

Evaluation method for offshore wind energy resources using scatterometer and weibull parameters

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The Great Wave off Kanagawa (Hokusai, 1831)

Can Satellite Sampling of Offshore Wind Speeds
Realistically Represent Wind Speed Distribution?

J. Applied Meteorology (Barthelmie and Pryor,
2003)

Uncertainties for evaluating offshore wind energy resources based on wind speed estimates

1. In situ measurement → cost, spatial representation
2. Mesoscale model → spatial resolution, wind speed accuracy
3. Scatterometer → wind speed accuracy, **operational wind speed range of SeaWinds (3<V<20m/s)** and **SeaWinds sampling time**

Purpose

to evaluate accuracies of scatterometer-derived offshore wind energy resources such as Weibull mean wind speed and energy density by considering uncertainties inherent in scatterometer wind speed estimates.

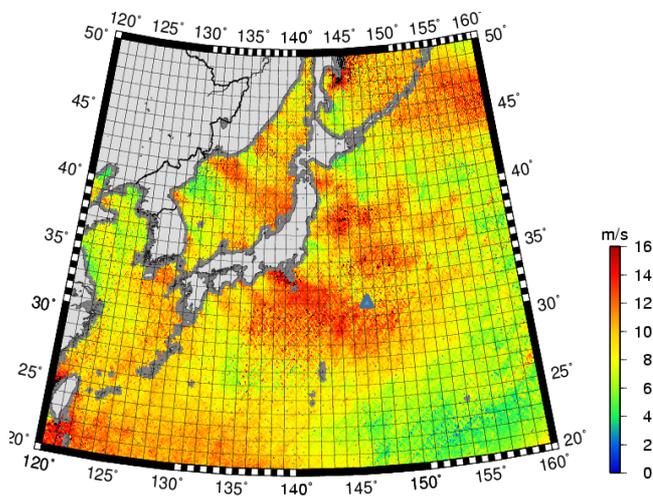


Fig.1 Study area covered by SeaWinds onboard QuikSCAT during the period from Jan.1 to 3, 2008. (A triangle indicates the location of the KEO buoy.)

Table 1 Specifications of QuikSCAT and SeaWinds

Orbit	Sun-synchronous
Altitude	803km
Inclination	98.616deg
Local time	09h, 21h(UT)
Frequency	13.4GHz(Ku band)
Coverage	90% of ice-free ocean everyday
Spatial res.	25km
Wind speed	RMSE 2m/s(3~20m/s) (Equivalent Neutral Wind at 10m)
Wind direction	RMSE 20deg
Period	Jun.2004-Dec.2008
No.of scene	1159

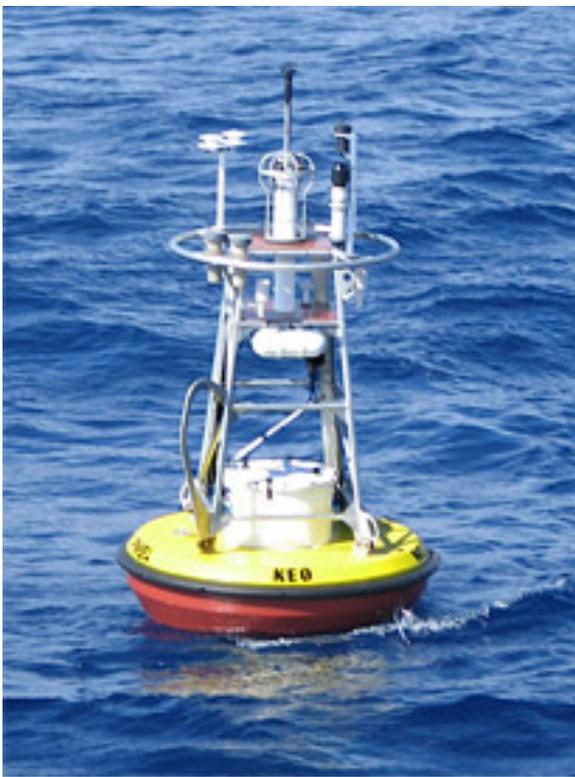
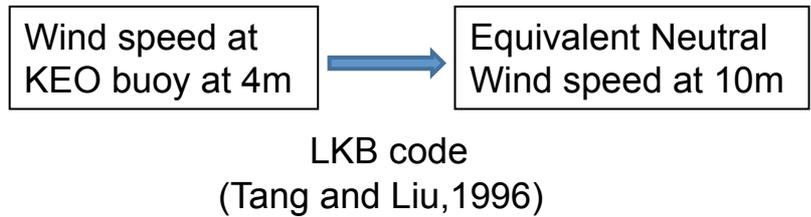


