoscale numerical models with numerous applications in research forecasting. When forecasting meteorological elements, the WRF model normally uses the GFS data developed by the National Centers for Environmental Prediction (NCEP). Using the WRF model in combination with daily GFS data resolution of 0.25° × 0.25°, the GFS data updates at 06:00 UTC and generates forecasting every 3 hours for a total duration of 90 hours. We selected the 24-h forecasting data from the WRF-resulted file after a spin-up time of 18 hours. The GFS data as the initial field and lateral boundary conditions for the WRF model. Surface static data, such as terrain, soil data, and vegetation coverage, are derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite with a resolution of 15 seconds (approximately 500 meters). Incorporating a two-layer grid nesting configuration, the forecast area is illustrated in Fig. 1. The WRF configuration process is detailed in Table 1. Given that the time scale of the meteorological station data in the study area is 1 hour, the forecast data time interval of the WRF model is also set to 1 hour. As a widely used numerical weather forecast model, the WRF model is suitable for weather studies from a few meters to several thousand kilometers. Therefore, this paper uses the WRF model to predict 10-meter wind speed as the input factor for the error correction model (Xu et al., 2021).*"

3. P6, Line 162-166: Please add the citations for these WRF parameterizations and schemes.

Response: Thank you very much for pointing this out. We have deleted Line 162-166 in section 2.2.1, and we have added the citations in Table 1.

Table 1: WRF configuration scheme

Model (Version)	WRF (V4.2)	
Domains	D1	D2
Horizontal grid points	600*500	967*535
Δx (km)	9	3
Vertical layers	58	
Longwave radiation	RRTMG (Iacono et al., 2008)	
Shortwave radiation	RRTMG (Iacono et al., 2008)	
Land surface	Noah LSM (Chen et al., 1997)	
Surface layer	MYJ (Janjić, 1994)	
Microphysics	Thompson (Thompson et al., 2008)	
Boundary layer	MYJ (Janjić, 1994)	
Cumulus	Tiedtke (Tiedtke, 1989; Zhang et al., 2011)	

Chen, F., Janjić, Z., and Mitchell, K.: Impact of Atmospheric Surface-layer

Parameterizations in the new Land-surface Scheme of the NCEP Mesoscale Eta Model, Boundary-Layer Meteorology, 85, 391 – 421, https://doi.org/10.1023/A:1000531001463, 1997.

Iacono, M. J., Delamere, J. S., Mlawer, E. J., Shephard, M. W., Clough, S. A., and Collins, W. D.: Radiative forcing by long-lived greenhouse gases: Calculations with the AER radiative transfer models, J. Geophys. Res., 113, D13103, https://doi.org/10.1029/2008JD009944, 2008.

Janjić, Z. I.: The Step-Mountain Eta Coordinate Model: Further Developments of the Convection, Viscous Sublayer, and Turbulence Closure Schemes, Monthly Weather Review, 122, 927 – 945, https://doi.org/10.1175/1520-0493(1994)122<0927:TSMECM>2.0.CO;2, 1994.

Thompson, G., Field, P. R., Rasmussen, R. M., and Hall, W. D.: Explicit Forecasts of Winter Precipitation Using an Improved Bulk Microphysics Scheme. Part II: Implementation of a New Snow Parameterization, Monthly Weather Review, 136, 5095–5115, https://doi.org/10.1175/2008MWR2387.1, 2008.

Tiedtke, M.: A Comprehensive Mass Flux Scheme for Cumulus Parameterization in Large-Scale Models, Monthly Weather Review, 117, 1779–1800, https://doi.org/10.1175/1520-0493(1989)117<1779:ACMFSF>2.0.CO;2, 1989.

Zhang, C., Wang, Y., and Hamilton, K.: Improved Representation of Boundary Layer Clouds over the Southeast Pacific in ARW-WRF Using a Modified Tiedtke Cumulus Parameterization Scheme*, Monthly Weather Review, 139, 3489–3513, https://doi.org/10.1175/MWR-D-10-05091.1, 2011.

4. P5 and P7: Figure 1 and Figure 2 both show the terrain heights in the study region. What's the difference between the two figures? I would suggest the authors to combine the two figures.

Response: Many thanks for your suggestion. We have combined the two figures. The revised figure is shown in Fig. 1 below.

