Online Supplemental Material

Wind speed forecasting based on wavelet decomposition and wavelet neural networks optimized by the Cuckoo search algorithm

Ye ZHANG[a], Shiping YANG[a], Zhenhai GUO[b], Yanling GUO[c] and Jing ZHAO[b]

[a]College of Physics and Information Engineering, Hebei Normal University, Shijiazhuang 050024, China; [b]State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China; [c]College of Atmospheric Science, Lanzhou University, Lanzhou 730000, China

This file includes:
Supplementary Figures S1–S9 and Tables S1–S2

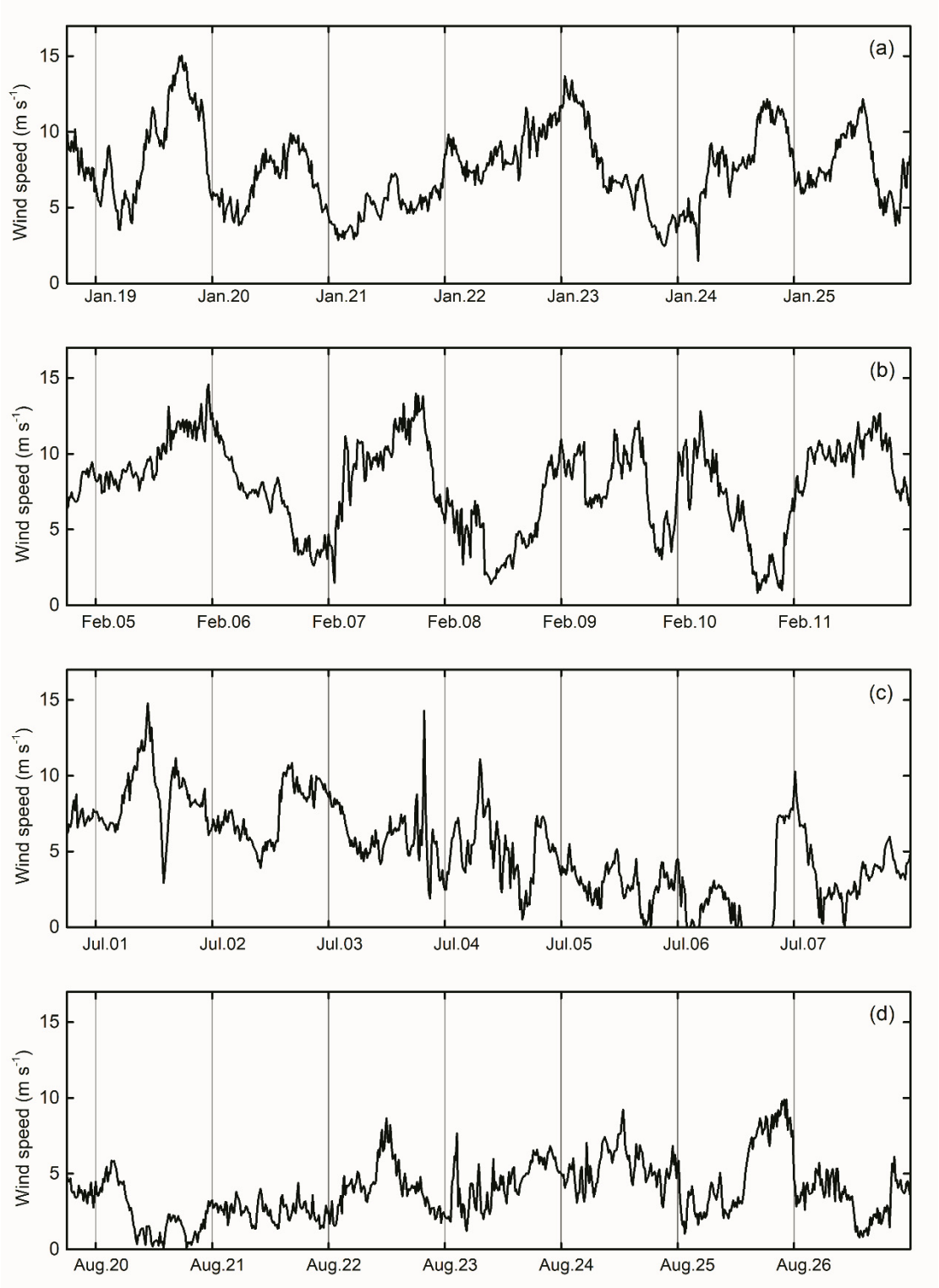

Figure S1. Original wind speed time series: (a) case1winter, (b) case2winter, (c) case1summer, and (d) case2summer.