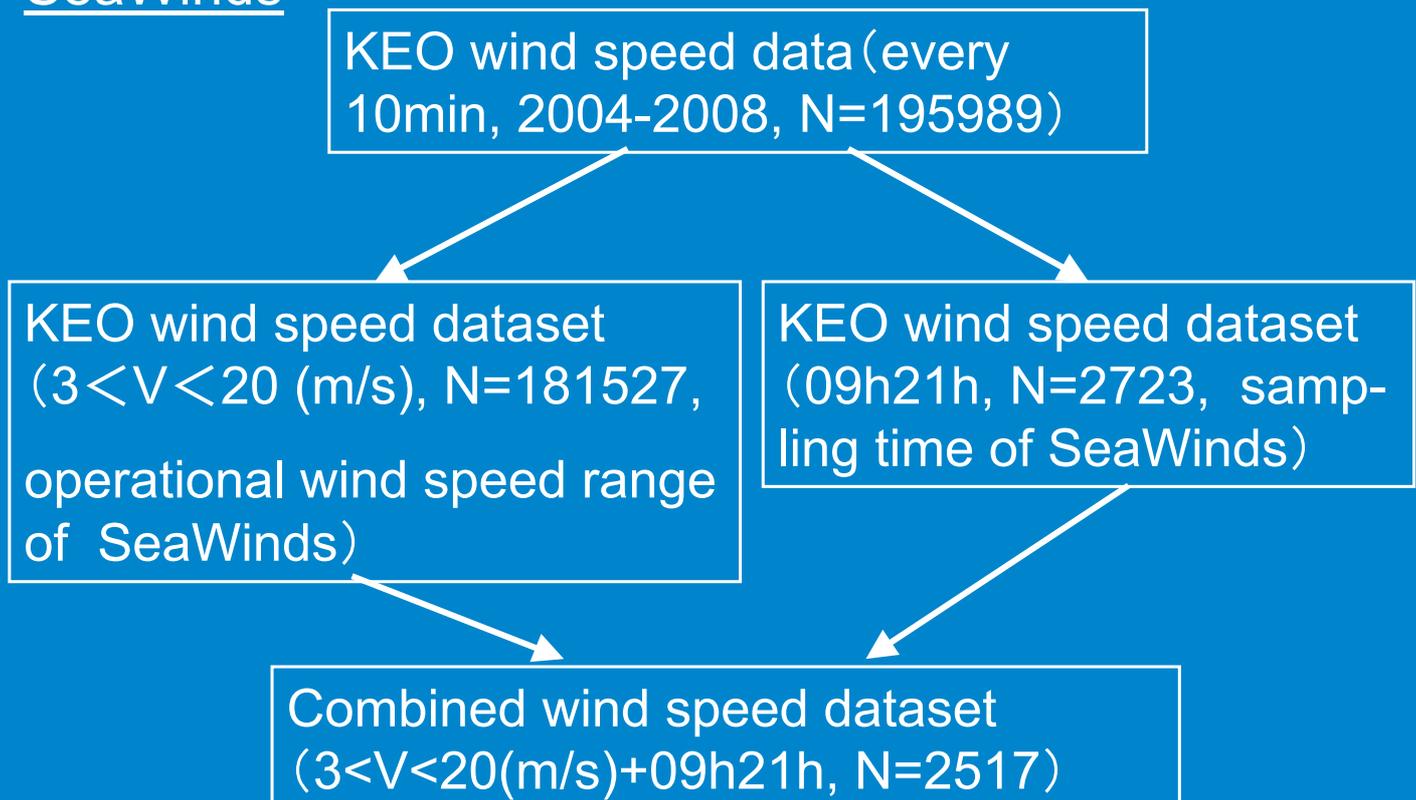
Table 2 Specifications of the KEO buoy for wind speed measurement (<http://www.pmel.noaa.gov/keo/>, Cronin et al.(2006))

Location	144.6E, 32.4N
Period	Jun. 2004-Dec.2008
Sensor type	Sonic anemometer
Measurement height	4m
Resolution	0.1m/s
Range Coverage	0-65m/s
Accuracy	±0.135m/s or 3%
No.of data	195989

