Iran Validation:

Vortex Mast & Series

1. Scope

The main objective of this validation is to check how accurate Vortex Mast & Series data are compared to data from real wind mast installed and used in the wind industry.

For this purpose, wind measurement series from 11 different sites in Iran have been analyzed in this study. These sites are located as shown in Table 1.

Table 1- *The location of sites*

Site No.	Site Name	Site Province	Height
1	Kuhin	Qazvin	80
2	Sarab	East Azerbaijan	40
3	Nehbandan	South Khorasan	40
4	Shorjeh	Qazvin	40
5	Rafsanjan	Kerman	40
6	Moaleman	Semnan	40
7	Mil Nader	Sistan & Baluchestan	40
8	Haddadeh	Semnan	40
9	Abhar	Zanjan	80
10	Nikouyeh	Qazvin	40
11	Rudab	Khorasan Razavi	40

It is important to mention that Vortex does not have control over the quality of these met mast stations info and they are received directly from the website of Renewable Energy Organization of Iran (www.suna.org.ir).

2. Vortex Mast

The mean absolute error (%) and BIAS detected for mean wind speed between Vortex Mast and actual installed met mast data are shown in table 2 and figure 1 for each site.

Table 2- *Mean Absolute Error & BIAS of Vortex Mast for mean wind speed*

Site No.	Site Name	MAE[1] (%)	BIAS[2]
1	Kuhin	15.79	1.29
2	Sarab	11.70	0.76
3	Nehbandan	8.28	-0.44
4	Shorjeh	6.85	0.47
5	Rafsanjan	11.28	0.61
6	Moaleman	3.76	0.22
7	Mil Nader	11.05	-0.76
8	Haddadeh	13.39	-0.73
9	Abhar	11.66	0.73
10	Nikouyeh	11.06	0.80
11	Rudab	8.76	0.53
Average		**10.33**	**0.32**