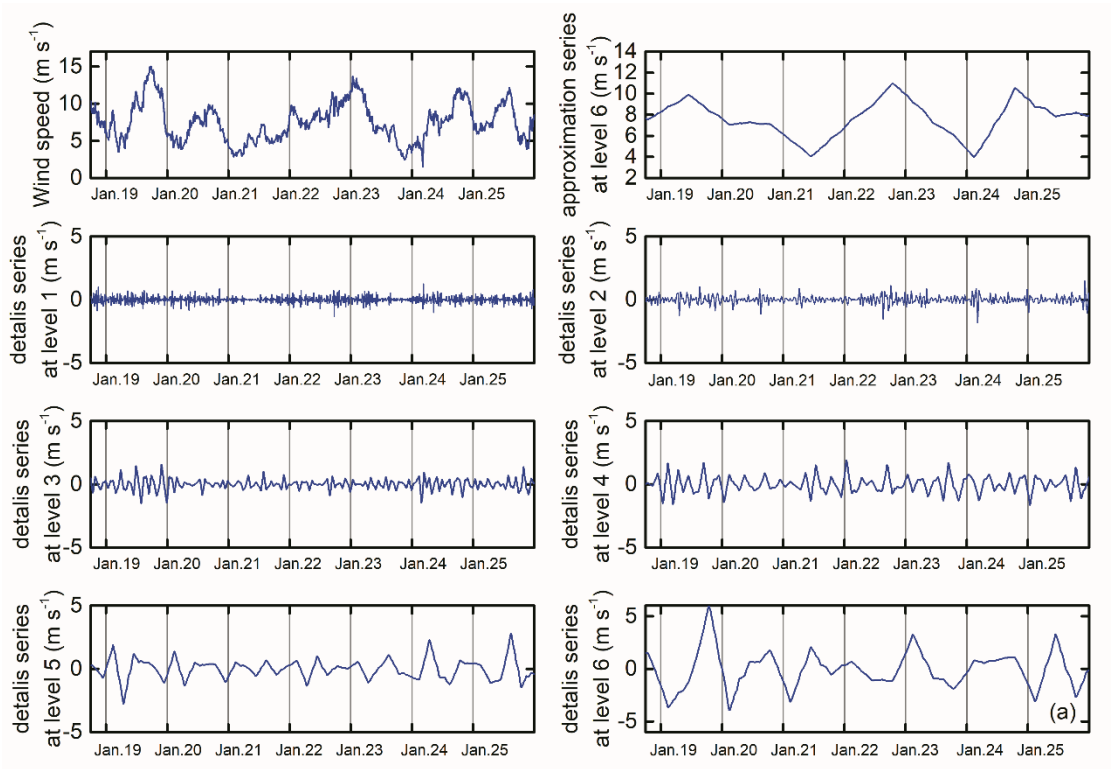

Figure S2. The wavelet decomposition result of case1winter.