Fig.2 KEO buoy
(<http://www.pmel.noaa.gov/keo/>)



Generation of KEO wind speed datasets for simulating operational wind speed range and sampling time of SeaWinds



Statistical models based on Weibull parameter

Weibull probability density function

$$f(v) = \frac{k}{A} \left(\frac{v}{A}\right)^{k-1} \text{Exp}\left(-\left(\frac{v}{A}\right)^k\right)$$

where v:wind speed, k: shape, A: scale

Weibull mean wind speed

$$V_m = \int_0^{\infty} v f(v) dv \quad \Rightarrow \quad V_m = A \Gamma\left(1 + \frac{1}{k}\right)$$

Γ : Gamma function

Available energy density (W/m²)

$$P_v = \frac{1}{2} \rho_a v^3$$

Available energy density for all wind speed (W/m²)

$$E_d = \int_0^{\infty} P_v f(v) dv \quad \Rightarrow \quad E_d = \frac{\rho_a A^3}{2} \Gamma\left(1 + \frac{3}{k}\right)$$

Flowchart of Weibull statistical analysis

Wind speed dataset

Estimating scale and shape using maximum likelihood method

Estimating standard error of scale and shape using inversion of information matrix

Estimating Weibull mean wind speed and energy density using maximum likelihood method

Estimating standard error of Weibull mean wind speed and energy density using Delta method

