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MULTI-STEP WIND SPEED FORECASTING BASED ON MULTI-STAGE DECOMPOSITION APPROACH

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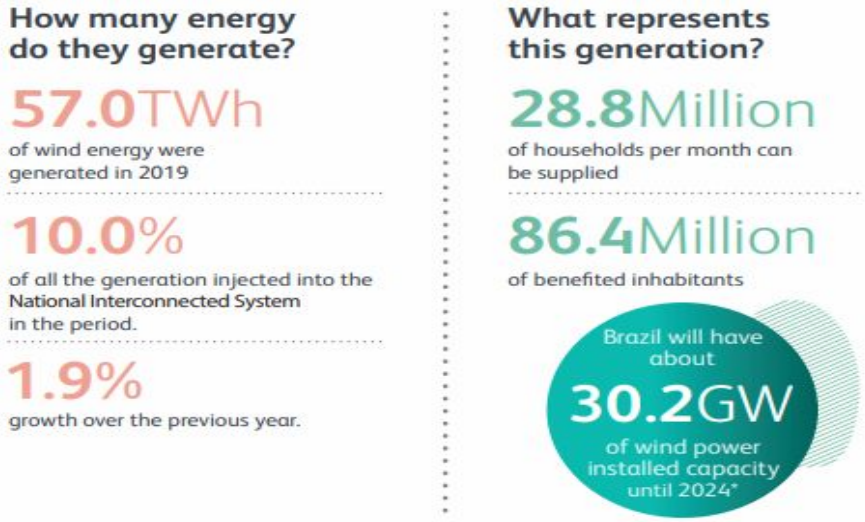
Agenda

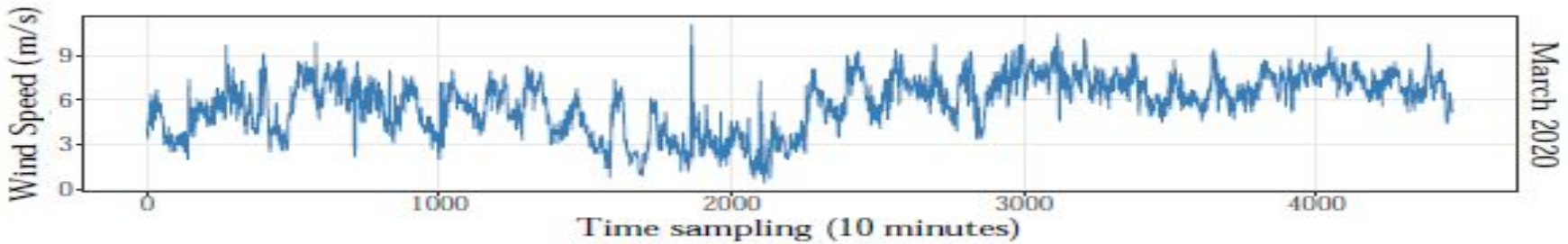
- Why Wind Power Forecasting ?
- Main Contribution
- Data Set
- Proposed Method
- Results
- Conclusion

Why Wind Power Forecasting ?



- Brazil is ranked 7th in the 2020 World Ranking of wind energy installed capacity. In 2012, Brazil was ranked 15th. (ABEEólica, 2021).
- With the lack of accurate wind forecasting models, as consequence, lots of curtailments have been imposed on wind power production by the National Operator System (O.N.S) to meet load flow constraints (da Silva et al., 2020b).

- Operation and Maintenance minimizing energy losses became a challenge;
- Wind power is highly sensitive to wind gusts.