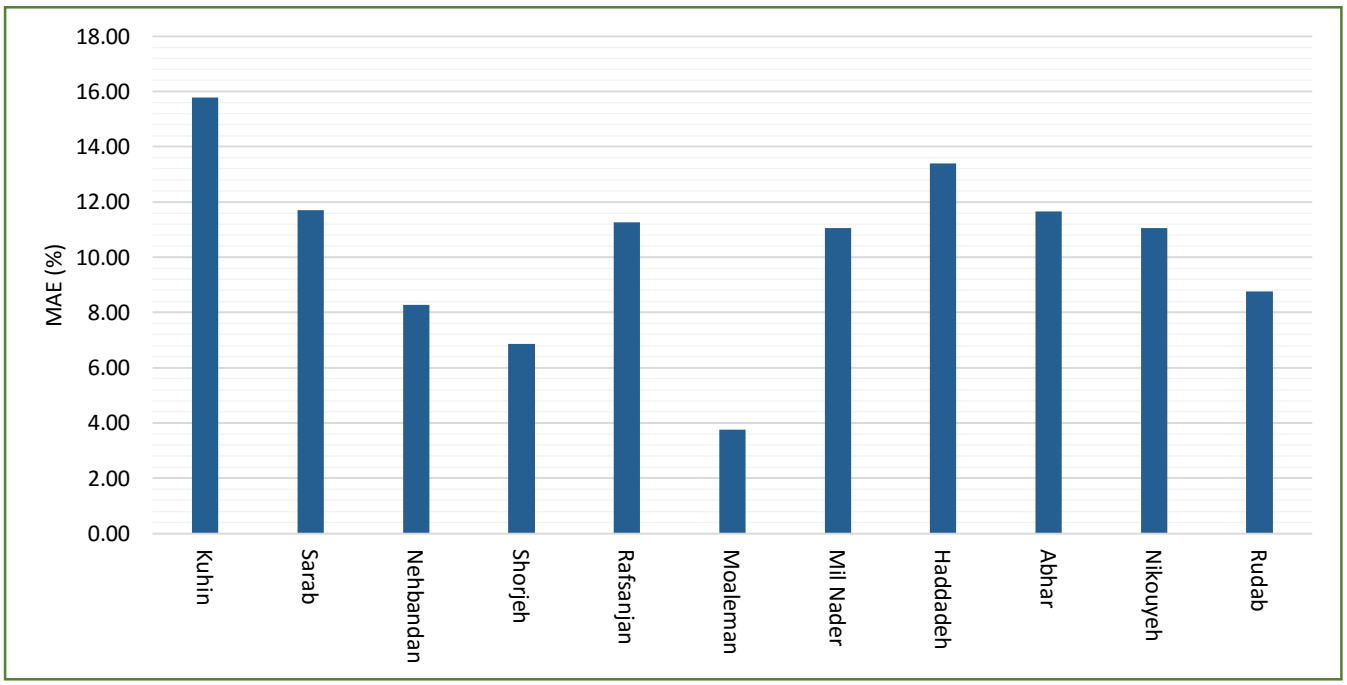

Figure 1- *Mean Absolute Error of Vortex Mast for mean wind speed*

[1] Mean Absolute Error

[2] $V_{measured} - V_{vortex\ mast}$

3. Vortex Series

The mean absolute error (%) of Vortex Series for mean wind speed is calculated as well. The results are shown in table 3 and figure 2 for each site.

Table 3- *Mean Absolute Error of Vortex Series for mean wind speed*

Site No.	Site Name	MAE (%)		
		Vortex Series (CFSR)	Vortex Series (ERA-I)	Vortex Series (MERRA2)
1	Kuhin	3.59	15.35	12.34
2	Sarab	3.98	4.60	1.27
3	Nehbandan	4.16	30.74	17.93
4	Shorjeh	10.03	9.42	18.72
5	Rafsanjan	14.38	13.14	15.36
6	Moaleman	15.93	10.55	11.26
7	Mil Nader	4.62	0.09	9.03
8	Haddadeh	19.73	28.31	28.20
9	Abhar	21.36	1.83	0.50
10	Nikouyeh	3.79	11.51	10.69
11	Rudab	21.53	12.66	30.01
Average		**11.19**	**12.56**	**14.12**