Estimating 90% confidence interval

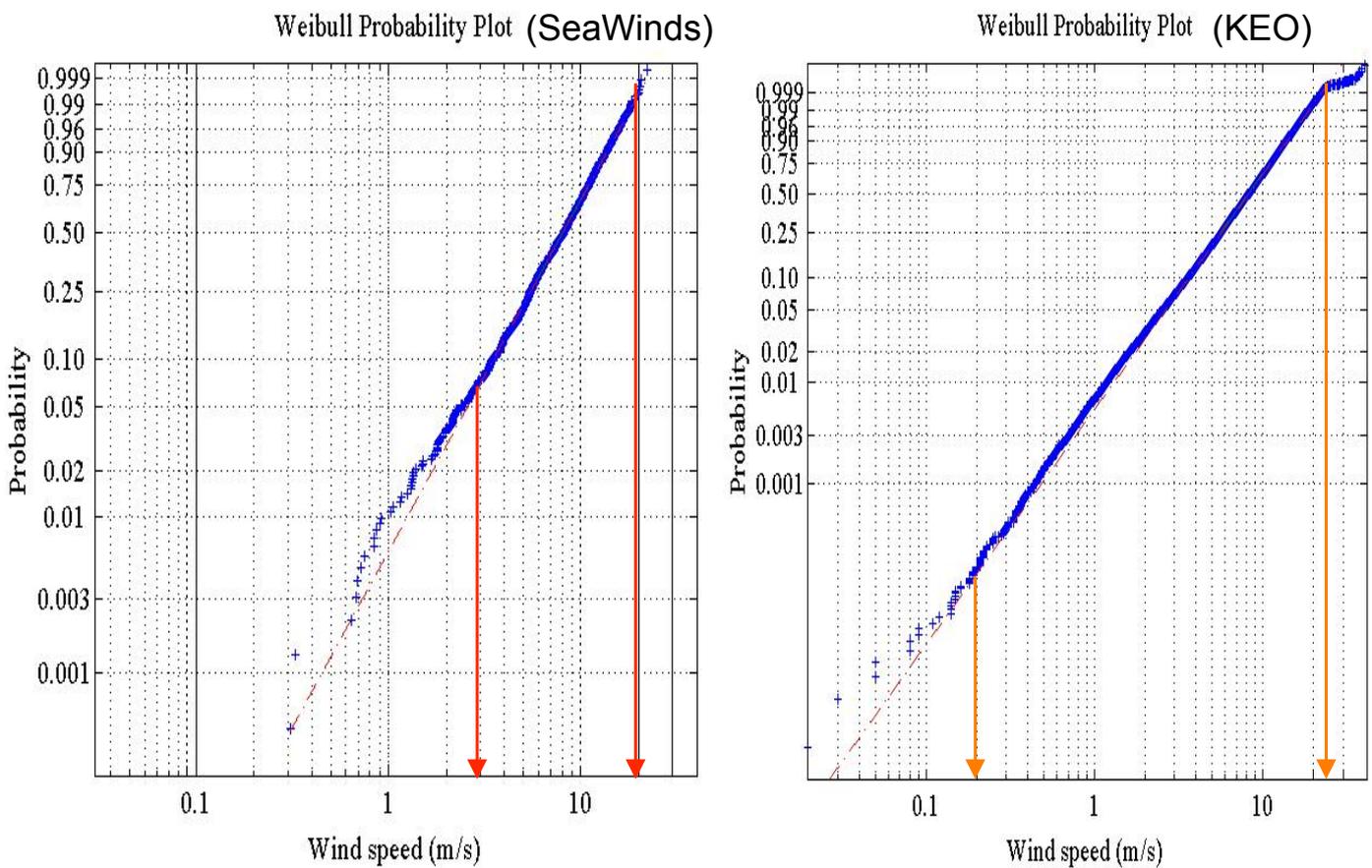


Fig. 3 Weibull probability plot (left: SeaWinds-derived wind speed, N=1159, right: in situ wind speed, N=195989)

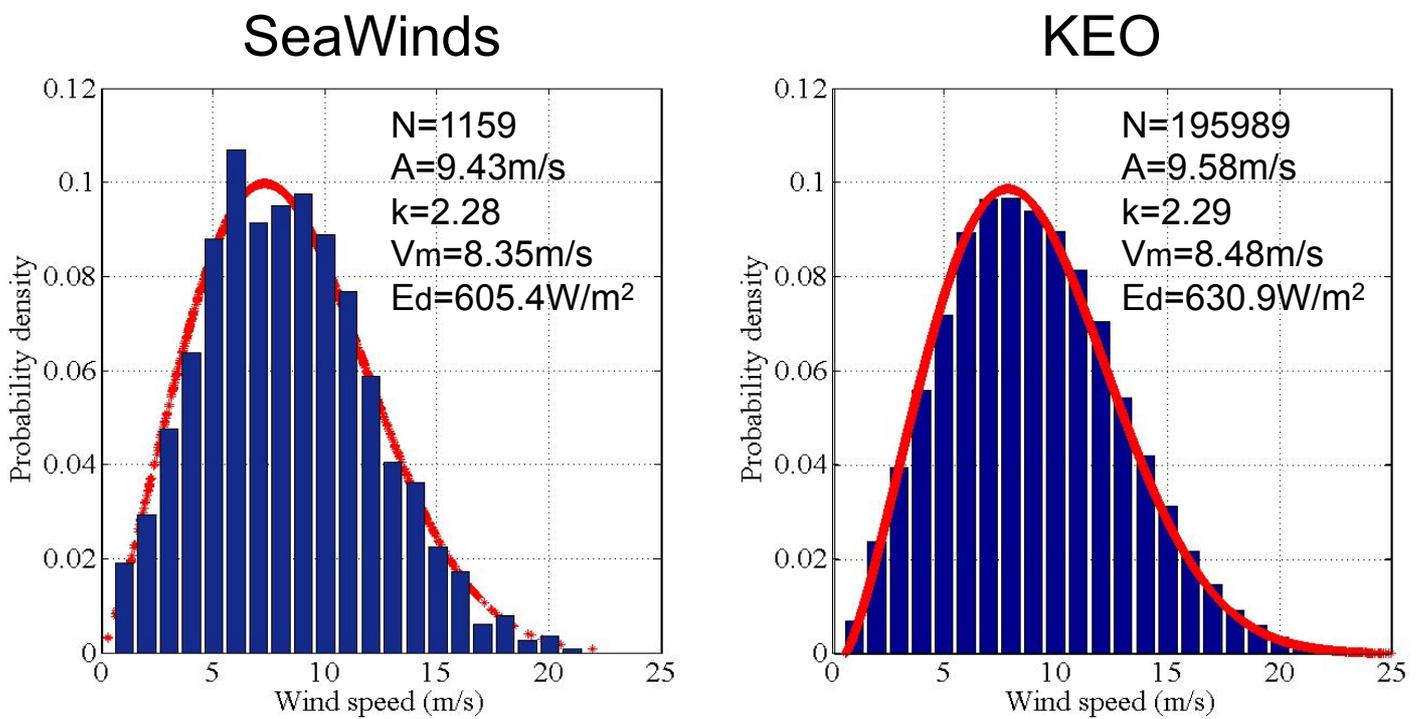


Fig.4 Weibull probability density functions overlaid with wind speed histograms (left: SeaWinds-derived wind speed, right: KEO wind speed)