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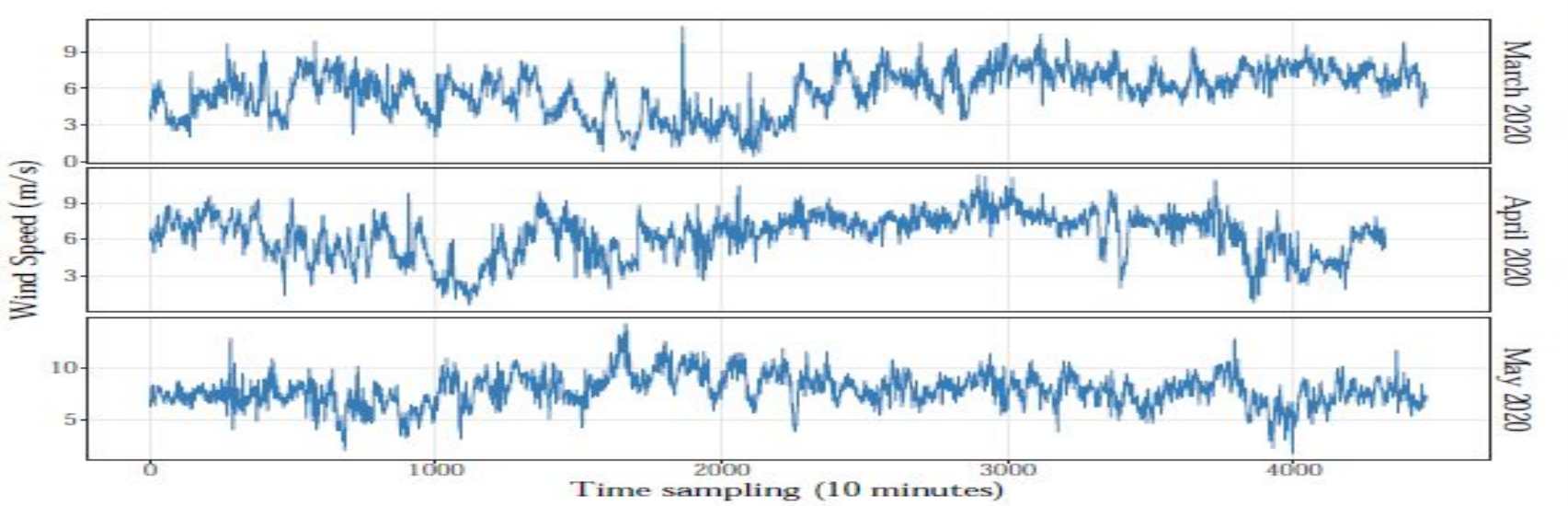
Main Contribution

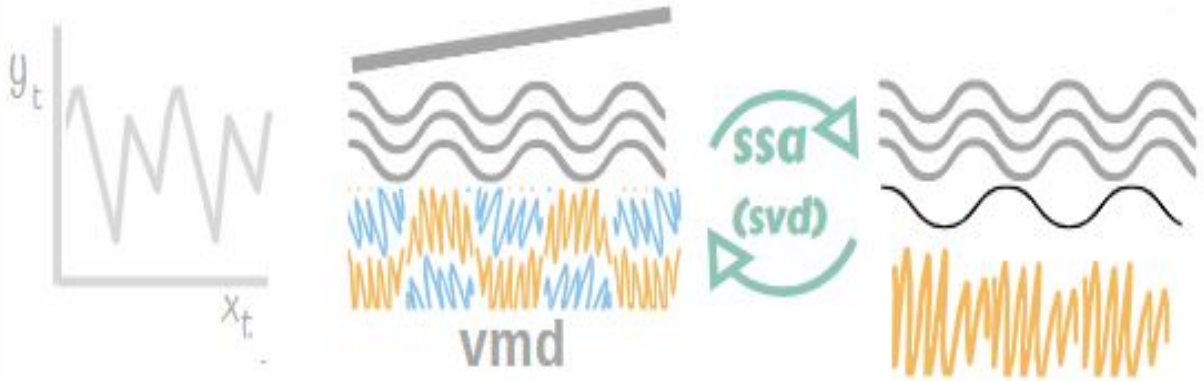
- Evaluating the use of a multi-stage signal decomposition approach for wind speed forecasting;
- The use of different machine learning forecasting models combined with the multi-stage signal decomposition;
- Assessment of the proposed framework considering a multi-step ahead forecasting strategy (10, 30, and 60 minutes ahead) for wind speed time series, obtaining promising results;
- Variational Mode Decomposition and Singular Spectrum Analysis (VMD–SSA) is an efficient model for preprocessing wind speed, improving the accuracy on forecasting *k*-step-ahead.