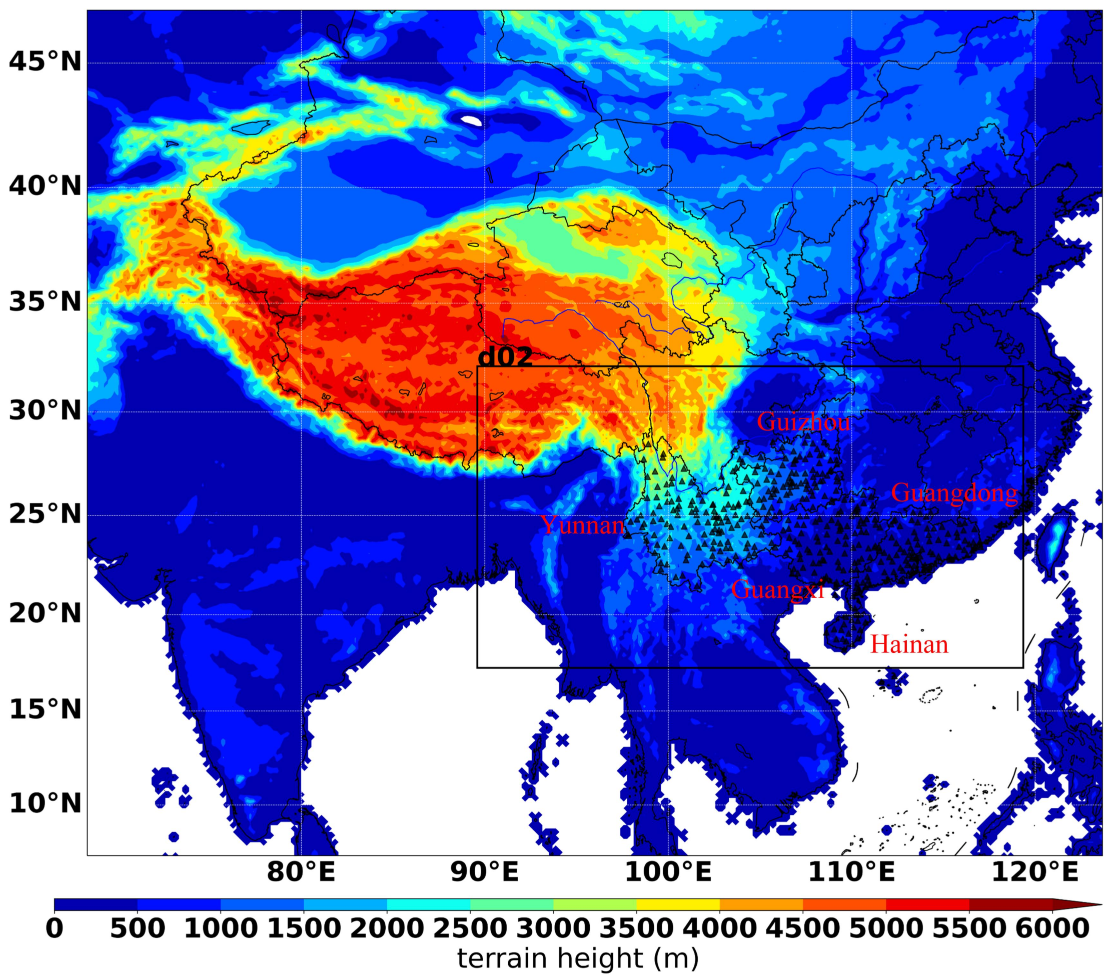

Figure 1: WRF model simulation area elevation diagram. (d02 represents the nested area of the second layer of the WRF model, and the black triangles represent the meteorological sites).

5. P10, Line 234: What's the criteria for the outliers?

Response: Thank you very much for your question. We cooperate with China Meteorological Public Service Center through the project (the second batch of service public bidding projects for EHV transmission companies in 2022 (2022-FW-2-ZB)).

The 3-km and 410-sites observation data transmitted by China Meteorological Public Service Center was interrupted or incomplete sometimes. Therefore, we need to eliminate the corresponding time point of the observation data when matching the WRF-predicted and observation data.

We have corrected line 234 to the following text: "*The time points in the dataset where missing values are located are eliminated.*"

6. P10, Line 235: There are only 7 meteorological elements in Figure 4. Please add the missing one in Figure 7.

Response: Thank you very much for pointing this out.

The eight meteorological elements are altitude (HGT), 10-meter wind speed (WS_{10}), latitude (LAT), longitude (LON), surface pressure (PRS), relative humidity (RH), 2-meter temperature (T_2), and hourly precipitation (PRE). But we have not drawn the longitude, latitude and altitude, because the longitude, latitude and altitude are already shown in Fig. 1.