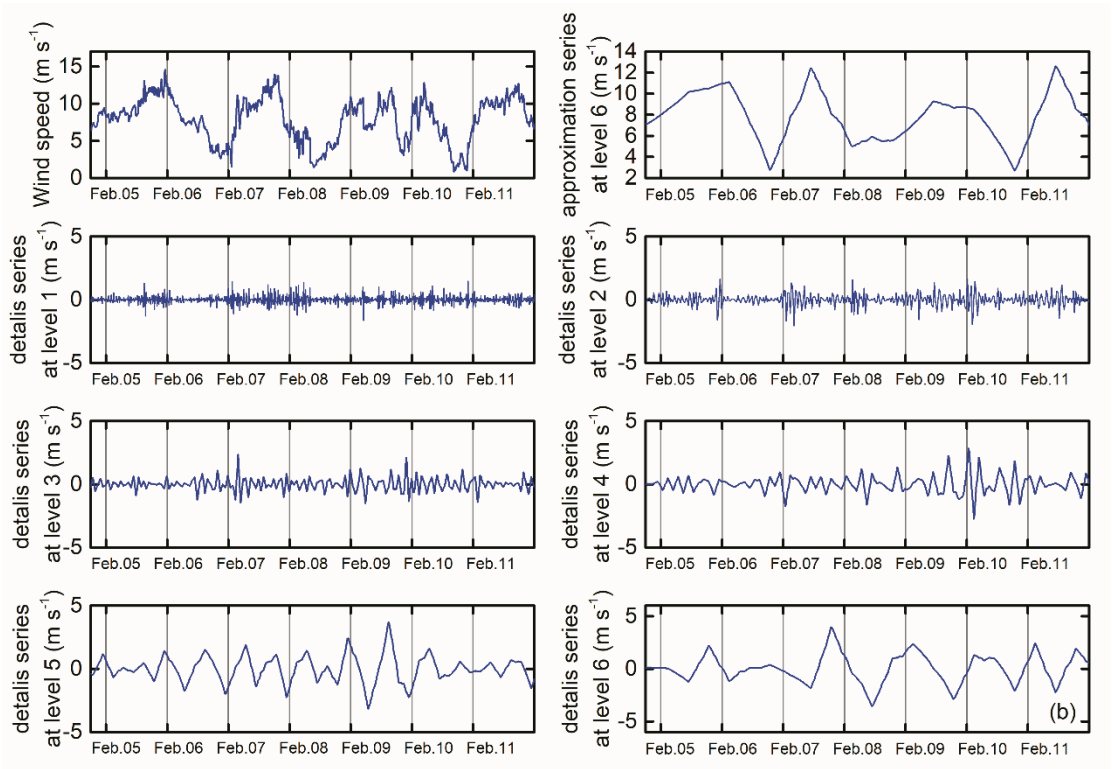

Figure S3. The wavelet decomposition result of case2winter.

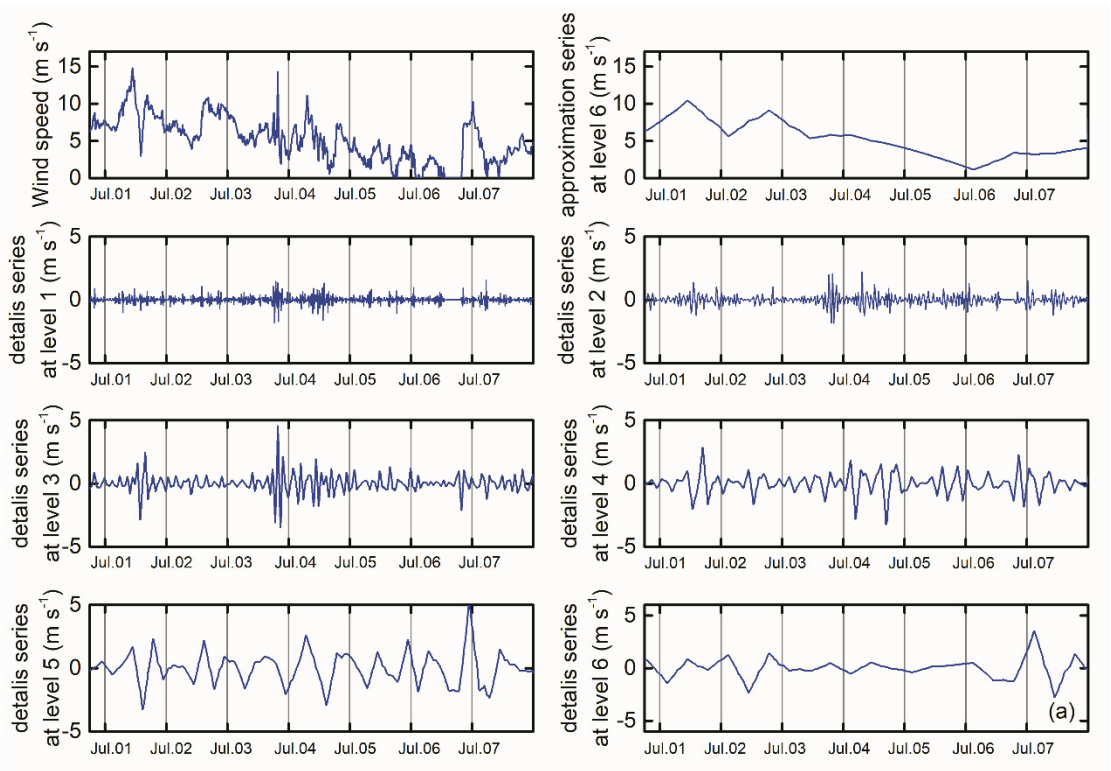

Figure S4. The wavelet decomposition result of case1summer.