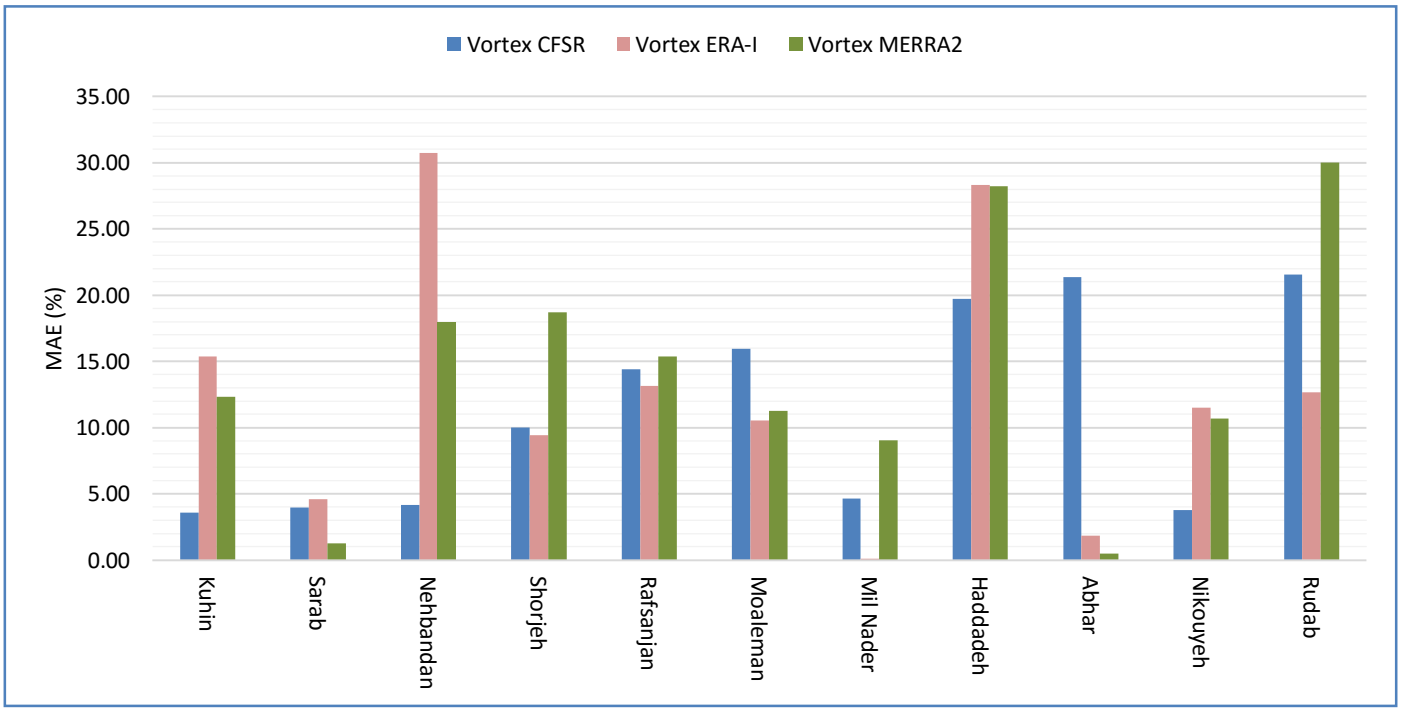

Figure 2- *Mean Absolute Error of Vortex Series for mean wind speed*

The hourly, daily and monthly correlation factors for both wind speed and wind direction between Vortex Series and actual installed met mast data are calculated in this study. The results are shown in the following tables and figures.

Table 4- *Correlation factors of Vortex Series for wind speed*

Site No.	Site Name	Hourly Correlation Factor			Daily Correlation Factor			Monthly Correlation Factor		
		CFSR	ERA-I	MERRA2	CFSR	ERA-I	MERRA2	CFSR	ERA-I	MERRA2
1	Kuhin	0.636	0.626	0.649	0.861	0.832	0.853	0.954	0.931	0.959
2	Sarab	0.559	0.598	0.553	0.776	0.796	0.787	0.885	0.887	0.906
3	Nehbandan	0.189	0.158	0.194	0.312	0.279	0.332	0.894	0.802	0.865
4	Shorjeh	0.105	0.127	0.096	0.164	0.198	0.131	0.817	0.839	0.754
5	Rafsanjan	0.281	0.266	0.277	0.504	0.474	0.481	0.422	0.266	0.422
6	Moaleman	0.409	0.486	0.391	0.483	0.458	0.459	0.508	0.562	0.55
7	Mil Nader	0.364	0.36	0.324	0.527	0.533	0.506	0.818	0.851	0.89
8	Haddadeh	0.336	0.39	0.329	0.67	0.717	0.639	0.979	0.96	0.919
9	Abhar	0.284	0.407	0.388	0.412	0.549	0.542	0.183	0.191	0.159
10	Nikouyeh	0.096	0.116	0.115	0.072	0.085	0.107	0.335	0.319	0.433
11	Rudab	0.338	0.391	0.287	0.337	0.358	0.334	0.694	0.746	0.498
Average		**0.33**	**0.36**	**0.33**	**0.47**	**0.48**	**0.47**	**0.68**	**0.67**	**0.67**

Table 5- *Correlation factors of Vortex Series for wind direction*

Site No.	Site Name	Hourly Correlation Factor			Daily Correlation Factor			Monthly Correlation Factor		
		CFSR	ERA-I	MERRA2	CFSR	ERA-I	MERRA2	CFSR	ERA-I	MERRA2
1	Kuhin	0.718	0.709	0.702	0.773	0.77	0.751	0.981	0.984	0.977
2	Sarab	0.639	0.649	0.609	0.752	0.788	0.714	0.801	0.706	0.761
3	Nehbandan	0.635	0.668	0.632	0.572	0.688	0.65	0.566	0.772	0.822
4	Shorjeh	0.75	0.736	0.724	0.793	0.784	0.791	0.969	0.986	0.975
5	Rafsanjan	0.675	0.685	0.678	0.543	0.576	0.571	0.109	0.344	0.32
6	Moaleman	0.366	0.337	0.345	0.35	0.243	0.278	0.233	0.06	0.263
7	Mil Nader	0.877	0.886	0.871	0.939	0.958	0.943	0.997	0.998	0.998
8	Haddadeh	0.662	0.691	0.674	0.692	0.757	0.648	0.544	0.535	0.561
9	Abhar	0.751	0.768	0.786	0.801	0.852	0.859	0.123	0.985	0.988
10	Nikouyeh	0.536	0.558	0.535	0.422	0.5	0.449	0.498	0.518	0.437
11	Rudab	0.576	0.584	0.579	0.428	0.386	0.471	0.078	0.143	0.204
Average		**0.65**	**0.66**	**0.65**	**0.64**	**0.66**	**0.65**	**0.54**	**0.64**	**0.66**