We have corrected line 235 to the following text: "*Experiment 1 (Experiment 2) standardize 12 sets of meteorological elements (8 sets of meteorological elements in Fig. 3, 9 IMF components, and three PCA vectors in Fig. 4) and wind speed observation data, respectively.*"

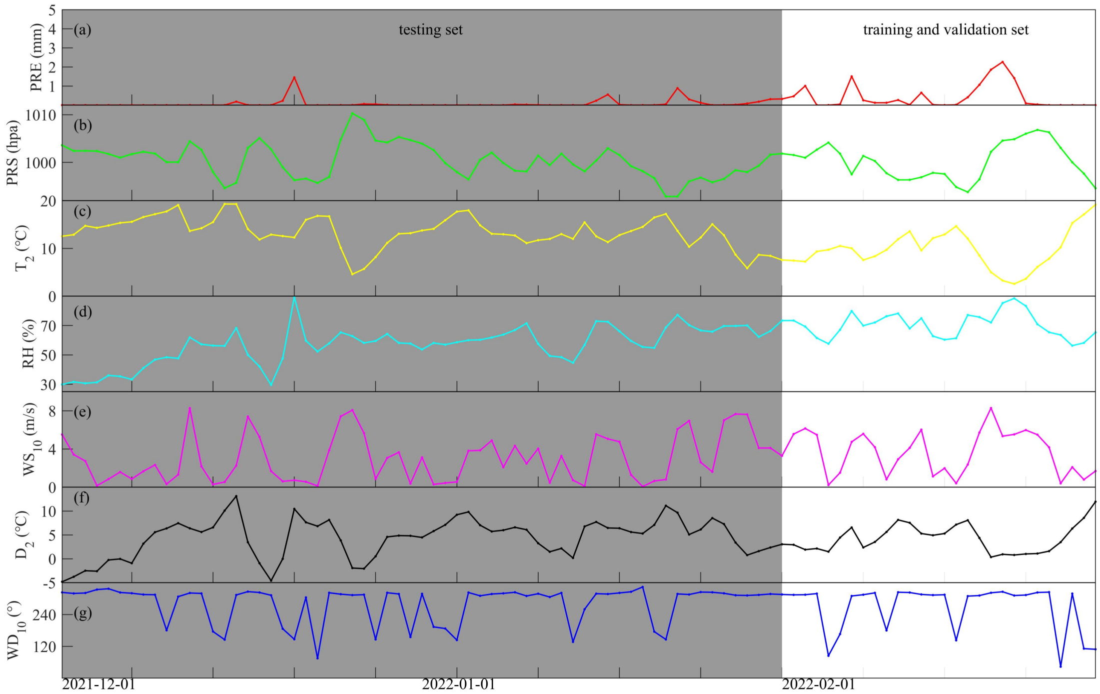

Figure 3: Daily average hourly rainfall (a), surface pressure (b), 2-meter temperature (c), 2-meter relative humidity (d), 10-meter wind speed (e), 2-meter dew point temperature (f), and 10-meter wind direction (g) which are located at Guangdong Lechang Station from December 1, 2021, to February 28, 2022. (February 2022 represents the training and verification sets, and December 2021 to January 2022 represents the testing set).

7. P10, Line 245: Why do the authors only use the data in February as training and validation dataset? I think there may be some seasonal variability for meteorological fields in the three months. I'm wondering if these machine learning models can successfully capture the relationship between the predictors and target variables in other two months.

Response: Thank you very much for your question.

We chose one of those months at random as the training set and the validation set. We did not only test in December and January, we tested over nearly a year and received a robust result (Fig. 13). We find that the VMD-PCA-RF evaluation indexes exhibit relative stability over nearly a year: correlation coefficient (R) is above 0.6, accuracy rate (FA) is above 85 %, mean absolute error (MAE) is below 0.6 m s^{-1}, root mean square error (RMSE) is below 0.8 m s^{-1}, relative mean absolute error (rMAE) is below 60 %, and relative root mean square error (rRMSE) is below 75 %.

In general, the other two months can also capture the relationship between the predictor and the target variable.

