Improved Monte Carlo simulation method for OWT design exposed to Tropical Cyclones

Paul Renaud[1], Nicolas Raillard[2], Jean-François Filipot[1]
[1] France Energies Marines, Plouzané, France | [2] IFREMER, Plouzané, France

EERA DeepWind CONFERENCE 2025

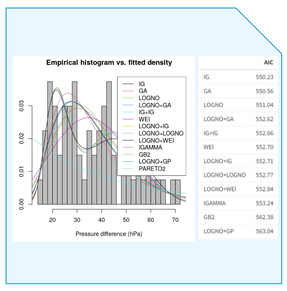
Context

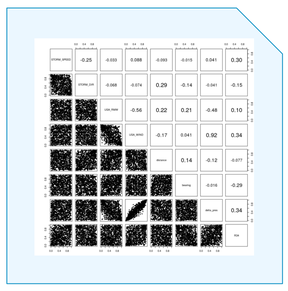
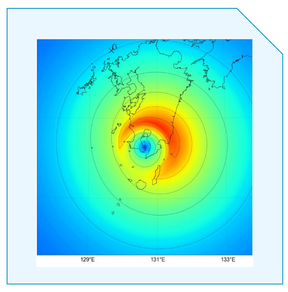
Typhoon Yagi caused damage to wind turbines in China

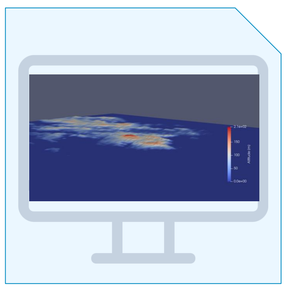
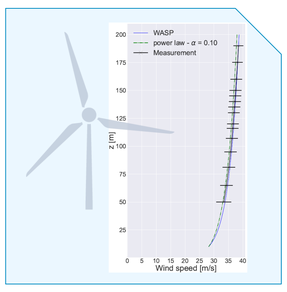
OROWSHI Project Objectives

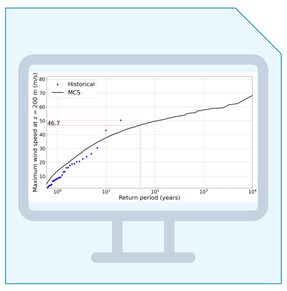
- To improve the current method recommended by IEC 61400-1 (Ishihara & Yamaguchi, 2015)
- To provide a versatile method applicable to any basin to derive the N-year wind speed at hub height

MCS Method



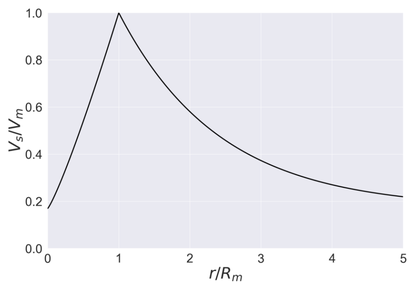
TC Parameters from IBTrACS	Fit Probability Density Functions	Fit Joint Distribution	Generation of a Synthetic TCs Database	Estimation of Surface Wind Speed	Speed-up Ratio (land effects)	Vertical Extrapolation at Hub Height	N-years 10-min Wind Speed
Parameters from the US Agency 2001-2024	16 PDFs > positive variables 10 PDFs > bounded variables Best fit selected with the **AIC**	3 Copula formula: Normal, Empirical Beta, Vine	10,000 years of TCs	Parametric surface wind model (Sym. + Asym.)	OpenFOAM utility	Low law using the drag coefficient from WASP	

OROWSHI Wind Model

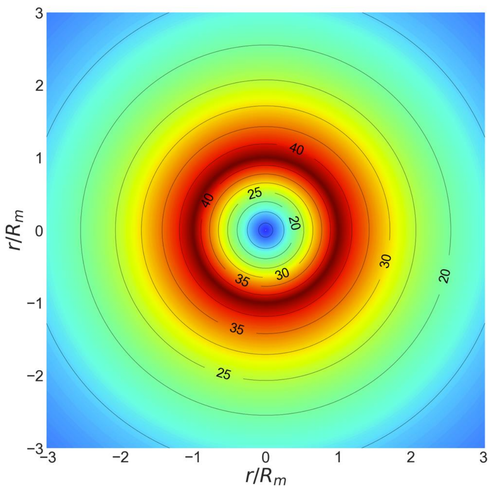
SYMMETRIC RADIAL PROFILE

- Model from Willoughby *et al.*, 2006
- Fitted on SAR dataset (Vinour *et al.*, 2024)

$$V_s(r) = \begin{cases} V_0 + (V_m - V_0)\left(\frac{r}{R_m}\right)^n & ; r \le R_m \\ V_0 + (V_m - V_0)e^{\left(-\frac{r-R_m}{X_1}\right)} & ; r > R_m \end{cases}$$