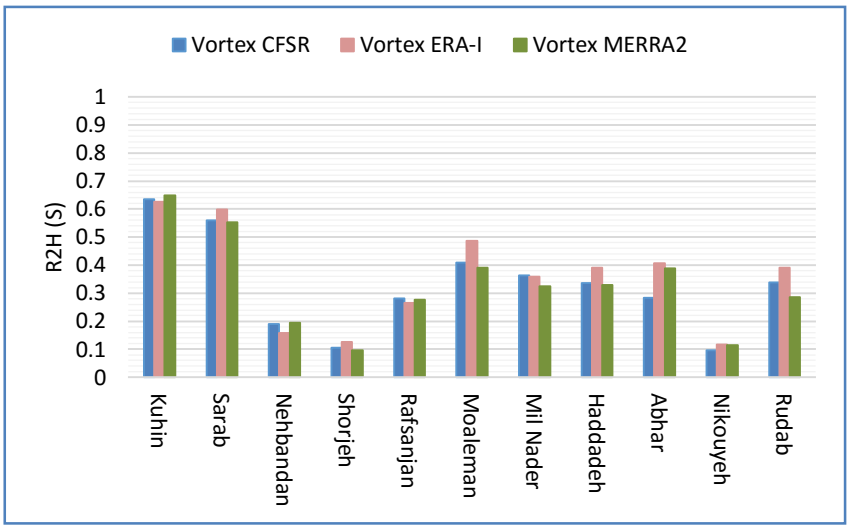

Figure 3- *Hourly correlation factor of Vortex Series for wind speed*

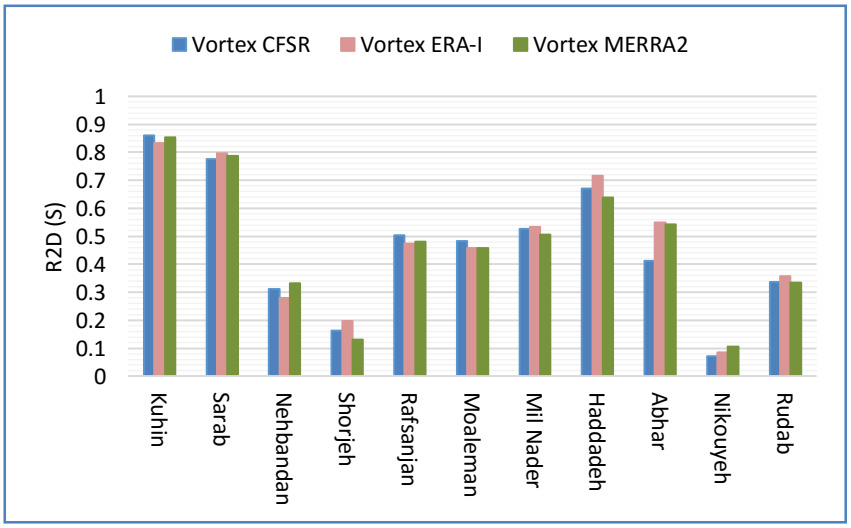

Figure 4- *Daily correlation factor of Vortex Series for wind speed*

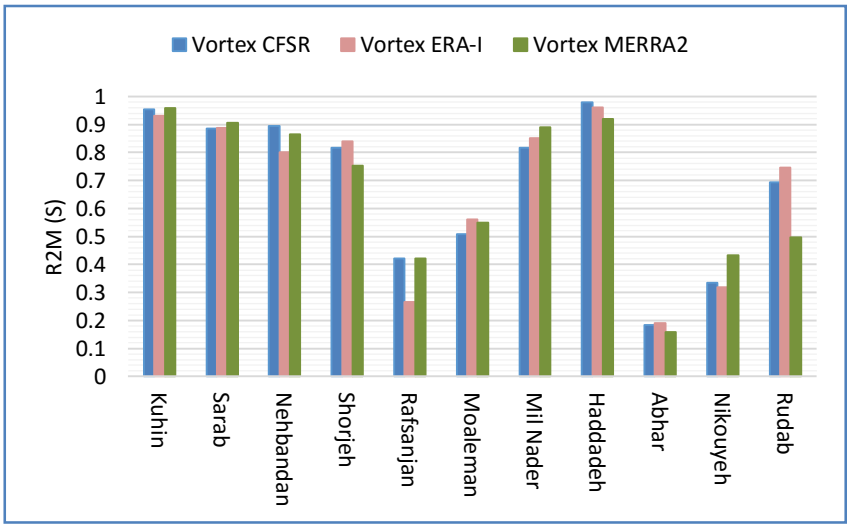

Figure 5- *Monthly correlation factor of Vortex Series for wind speed*

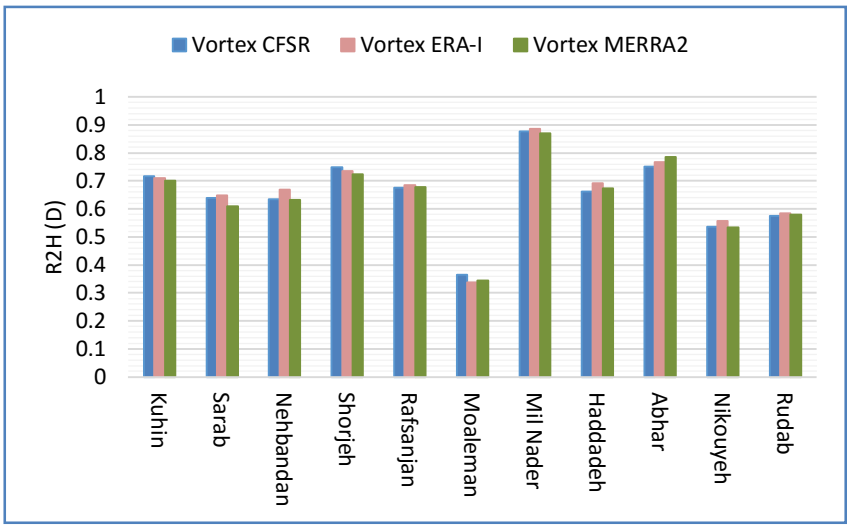

***Figure 6**- Hourly correlation factor of Vortex Series for wind direction*

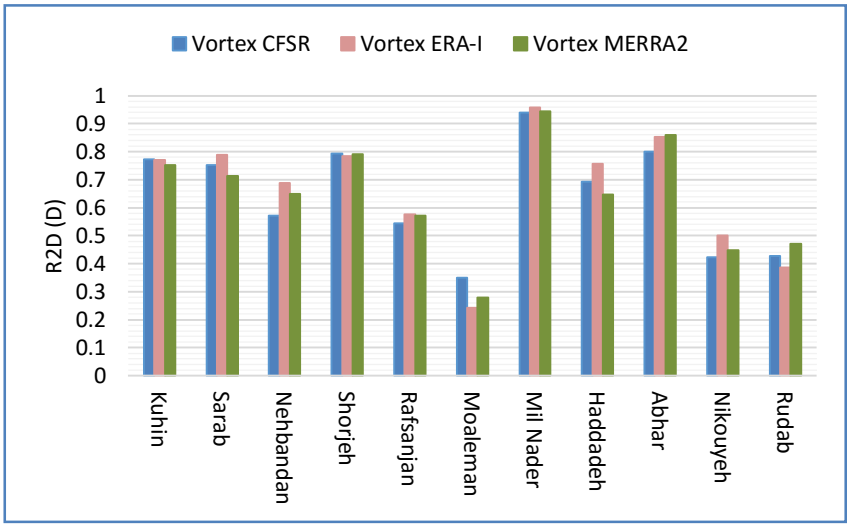

***Figure 7**- Daily correlation factor of Vortex Series for wind direction*

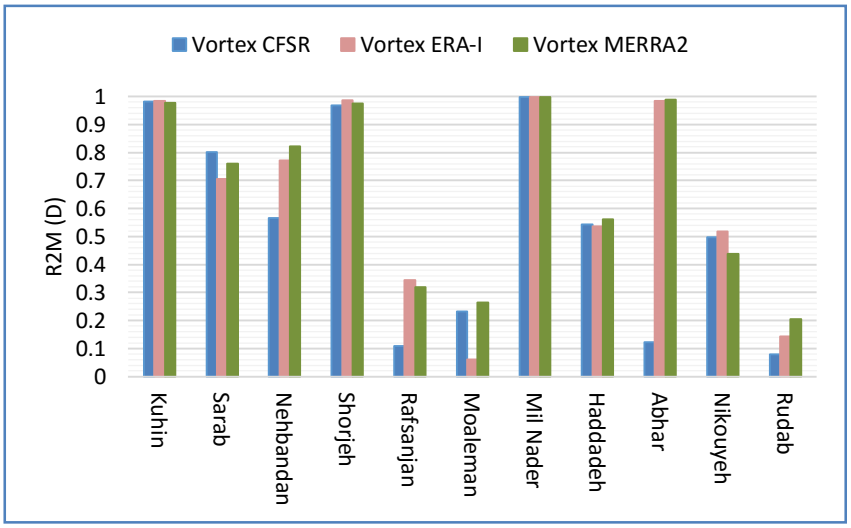

***Figure 8**- Monthly correlation factor of Vortex Series for wind direction*

4. Conclusion