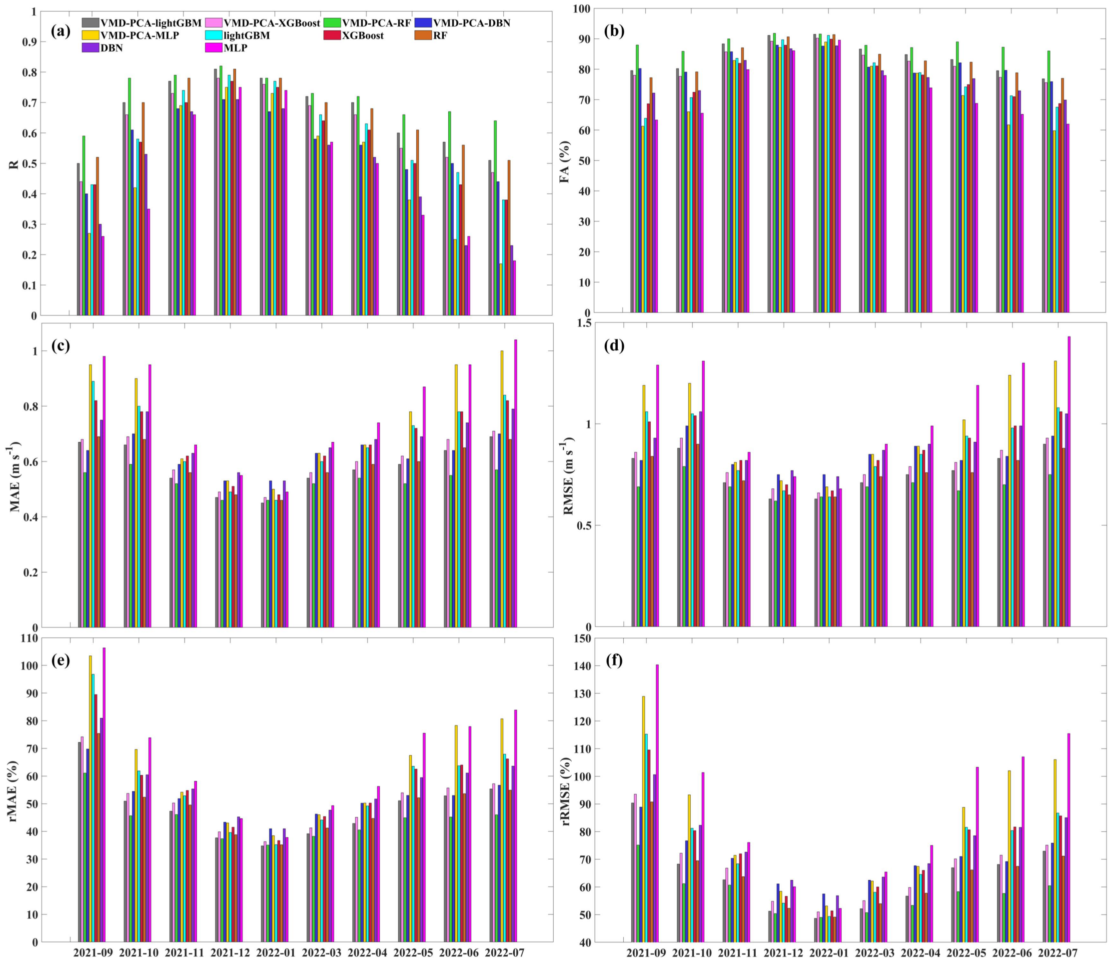

Figure 13: Evaluation histograms of 10-meter wind speed predicted by 10 models and actual wind speed in different months in Experiment 1 and Experiment 2 ((a), (b), (c), (d), (e), and (f) represent R, FA (%), MAE (m s^{-1}), RMSE (m s^{-1}), rMAE (%), and rRMSE (%) respectively).

8. P16, Figure 6: How does the feature importance calculate? What's the correlation coefficients represent? Please add more details in the main text or in the caption.

Response: Thank you very much for your question.

Feature importance is calculated by "RandomForestRegressor.Feature_importances_" function of scikit-learn python package. Feature importance has been calculated in the paper (Duan et al., 2021). Correlation coefficients represent the WS_{10} and input variables in two sets of experiments.

We have corrected title of Fig. 5 to the following text: "*Schematic diagram of correlation coefficients (represented the WS_{10} and input variables) and feature importance (calculated by the scikit-learn python package) for two sets of experiments. (a) and (c) represent experiment 1, and (b) and (d) represent experiment 2.*"

Duan, Z., Yang, Y., Zhou, S., Gao, Z., Zong, L., Fan, S., and Yin, J.: Estimating Gross Primary Productivity (GPP) over Rice–Wheat-Rotation Croplands by Using the

Random Forest Model and Eddy Covariance Measurements: Upscaling and Comparison with the MODIS Product, 21, 2021.

