Intra-farm Wind Speed Variability Observed by Nacelle Anemometers in a Large Inland Wind Farm

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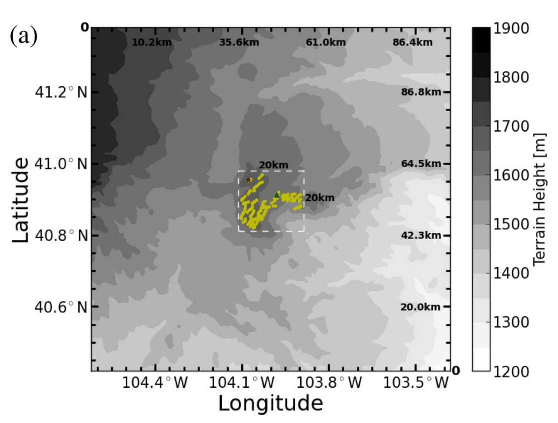
Introduction

Concerning that a large inland wind farms are often constructed over heterogeneous surfaces such as mountainous areas, it is critical to understand the significance of variability of intra-farm wind flows as they influence power production. In the research, we studied the spatial and temporal characteristics of wind speed measurements by nacelle anemometers at 274 wind turbines in a large wind farm of an area of about 20 km by 20 km. Our hypothesis is that spatial variability of wind speed in a wind farm on scales ≤ O(10 km) is associated with temporal variability on scales ≤ O(10 h) [Manwell et al.,2010; Orlanski,1975; Stull,1988]. We also discuss the intra-farm spatial and temporal variability of wind speed in terms of the accuracy of wind power production estimates.

DATA

Turbine map



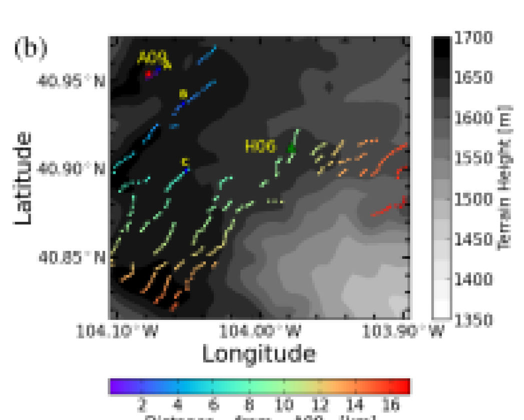
Total 274 wind turbines: 69 m hub height for 221 and 80 m for the rest.

15 minute averaged from 3 cup-anemometer measurements on the nacelle.

From 1 January to 30 November 2012

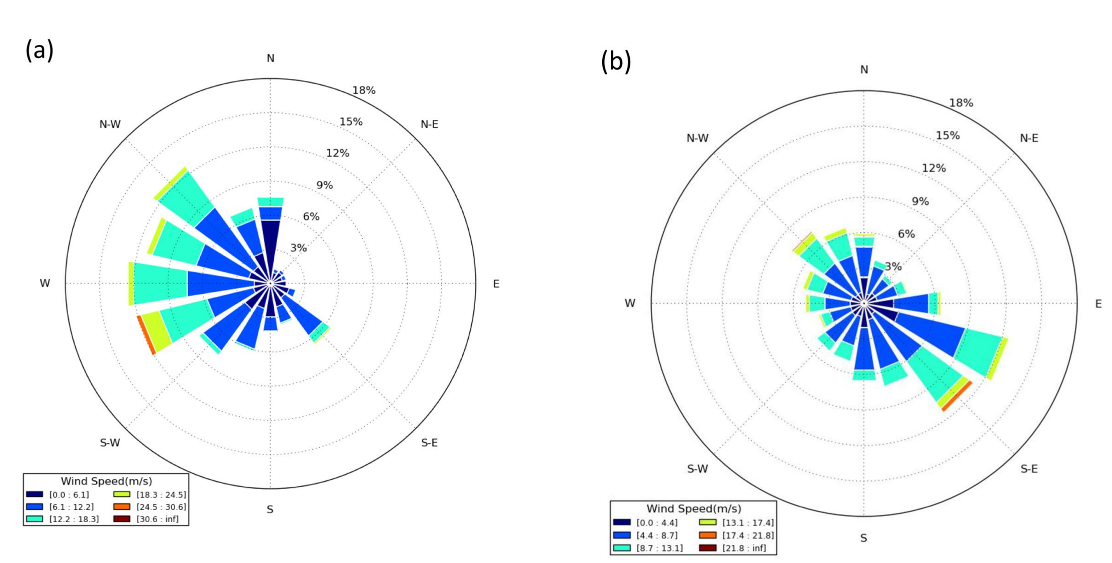
Each 5 weeks from winter and summer;