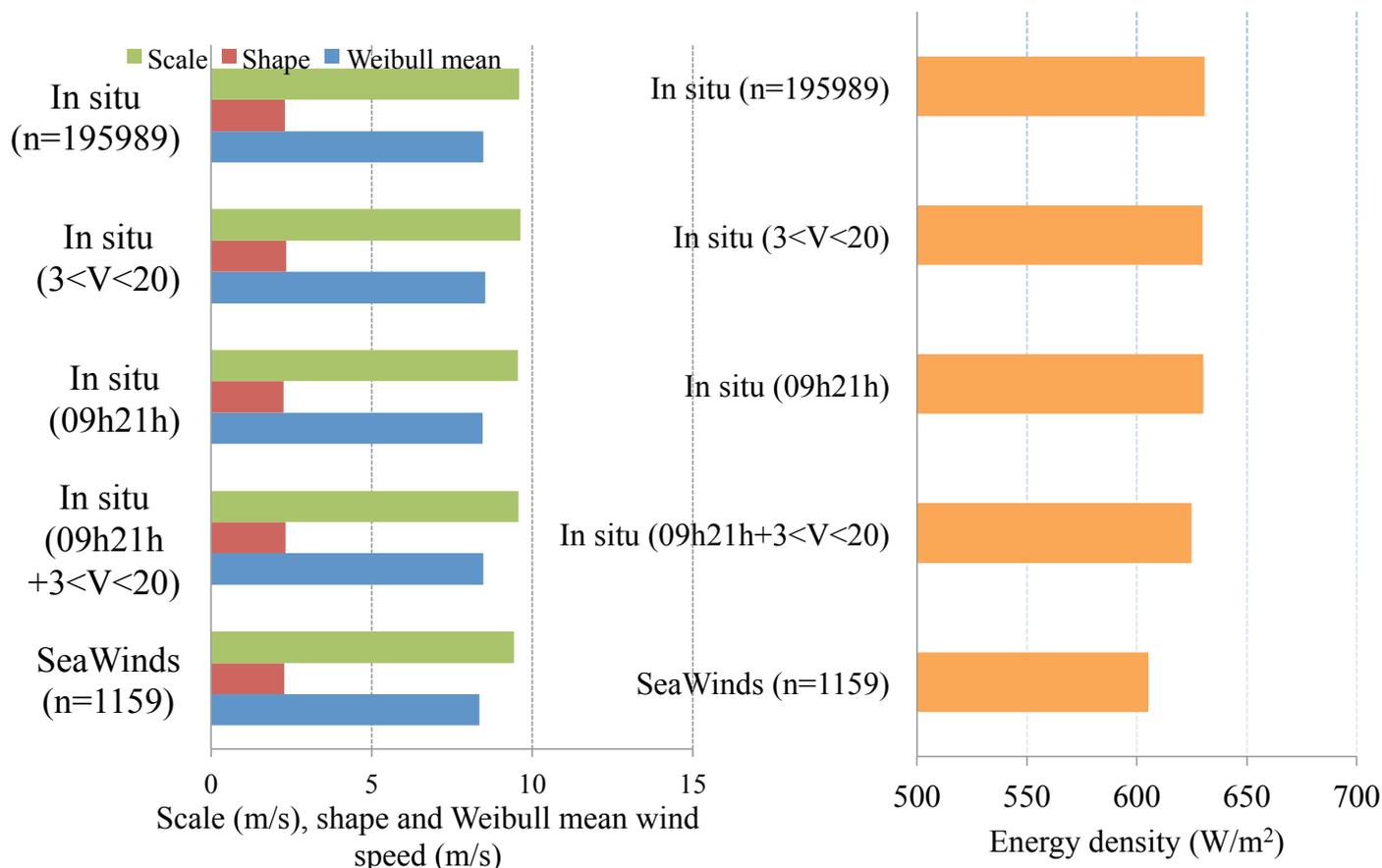


Fig.5 Comparison of wind speed statistical parameters based on 3 simulated datasets for (1) operational wind speed range ($3 < V < 20$), (2) SeaWinds sampling time (09h, 21h (UT)) and (3) combination of (1) with (2) (left: scale, shape and Weibull mean wind speed, right: Weibull energy density)