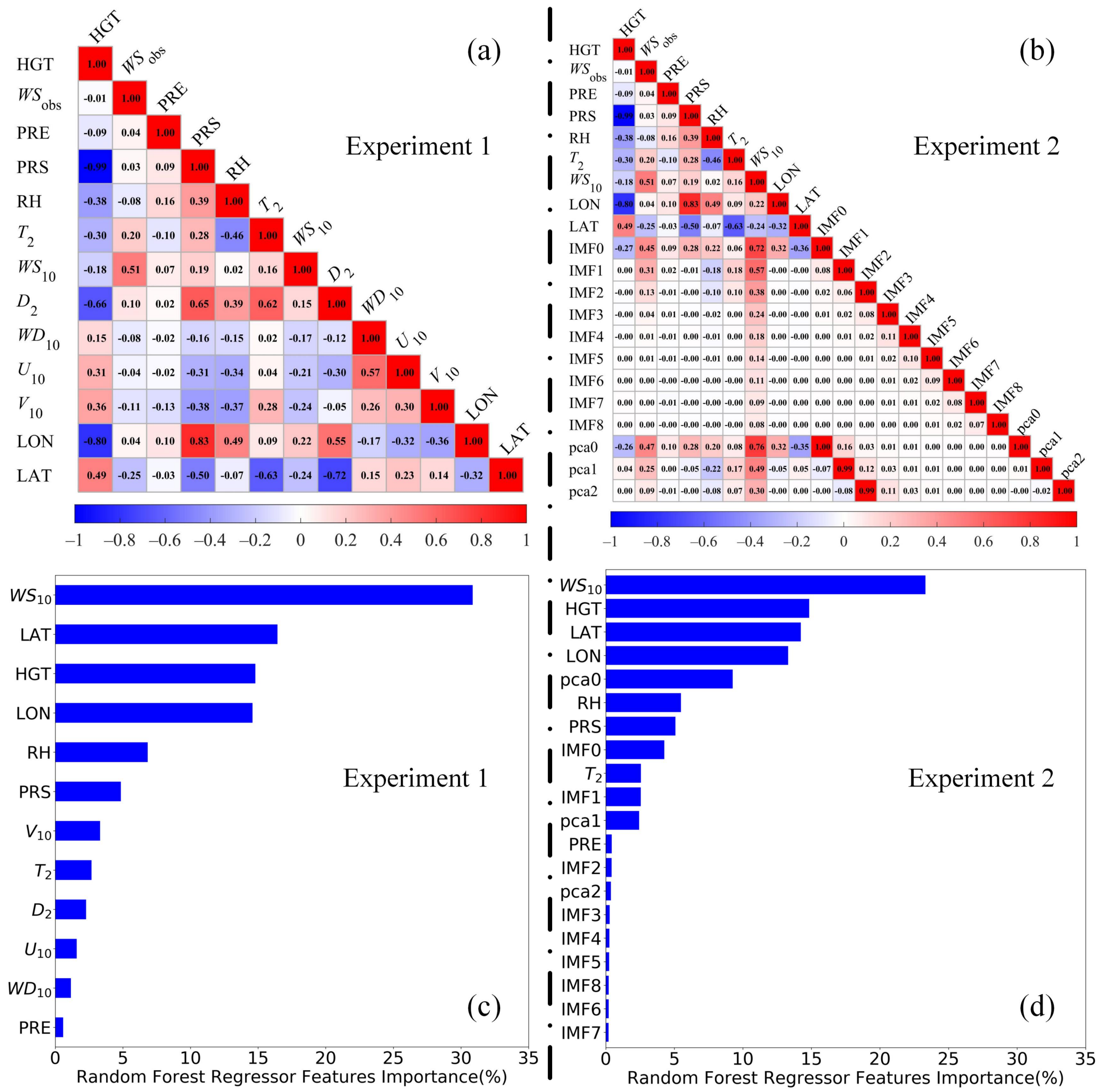

Figure 5: Schematic diagram of correlation coefficients (represented the WS_{10} and input variables) and feature importance (calculated by scikit-learn python package) for two sets of experiments. (a) and (c) represent experiment 1, and (b) and (d) represent experiment 2.

8. P21, Line 382: I think there is no significant differences in statistics for most models except for the DBN and VMD-PCA-DBN based on the Taylor chart in Figure 9. The Taylor chart and Table 3 provide the same information. I would suggest the authors to remove the Taylor chart in Figure 9.

Response: Many thanks for your suggestion.

In addition to the correlation coefficient and root mean square error, there is also an index (standard deviation) of its own data in the Taylor chart. If the standard deviation of the 10-meter wind speed corrected by the model is closer to the standard deviation of the actual 10-meter observation data, the effect of the revision is more consistent with the actual distribution. Therefore, from the Taylor chart, we can see that although the correlation coefficients and mean square deviations of other models are relatively close except DBN and VMD-PCA-DBN models, their standard deviations are still different.