Adjustable parameters: V_0, n, X_1
Function of V_m, R_m, ϕ (latitude)

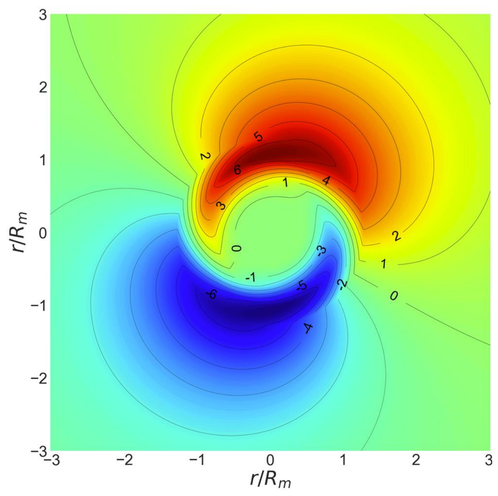


ASYMMETRIC RADIAL PROFILE

- Model from Olfateh *et al.*, 2017
- Fitted on SAR dataset (Renaud *et al.*, 2025)

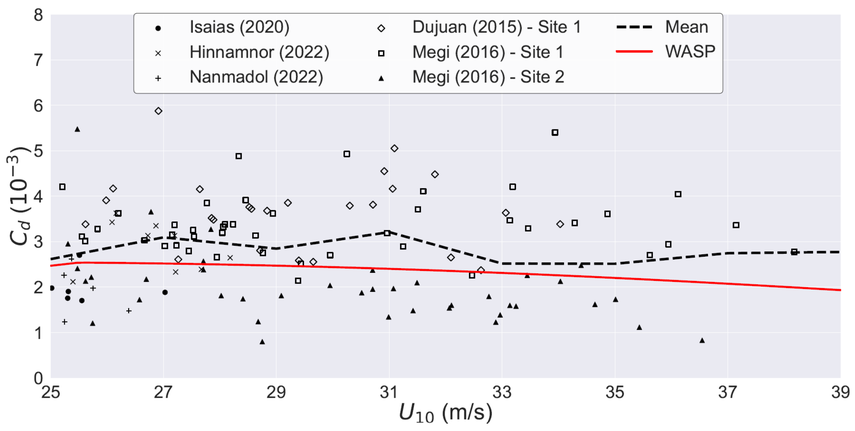
$$V_{as}(r) = \epsilon V_s(r)\sin(\delta + \alpha)\left[e\left(\frac{R_a}{r}\right)^D e^{-\left(\frac{R_a}{r}\right)^D}\right]^{1/2}$$

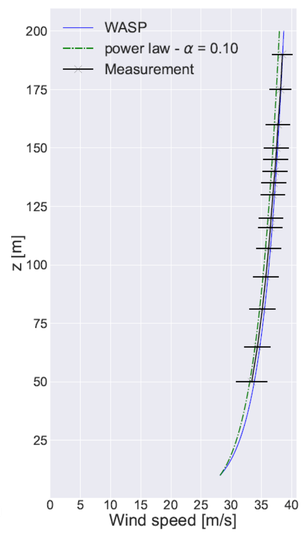
Adjustable parameters: ε, R_a, D, α
Function of V_m, R_m, C (translation speed)



VERTICAL EXTRAPOLATION

- Log law
- Drag coefficient from WASP (Bouin *et al.*, 2024)
- Consistent with in-situ data (Renaud *et al.*, 2025)