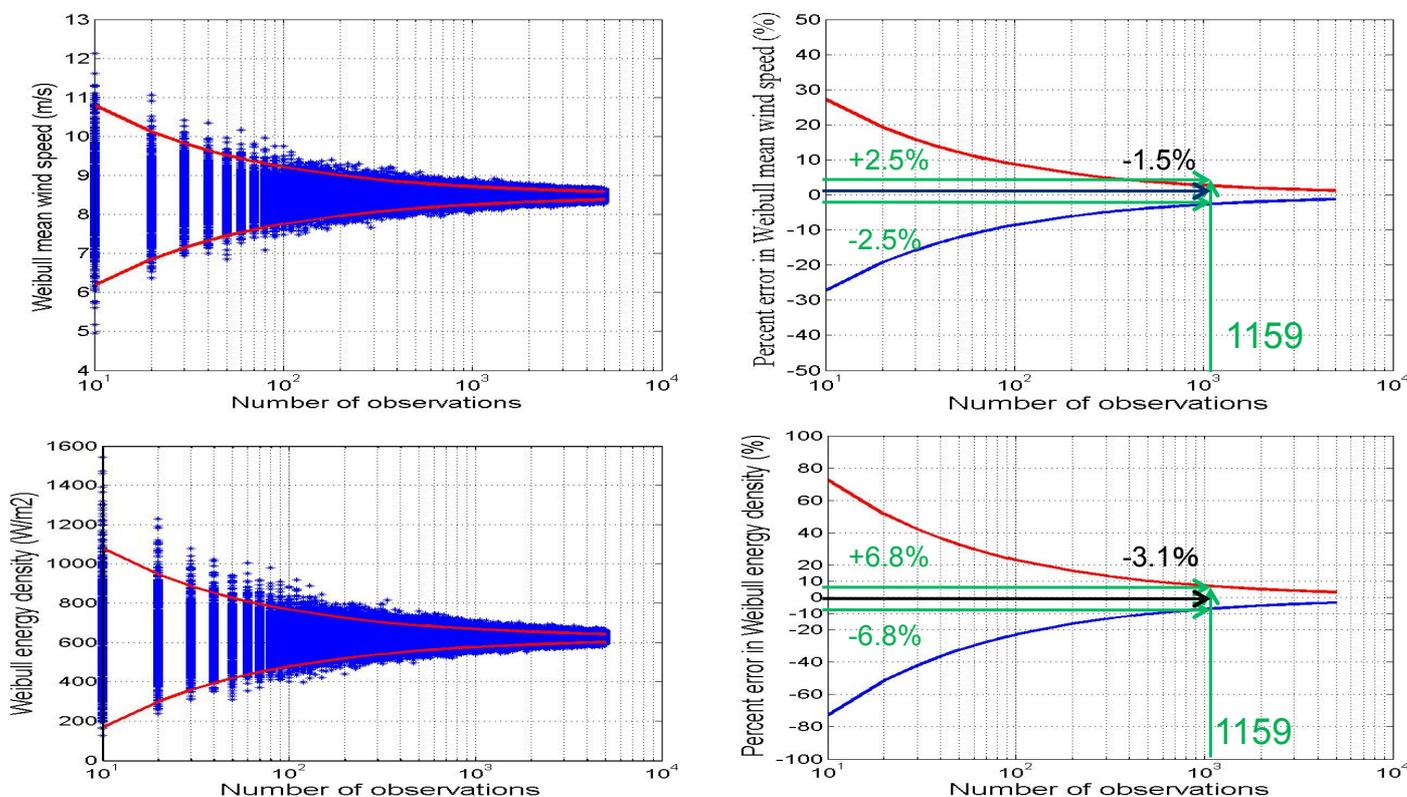


Fig. Estimated Weibull mean wind speed(upper left) and energy density (lower left) corresponding to the operational range of SeaWinds and SeaWinds sampling time (09h, 21h(UT)) overlaid with upper and lower bounds of 90% confidence interval indicated as red lines. Percent error curves in Weibull mean wind speed (upper right) and energy density (lower right) corresponding to 90% confidence interval and SeaWinds-derived Weibull mean wind speed and energy density are also indicated.

Conclusions

(1) Uncertainties associated with SeaWinds-derived wind speed estimates (operational wind speed range, sampling time) show small differences of Weibull mean wind speed and energy density among the simulated datasets based on KEO buoy wind speeds.