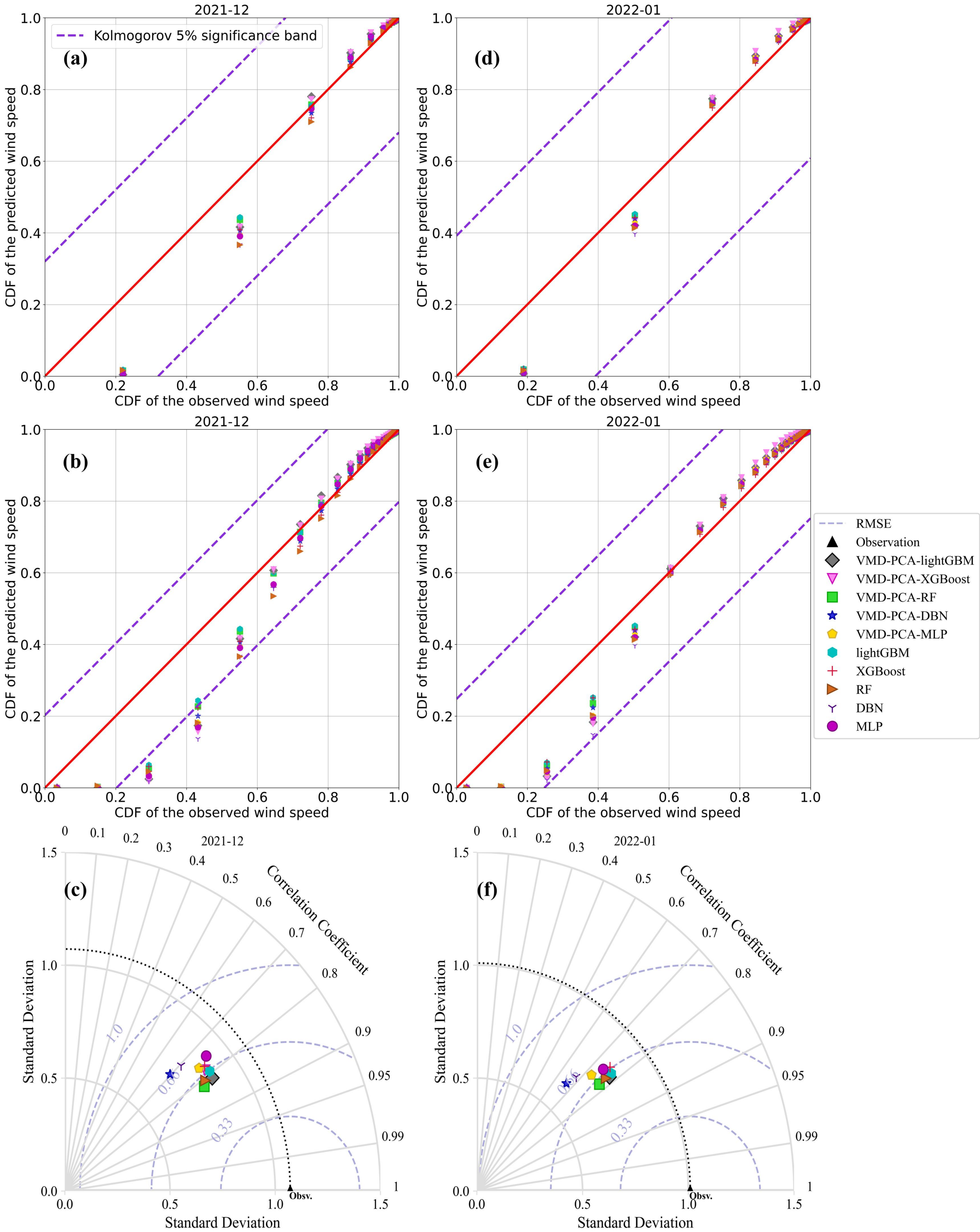

Figure 8: The cumulative distribution probability scatter plots of the actual wind speed and the predicted wind speed of 10 models in wind speed intervals of 0.5 m s^{-1} ((a) represents December 2021, (d) represents January 2022) and 0.2 m s^{-1} ((b) represents December 2021, (e) represents January 2022) respectively; Taylor distribution map ((c) represents December 2021, (f) represents January 2022).

9. P24, Figure 10: What do the shading areas and colored curves in Figure10c and 10d represent? Please clarify in the caption.

Response: Thank you very much for pointing this out. Colored curves are shown in the legend.

For clarity, we have corrected title of Fig. 9 to the following text: "Figure 9: VMD-PCA-lightGBM,VMD-PCA-RF and WRF daily variation of predicted and actual wind speeds in December 2021 and January 2022. (The shading areas represent an interval of 1 standard deviation, which is a 68% confidence interval.)"