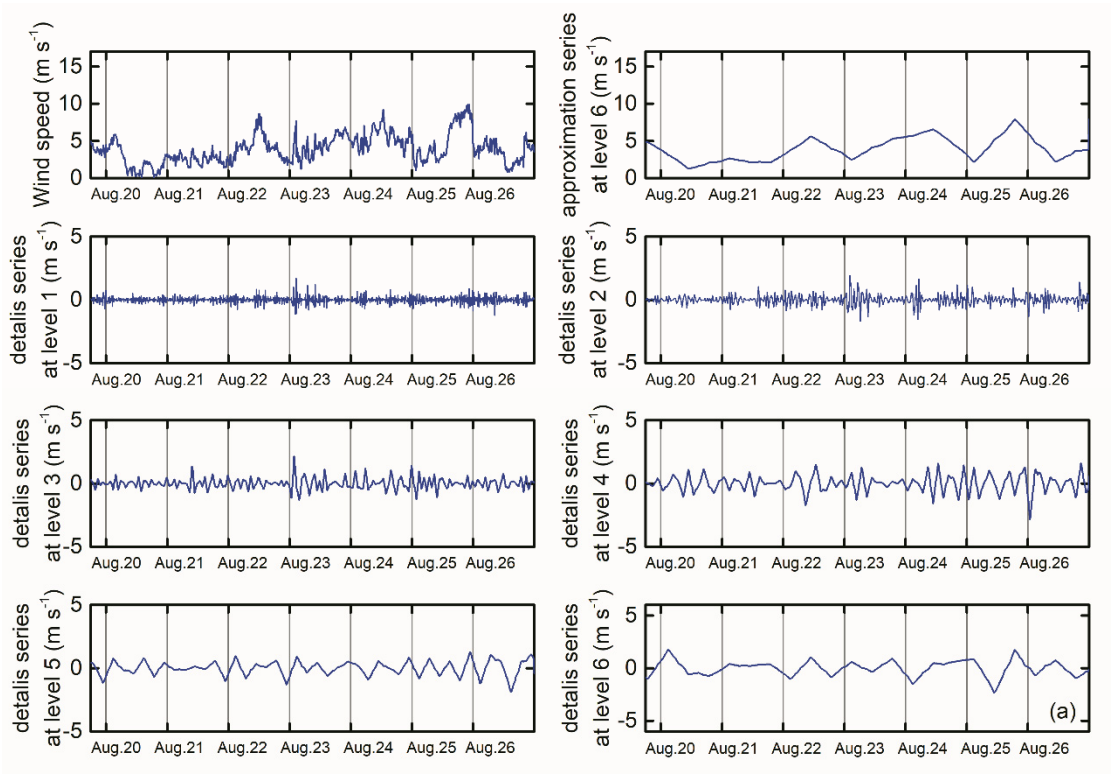

Figure S5. The wavelet decomposition result of case2summer.