-The longest consecutive missing point ≤ 3 hours



Month	Missing points/Total points (%)	Median of the longest periods of consecutive missing data points (hours)
January	2	0.75
February	10	2.75
March	22	10
April	32	43.25
May	7	4.25
June	15	1.25
July	11	4.75
August	7	2.25
September	16	6.25
October	10	5.5
November	20	13
Total 11 months	14	3.75

Wind Rose for Winter and Summer

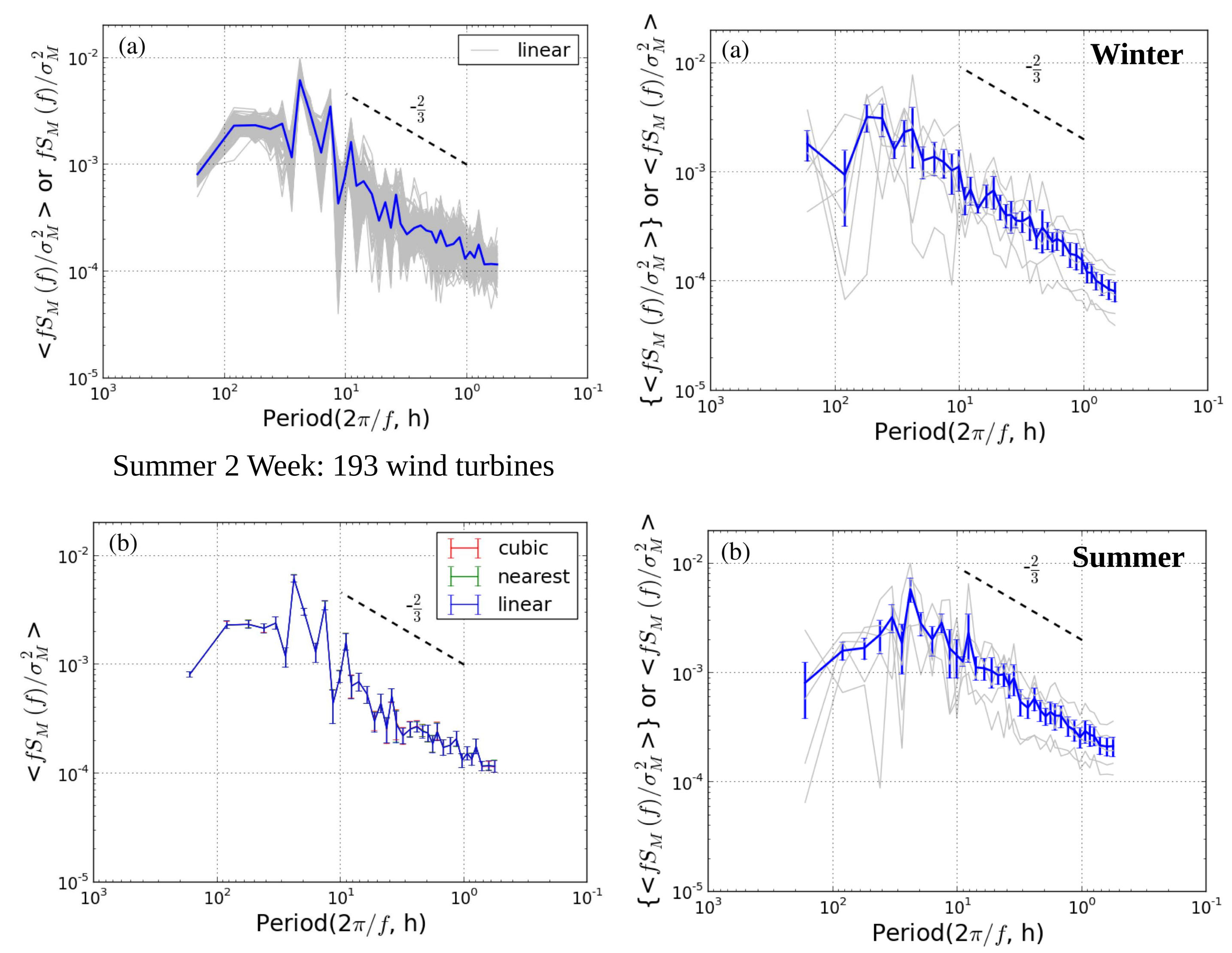


Winter **Summer**

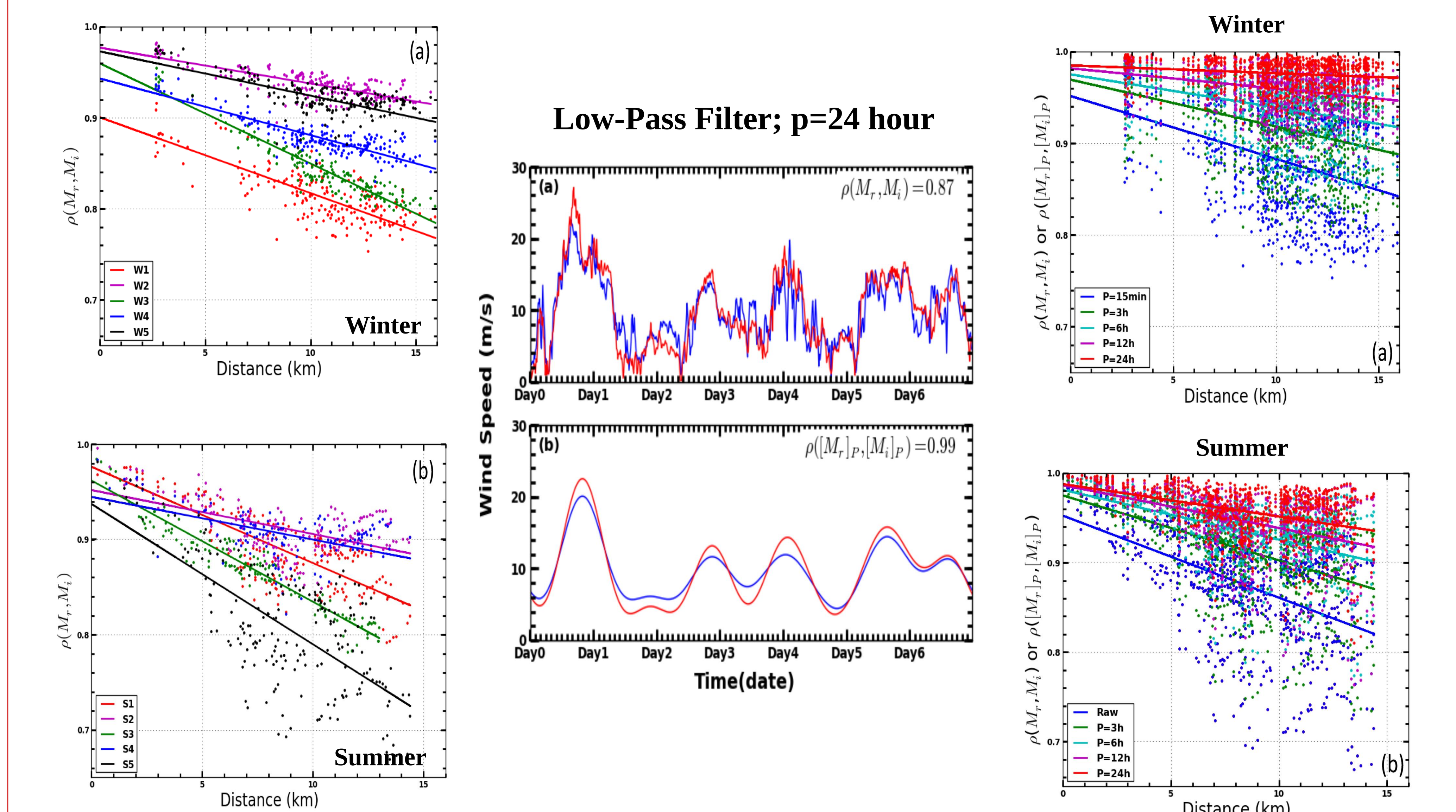
The number *N* of nacelle anemometers whose time series have the longest period of consecutive missing points ≤ 3 hours, the percentage *R* of missing points out of the total data points, the median value *Me* of the longest periods of consecutive missing points over the 274 anemometer time series.