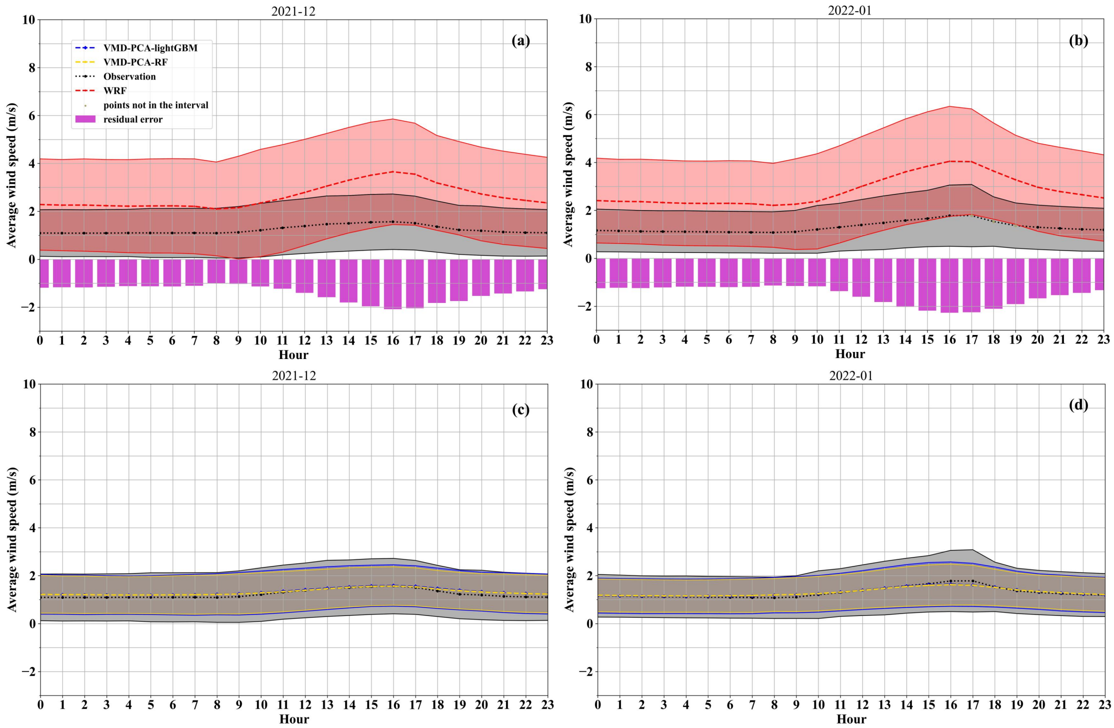

Figure 9: VMD-PCA-lightGBM,VMD-PCA-RF and WRF daily variation of predicted and actual wind speeds in December 2021 and January 2022. (The shading areas represent an interval of 1 standard deviation, which is a 68% confidence interval.)

10. Technical corrections

P6, Line 140: Please add citations for the WRF v4.2 model.

Response: Thank you very much for pointing this out. we have updated line 140 to the following text: *"The WRF 4.2 model (Skamarock et al., 2021), developed by the National Center for Atmospheric Research (NCAR), …"*

Skamarock, W. C., Klemp, J. B., Dudhia, J., Gill, D. O., Liu, Z., Berner, J., Wang, W., Powers, J. G., Duda, M. G., Barker, D. M., and Huang, X.-Y.: A Description of the Advanced Research WRF Model Version 4, 2021.

11. P6, Line 140: It should be "National Centers for Environmental Prediction (NCEP)".

Response: Thank you very much for pointing this out. We have updated line 140 to the following text: *"The WRF 4.2 model (Skamarock et al., 2021), developed by the National Center for Atmospheric Research (NCAR), represents a new generation of mesoscale numerical models with numerous applications in research forecasting. When forecasting meteorological elements, the WRF model normally uses the GFS data developed by the National Centers for Environmental Prediction (NCEP)."*

12. P10, Line 224: Please rearrange the order of the figures and tables, which should be numbered in the order of their appearance in the main text.

Response: Thank you very much for pointing this out.