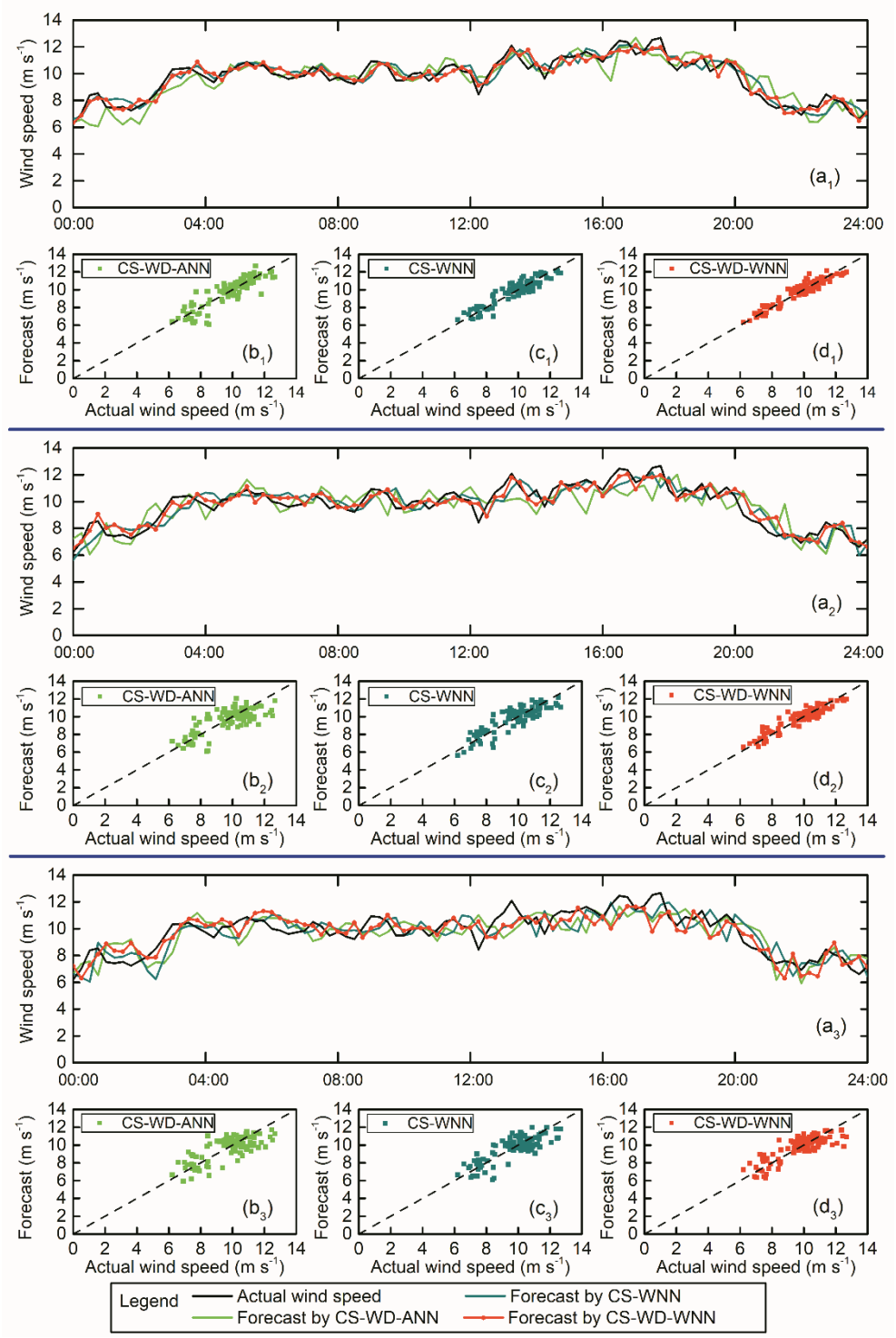

Figure S6. Wind speed forecasting results by CS-WD-ANN, CS-WNN, and CS-WD-WNN for case2winter: (1) one-step, (2) three-step, and (3) five-step. (a) Wind speed forecasting on 11th February 2014. (b), (c), (d) Scatter plots for CS-WD-ANN, CS-WNN, and CS-WD-WNN models respectively.