In this study mean absolute errors of wind speed for Vortex Mast and Series are calculated. The average errors are shown in figure 9. As it is shown, the average error of Vortex Mast is less than Vortex Series since the resolution for Vortex Mast is 100m while it's 3km for Vortex Series.

The average speed error of Vortex Mast is around 10 %, hence, they are useful to be considered at prospecting stages to decide where to install a real met, in order to save time and money.

Moreover, other metrics like BIAS or the standard deviation of the errors are better for Vortex MAST.

The correlation factors for both wind speed and wind direction between Vortex Series and measured wind data are calculated as well in this study. The average values are shown in figure 10. The results indicate that the Vortex Series can be used in high quality for MCP (Measure, Correlate and Predict) process.

For the above reasons we do recommend to use **Vortex Mast** for prospection and site hunting and the **Vortex time series** for correlation purposes once a met tower have been installed during a 1 year period.

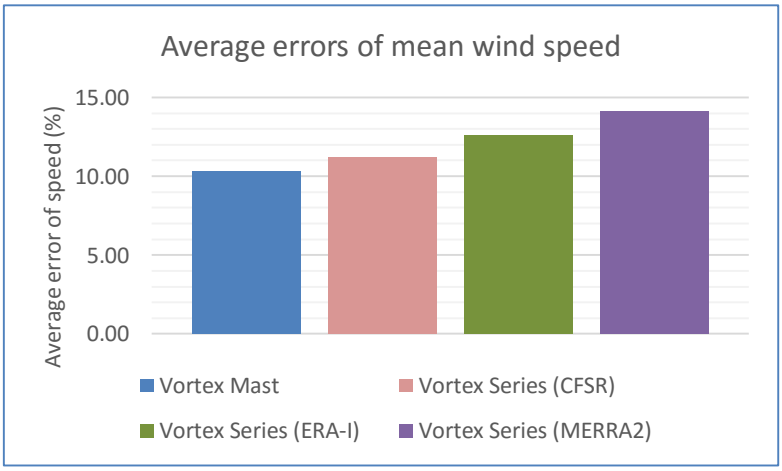

Figure 9- *Average mean absolute errors of wind speed*

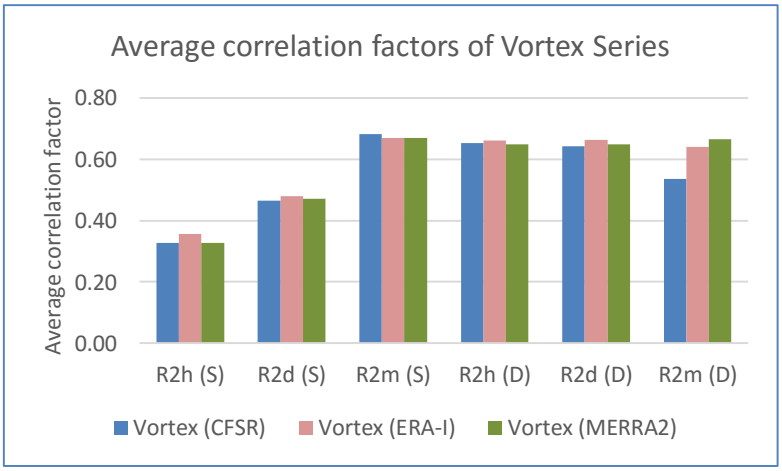

Figure 10- *Average correlation factors of Vortex Series*

ON GOING VALIDATION:

If you installed a met mast in Iran and you want to participate in the validation we are performing in Iran between our Mast and Series data and your local measured wind data, please contact us.

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