We have rearranged the order of the figures, and added the following in the text: *"In Experiment 1, as shown in Fig. 2, 12 sets of data are selected from the WRF forecast field, including altitude (HGT), 10-meter wind speed (WS_{10}), latitude (LAT), longitude (LON), surface pressure (PRS), relative humidity (RH), 10-meter meridional wind (V_{10}), 10-meter zonal wind (U_{10}), 2-meter temperature (T_2), 2-meter dew point temperature (D_2), 10-meter wind direction (WD_{10}), and hourly precipitation (PRE)."*

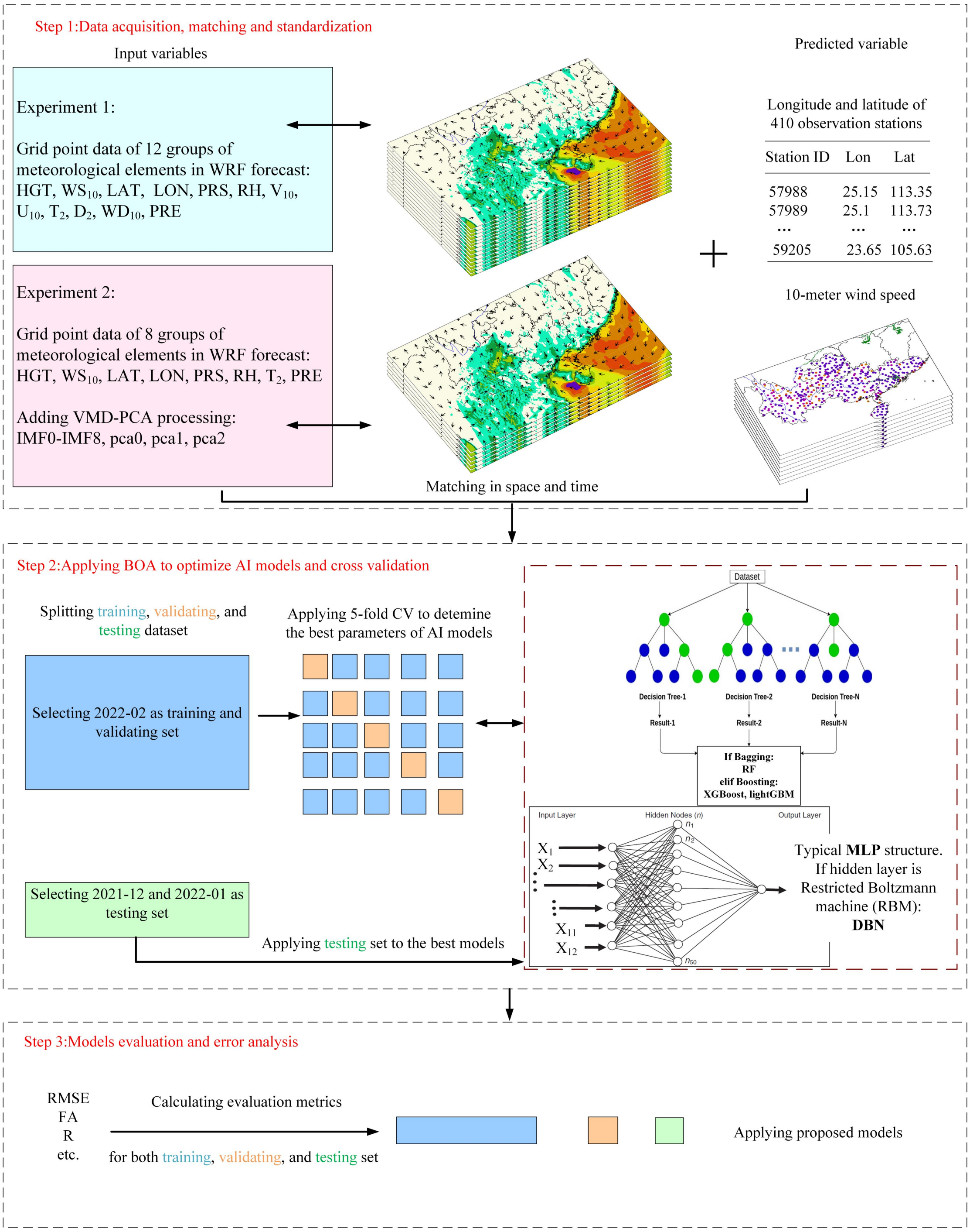

Figure 2: Flowchart of the AI model used to correct WRF-predicted wind speeds in the two main experimental pathways.

12. P13, Line 276: Please spell out the acronyms “FA”.

Response: Thank you very much for pointing this out.

It means Forecasting Accuracy (FA), which has been used in past literature (Sun et al., 2019).

Sun, Q., Jiao, R., Xia, J., Yan, Z., Li, H., Sun, J., Wang, L., and Liang, Z.: Adjusting Wind Speed Prediction of Numerical Weather Forecast Model Based on Machine

Learning Methods. Meteorological Monthly, 45(3): 426-436. https://doi.org/10.7519/j.issn.1000-0526.2019.03.012, 2019.

13. P14: Please change the “m/s” to “m s-1".

Response: Thank you very much for pointing this out.

We have changed the “m/s” to “m s^{-1}”.