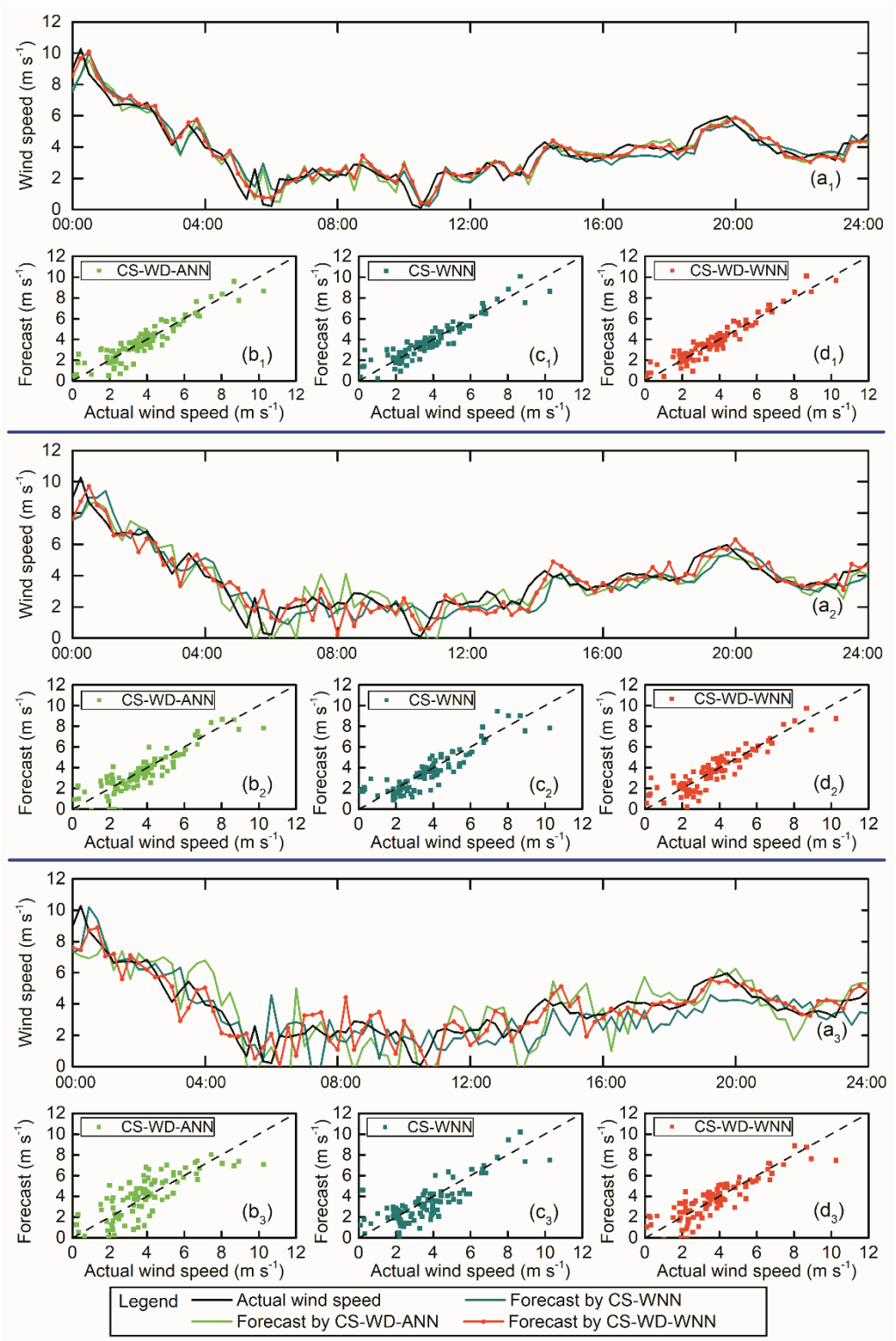

Figure S7. Wind speed forecasting results by CS-WD-ANN, CS-WNN, and CS-WD-WNN for case1summer: (1) one-step, (2) three-step, and (3) five-step. (a) Wind speed forecasting on 7th July 2014. (b), (c), (d) Scatter plots for CS-WD-ANN, CS-WNN, and CS-WD-WNN models respectively.