Season	Week	*N*	*R* (%)	*Me* (h)	Reference turbine
Winter	W1	196	0.9	0.75	A
	W2	199	0.7	0.75	A
	W3	168	3	2.75	A
	W4	199	0.2	0.25	A
	W5	199	2	1.00	A
Summer	S1	195	0.3	0.25	B
	S2	193	1.6	1.25	B
	S3	137	1.8	0.75	C
	S4	137	1.5	1.25	B
	S5	198	1.4	1.75	B

Dominant Time Scales of Wind Speed Fluctuations

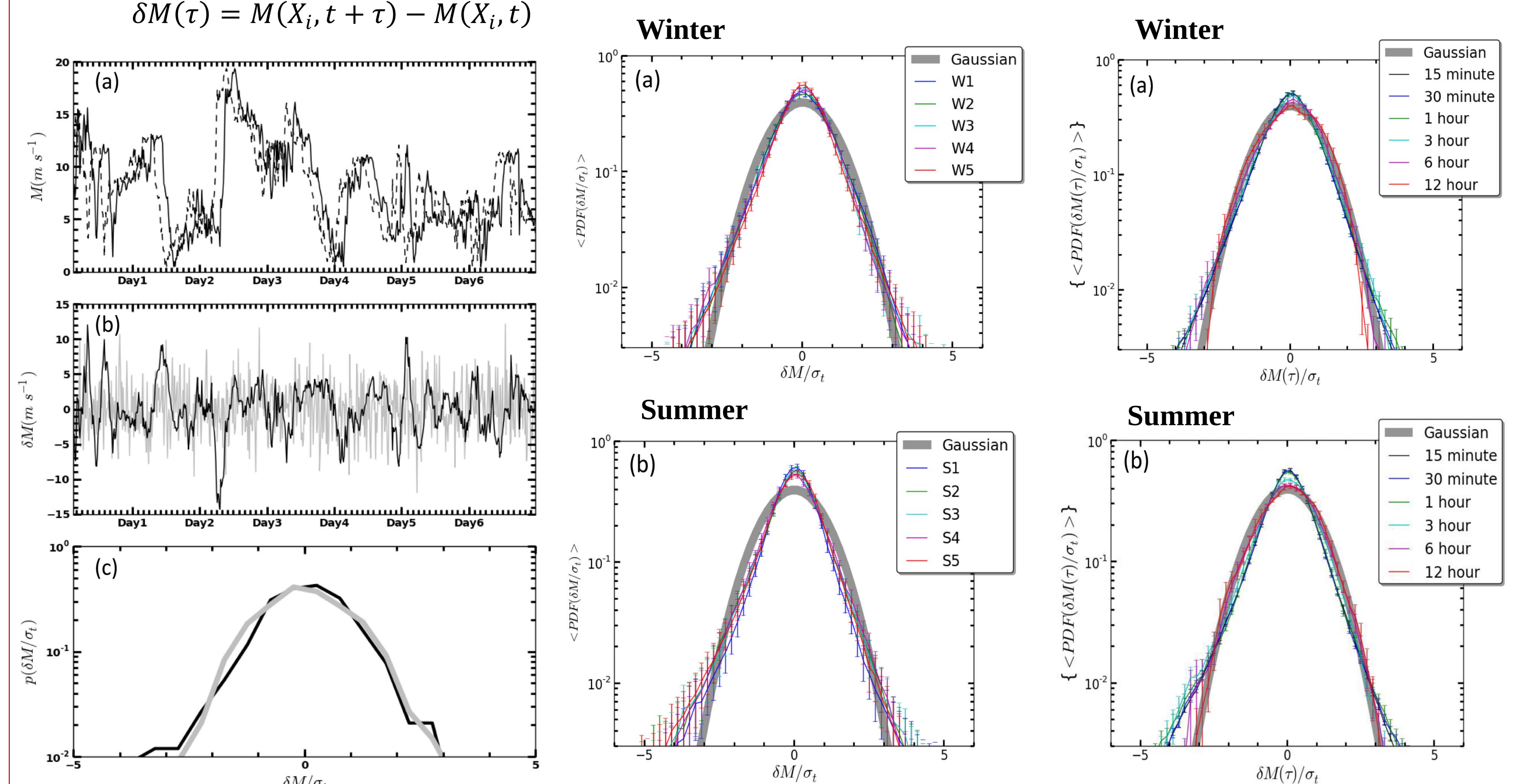


Spatial correlations between the intra-farm time series

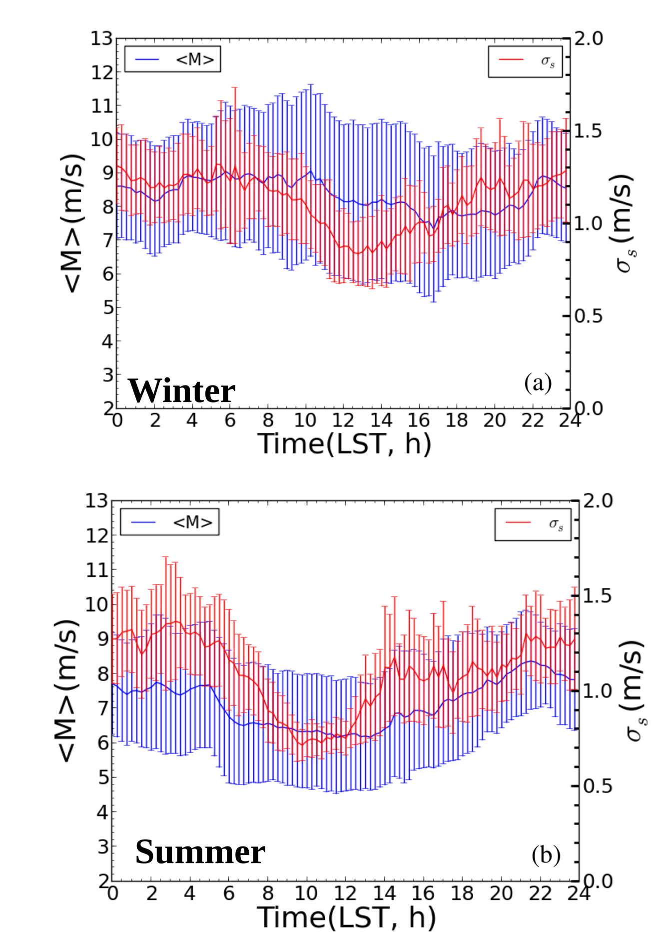


Probability Density Functions (PDFs) of Temporal Velocity Increments

$$\delta M(\tau) = M(X_i, t+\tau) - M(X_i, t)$$

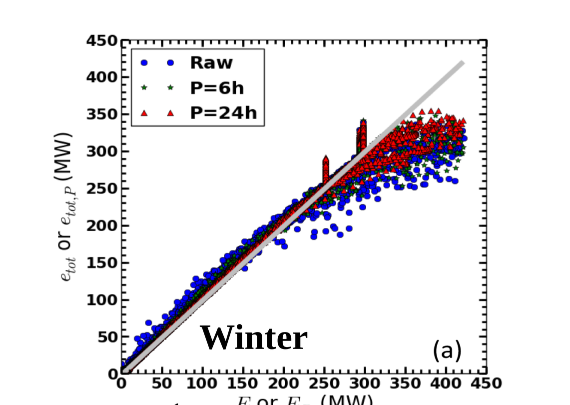


Diurnal variation of wind speed

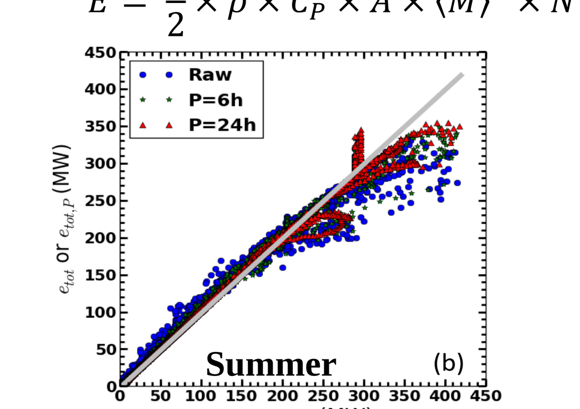


Intra-farm wind speed variability and wind power production

$e = \frac{1}{2} \times \rho \times C_P \times A \times M^3$ $\quad e_{tot} = \sum_{i=1}^{N} e_i$



$$E = \frac{1}{2} \times \rho \times C_P \times A \times \langle M \rangle^3 \times N$$



Conclusion

During summer the influence of diurnal variation is the most significant factor on wind flow in temporal scale, while the spectral peak during winter is located at longer than 24 hours.

Correlation coefficients are larger during winter than during summer with as well as without temporal low-pass filter.

The wind speed temporal intermittency is more significant during summer than during winter.

Rapid wind ramp-down events are much more frequent, on temporal scales ≤ 3 h, during both winter and summer than a Gaussian PDF suggests.

The effect of the intra-farm variability becomes more significant when the wind power production is greater.

Reference

Manwell JF, McGowan JG, Rogers AL. WIND ENERGY EXPLAINED THEORY, DESIGN AND APPLICATION. 2nd ed. John Wiley & Sons LTD: United Kingdom, 2010; 28, 37.

Orlanski I. A rational subdivision of scales for atmospheric processes. Bulletin of the American Meteorological Society 1975; 56: 527–530.

Stull R. An Introduction to Boundary Layer Meteorology. Springer, 1988; 20.