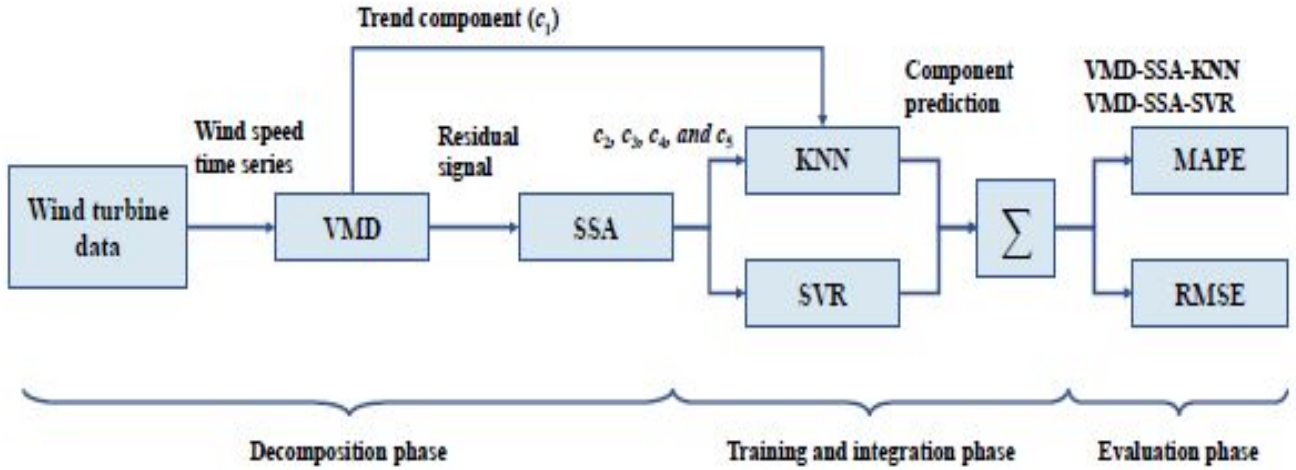
Data Set

- Wind Farm Characteristics
  - 75 Wind Turbines (WT);
  - 2MW rated power each;
  - Rotor Diameter 90m;
  - Hub height 80m;
  - Installed Capacity 150MW.