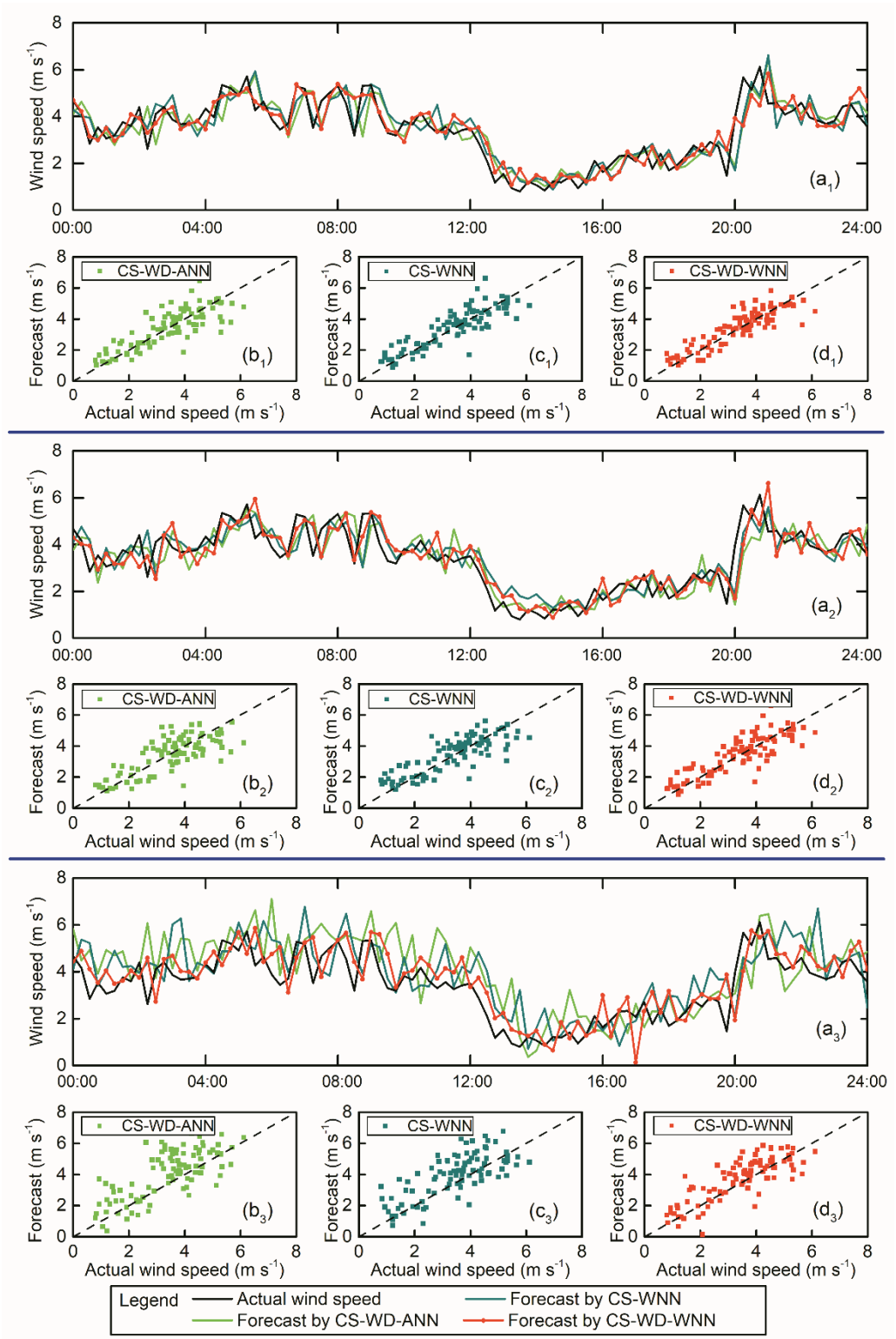

Figure S8. Wind speed forecasting results by CS-WD-ANN, CS-WNN, and CS-WD-WNN for case2summer: (1) one-step, (2) three-step, and (3) five-step. (a) Wind speed forecasting on 26th August 2014. (b), (c), (d) Scatter plots for CS-WD-ANN, CS-WNN, and CS-WD-WNN models respectively.