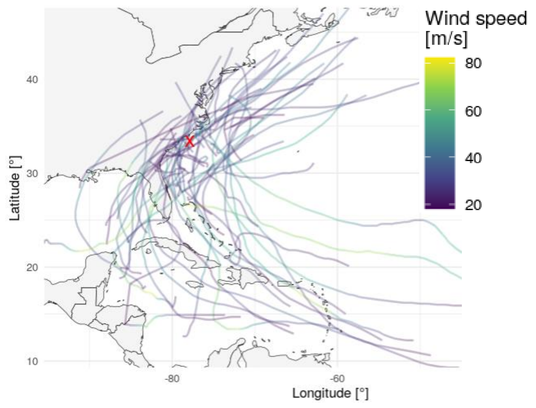


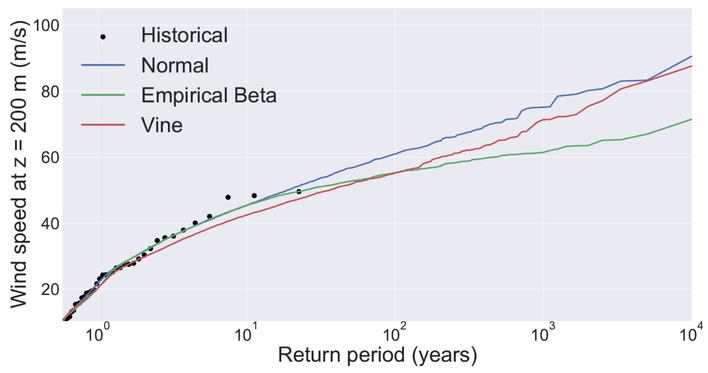


Application

US East Coast: 77.82°W 33.44°N

Parameter	PDF
Pressure difference	GA
Radius of maximum wind speed	IG
Radius of 34-kt	WEI
Maximum wind speed	IGAMMA
Storm translation speed	GA
Storm direction	Circular KDE
Distance to location	LOGITNO
Bearing to location	Circular KDE

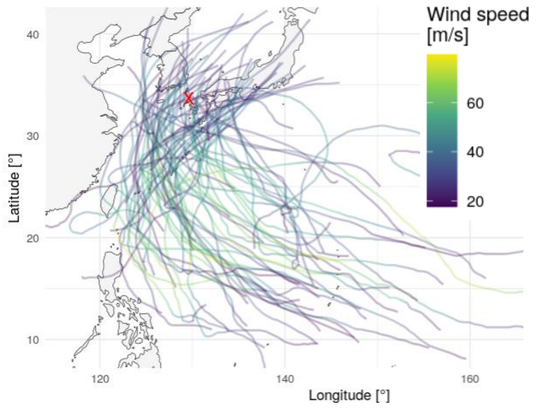


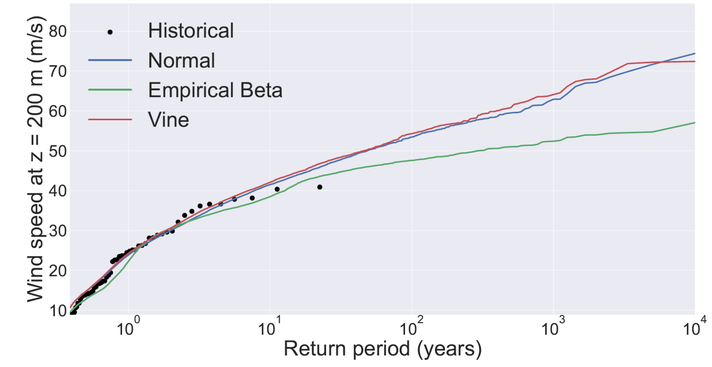


Copula formula	50-years wind speed at 200 m (m/s)
Normal	56.7
Empirical Beta	52.7
Vine	51.8

JAPAN: 129.62°E 33.70°N

Parameter	PDF
Pressure difference	GA
Radius of maximum wind speed	IG
Radius of 34-kt	WEI
Maximum wind speed	IG
Storm translation speed	WEI
Storm direction	Circular KDE
Distance to location	LOGITNO
Bearing to location	Circular KDE





Copula formula	50-years wind speed at 200 m (m/s)
Normal	50.2
Empirical Beta	46.0
Vine	50.4

Conclusion and Perspectives

- MCS applied to two sites of interest in different basins
- GoF criterion for model selection
- Uncertainty of the extreme wind from MCS

Implementation in a R/Shiny app

References

- Ishihara, T. & Yamaguchi, A. (2015) Prediction of the extreme wind speed in the mixed climate region by using Monte Carlo simulation and measure-correlate-predict method. Wind Energy
- Bouin, M.-N., *et al.* (2024) The wave-age dependent stress parameterization (WASP) for momentum and heat turbulent fluxes at sea in surfex v8.1. Geoscientific Model Development Discussions
- Vinour, L., *et al.* (2024) Review and Improvement of Tropical Cyclone Symmetric Surface Wind Parametric Models Using SAR Imagery, Journal of Applied Meteorology and Climatology
- Renaud, P., *et al.* (2025) Extreme wind speeds in Tropical Cyclones using parametric models (in preparation)

This work is part of the OROWSHI project which receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme (ANR-10-IEED-0006-34).