Proposed Method

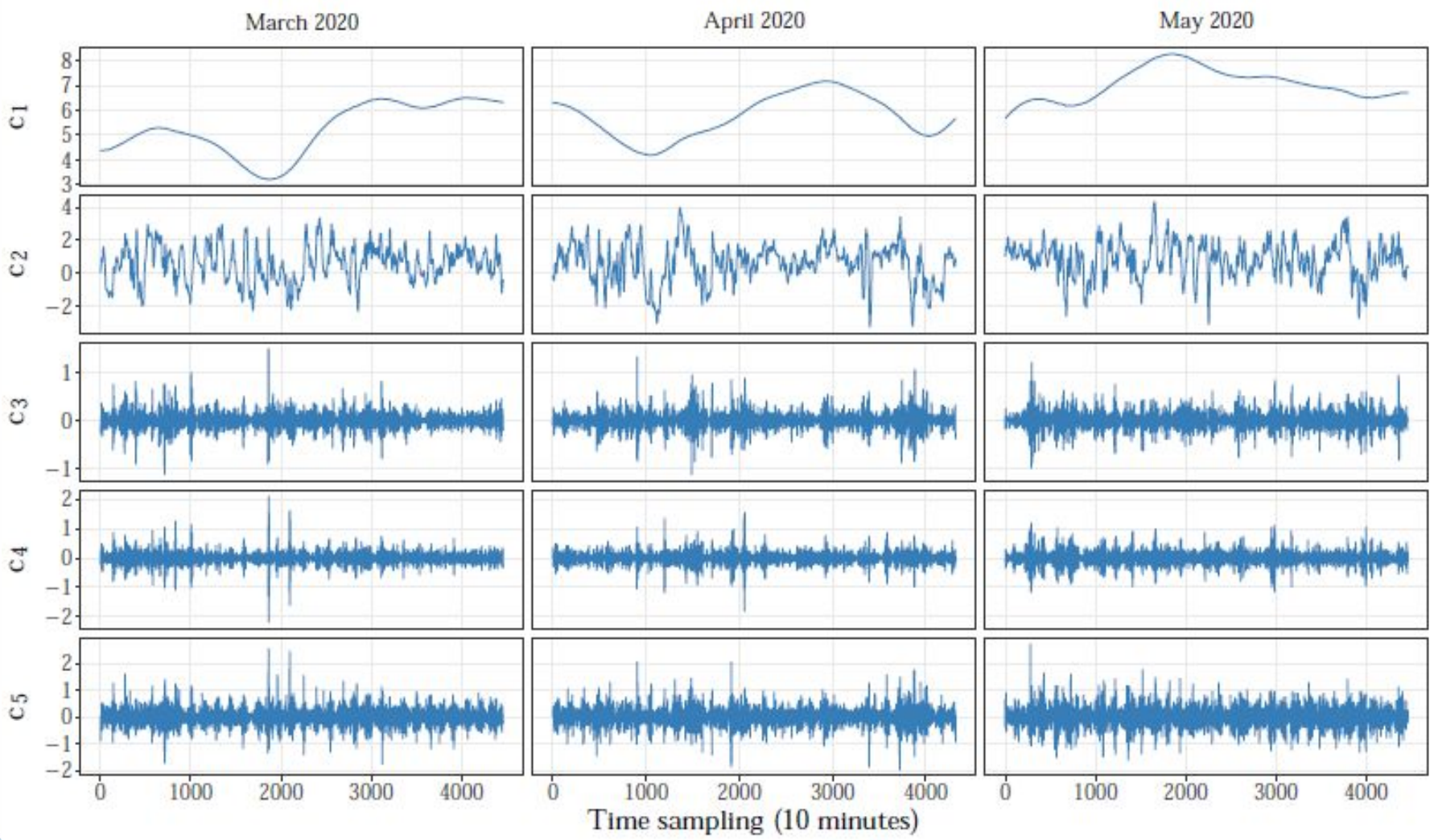




Proposed Architecture

- Decomposition
  - Variational Mode Decomposition (VMD);
  - Singular Spectrum Analysis (SSA).
- Forecasting
  - On recursive way: 10 up to 60 steps-ahead;
  - k-Nearest Neighbor (KNN);
  - Support Vector Regression (SVR);
  - Parameters tunning : Grid Search
- Metrics
  - Mean Absolute Percentual Error (MAPE);
  - Root Mean Square Error (RMSE).

Results


March 2020
April 2020
May 2020
c1
c2
c3
c4
c5
Time sampling (10 minutes)

Results

Table 1. Performance measures of the single and decomposed models

Dataset	Forecasting horizon	Criteria	VMD–SSA–KNN	VMD–SSA–SVR	SSA–KNN	SSA–SVR	VMD–KNN	VMD–SVR	KNN	SVR
March	10 minutes ahead	MAPE	**3.226%**	3.288%	4.050%	3.546%	5.195%	5.436%	5.750%	5.596%
		RMSE	0.2884	**0.2878**	0.3604	0.3171	0.4631	0.4739	0.5045	0.4936
	30 minutes ahead	MAPE	**3.483%**	3.628%	5.755%	5.630%	6.152%	6.363%	7.009%	6.846%
		RMSE	**0.3073**	0.3176	0.5220	0.5059	0.5464	0.5545	0.6045	0.5960
	60 minutes ahead	MAPE	**4.168%**	4.791%	6.374%	6.357%	6.607%	6.926%	8.262%	7.760%
		RMSE	**0.3724**	0.4226	0.5792	0.5657	0.5900	0.5974	0.7070	0.6688
April	10 minutes ahead	MAPE	5.355%	**4.657%**	7.128%	5.760%	8.447%	7.749%	8.871%	8.249%
		RMSE	0.3899	**0.3317**	0.5196	0.3800	0.6169	0.5731	0.6460	0.6066
	30 minutes ahead	MAPE	5.950%	**5.182%**	9.563%	8.851%	10.288%	9.843%	11.116%	10.778%
		RMSE	0.4373	**0.3664**	0.7143	0.6563	0.7628	0.7242	0.8287	0.7953
	60 minutes ahead	MAPE	7.290%	**6.893%**	10.741%	10.446%	11.290%	10.822%	12.626%	11.868%
		RMSE	0.5505	**0.4950**	0.8154	0.7833	0.8691	0.8228	0.9669	0.9328
May	10 minutes ahead	MAPE	4.129%	**3.713%**	5.197%	4.166%	6.907%	6.366%	7.009%	6.663%
		RMSE	0.3834	**0.3366**	0.4789	0.3739	0.6250	0.5716	0.6490	0.6035
	30 minutes ahead	MAPE	4.595%	**3.991%**	7.194%	6.809%	8.182%	7.545%	8.350%	8.116%
		RMSE	0.4270	**0.3595**	0.6676	0.6497	0.7427	0.6980	0.7979	0.7648
	60 minutes ahead	MAPE	5.770%	**4.874%**	8.255%	8.277%	9.108%	8.747%	10.237%	9.874%
		RMSE	0.5403	**0.4536**	0.7739	0.7780	0.8362	0.8077	0.9908	0.9344