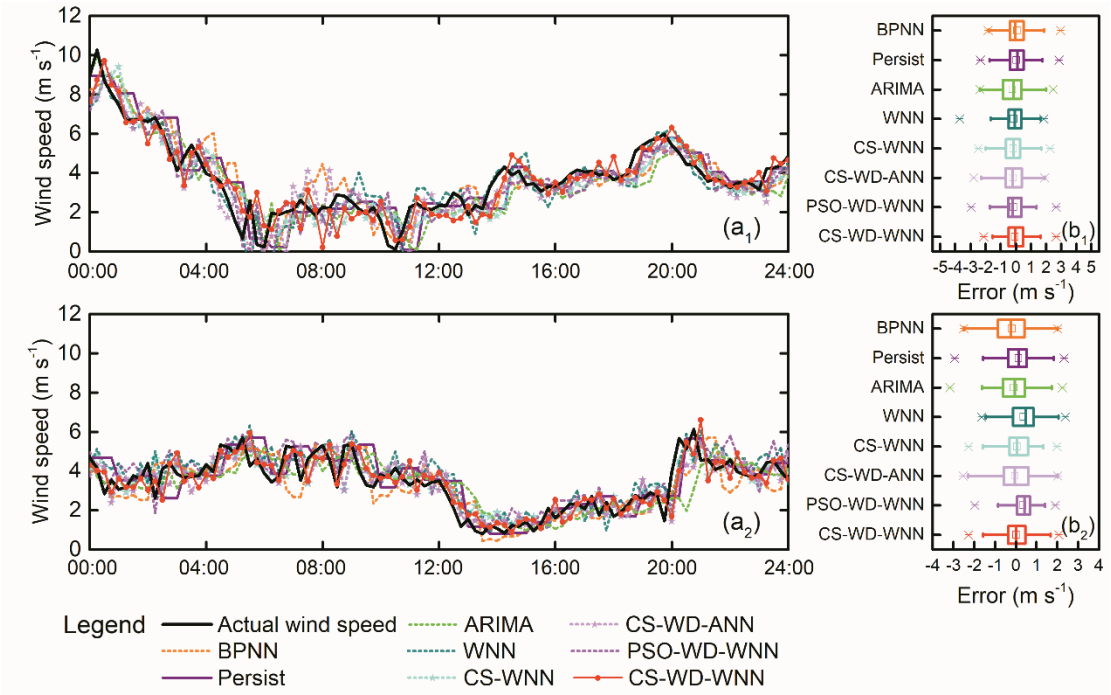

Figure S9. Three-step wind speed forecasting results by different models for case1summer and case2summer: (a_1) wind speed forecasting on 7th July 2014 in case1summer; (a_2) wind speed forecasting on 26th August 2014 in case2summer; (b_1), (b_2) box plot of forecasting error.

Table S1. Results of errors for multi-step prediction in case1winter and case2summer for the three developed models.

Wind farm	Index	One-step			Three-step			Five-step		
		CS-WD-ANN	CS-WNN	CS-WD-WNN	CS-WD-ANN	CS-WNN	CS-WD-WNN	CS-WD-ANN	CS-WNN	CS-WD-WNN
case1 summer	MAE (m s^{-1})	0.578	0.5505	0.4404	0.6965	0.6626	0.6214	1.165	0.9404	0.7736
	MAPE (%)	35.02	36.36	25.85	41.86	54.1	41.34	62.1	62.43	51.62
	RMSE (m s^{-1})	0.7468	0.7129	0.5648	0.9122	0.88	0.8098	1.473	1.201	0.9656
	r	0.9212	0.9272	0.9567	0.8884	0.8952	0.909	0.7722	0.8206	0.8671
case2 summer	MAE (m s^{-1})	0.5771	0.5155	0.4619	0.6757	0.5796	0.5604	1.004	0.9028	0.6906
	MAPE (%)	19.56	18.41	16.93	22.81	22.35	19.82	38.06	34.54	25.48
	RMSE (m s^{-1})	0.7662	0.6837	0.4756	0.8463	0.7586	0.7347	1.277	1.134	0.8806
	r	0.8205	0.8579	0.949	0.7807	0.8174	0.8354	0.7256	0.7268	0.8053

Table S2. Results of errors for multi-step prediction for CS-WD-WNN and other existing wind speed forecasting models (summer).

Wind farm	Model	Error criterion			
		MAE (m s^{-1})	RMSE (m s^{-1})	MAPE (%)	*r*
case1summer	BPNN	0.7018	0.9362	37.07	0.8795
	Persist	0.6999	0.9664	56.05	0.8839
	ARIMA	0.7692	0.9929	53.82	0.8772
	WNN	0.6474	0.8951	50.63	0.8905
	CS-WNN	0.6626	0.8800	54.10	0.8952
	CS-WD-ANN	0.6965	0.9122	41.86	0.8884
	PSO-WD-WNN	0.6318	0.8524	38.36	0.9031
	CS-WD-WNN	0.6214	0.8098	41.34	0.9090
case2summer	BPNN	0.7897	0.9575	26.15	0.7483
	Persist	0.6584	0.8844	22.95	0.7867
	ARIMA	0.6821	0.9303	24.79	0.7229
	WNN	0.7441	0.8969	26.87	0.8126
	CS-WNN	0.5796	0.7586	22.35	0.8174
	CS-WD-ANN	0.6757	0.8463	22.81	0.7807
	PSO-WD-WNN	0.5907	0.7375	22.77	0.8756
	CS-WD-WNN	0.5604	0.7347	19.82	0.8354
Mean	BPNN	0.7457	0.9469	31.61	0.8139
	Persist	0.6791	0.9254	39.50	0.8353
	ARIMA	0.7257	0.9616	39.31	0.8000
	WNN	0.6958	0.8960	38.75	0.8516
	CS-WNN	0.6211	0.8193	38.23	0.8563
	CS-WD-ANN	0.6861	0.8793	32.34	0.8345
	PSO-WD-WNN	0.6113	0.7950	30.57	0.8894
	CS-WD-WNN	0.5909	0.7723	30.58	0.8722