(2) The upper and lower bounds of 90% confidence interval corresponding to SeaWinds number of observations indicate $\pm 2.5\%$ error of Weibull mean wind and $\pm 6.8\%$ error of energy density respectively.

(3) SeaWinds-derived Weibull mean wind speed and energy density for 5 years are found to be -1.5 and -3.1% errors within 90% confidence interval respectively.

Acknowledgements

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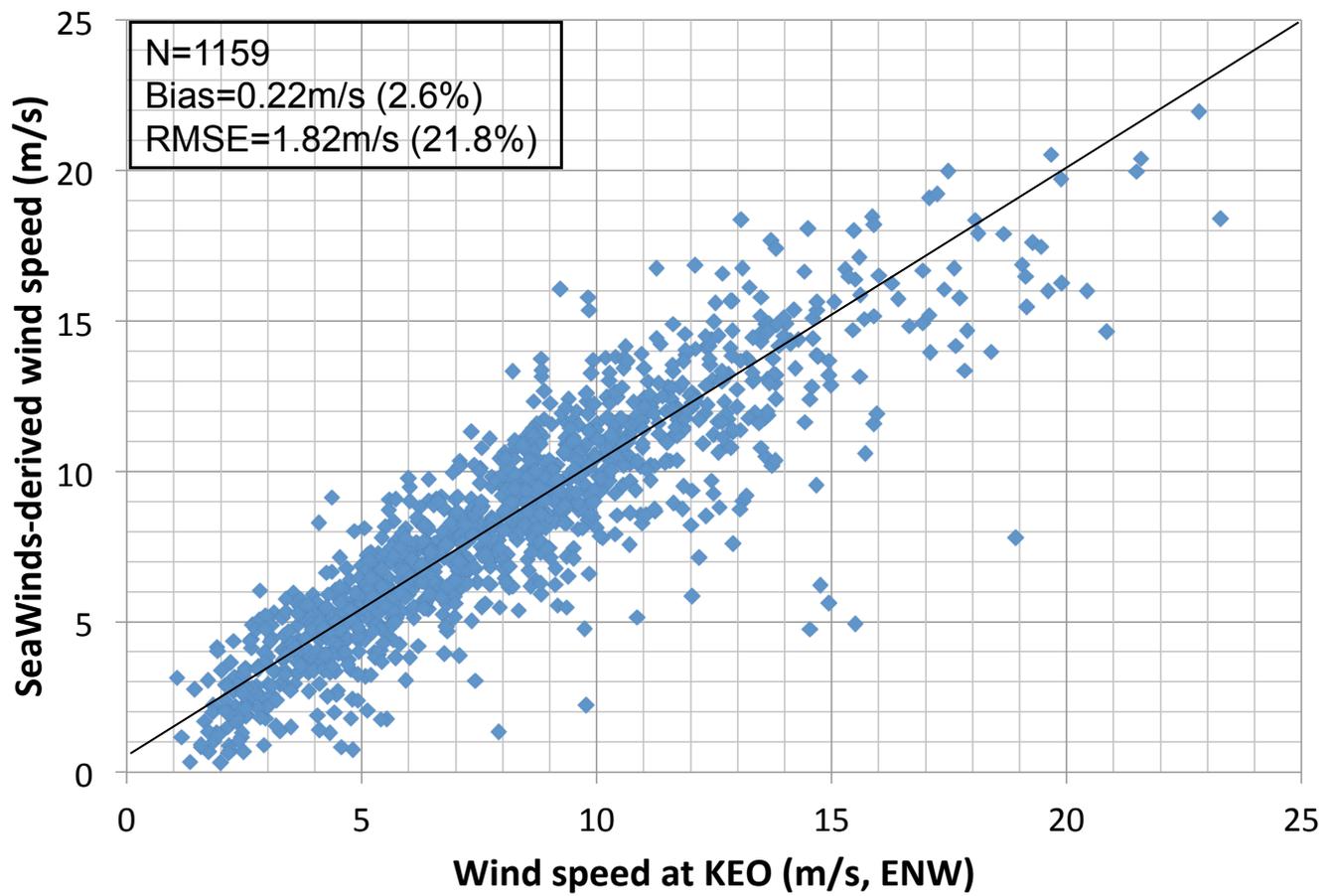


Fig. Comparison of SeaWinds-derived wind speed with wind speed at KEO buoy.