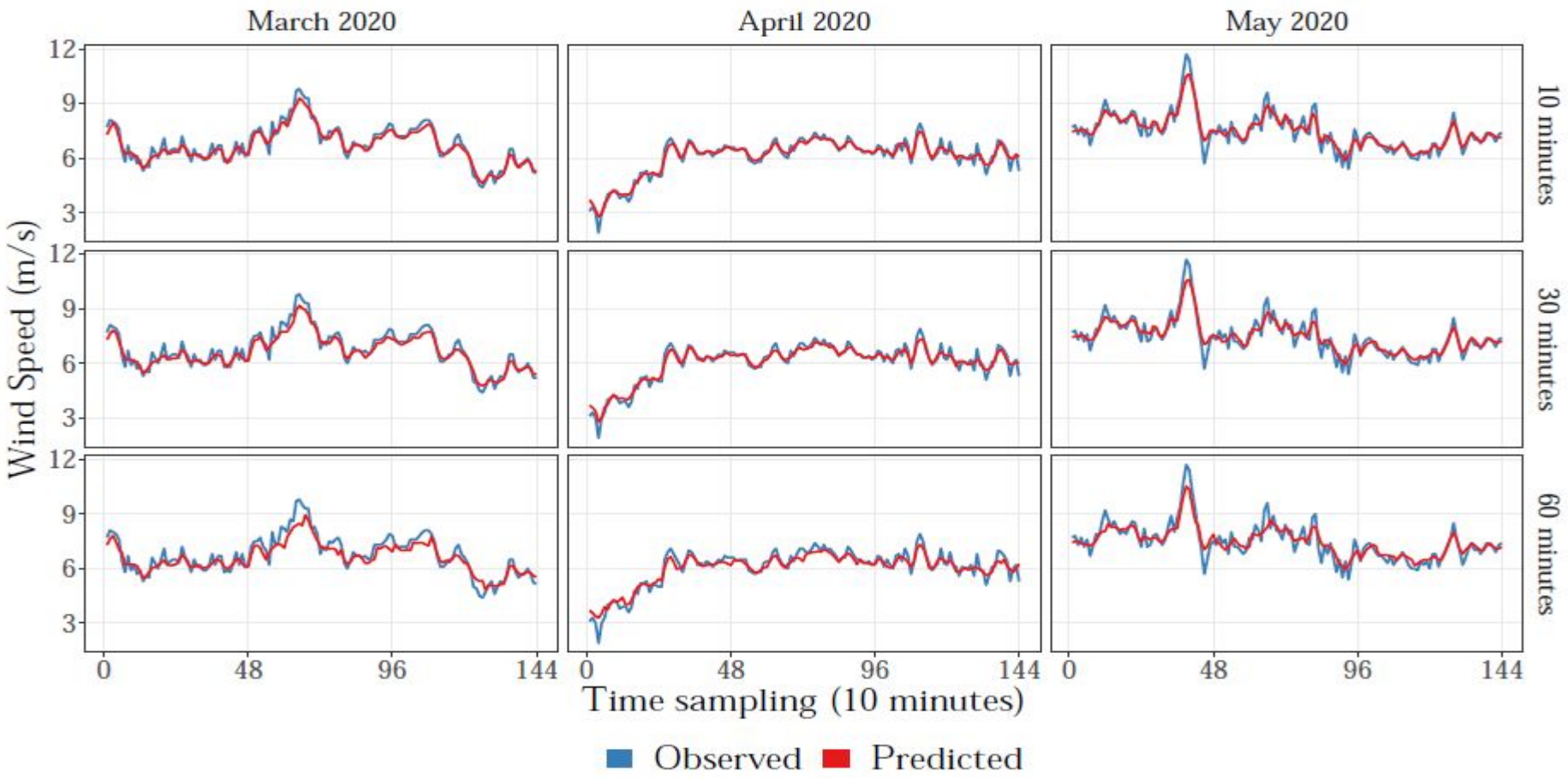
Results

Improved Performance (IP index)

- Models Label
  - A: VMD-SSA-KNN;
  - B: VMD-SSA-SVR;
  - C: SSA-KNN;
  - D: SSA-SVR;
  - E: VMD-KNN;
  - F: VMD-SVR;
  - G: KNN, and
  - H: SVR.

Results

Best Model: VMD-SSA-SVR



Conclusion

- Accuracy and Forecasting Horizon:
  - The VMD–SSA models outperform the SSA, VMD, and single models in all evaluated forecasting horizons, with a performance improvement that ranges within 0.20%–55.78%.
  - March: in 10 minutes ahead forecasting, and RMSE assessment, the performance metric improvement of VMD–SSA–SVR model ranged within 0.20%–42.94%, and for MAPE the VMD–SSA–KNN model ranged within 1.89%–43.89%. For 30 and 60 minutes ahead, for both criteria, the VMD–SSA–KNN improved between 3.23%–50.30%.
  - April and May datasets, for all forecasting horizons in both performance criteria, the VMD–SSA–SVR presented better performance, with a performance improvement that ranged within 5.45%–55.78%.
  - Further, the worst performance in all datasets for all forecasting horizons was presented by the KNN model with an average IP of 49.53%. The second better performance approach in all datasets and all forecasting horizons was the SSA–SVR approach with an average IP of 30.12%.

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Multi-Step Wind Speed Forecasting Based on Multi-Stage Decomposition Approach

Q & A Session

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