Normalization of Winds for Tropical Cyclone Comparisons Between Model and Measurements

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2025-09-22

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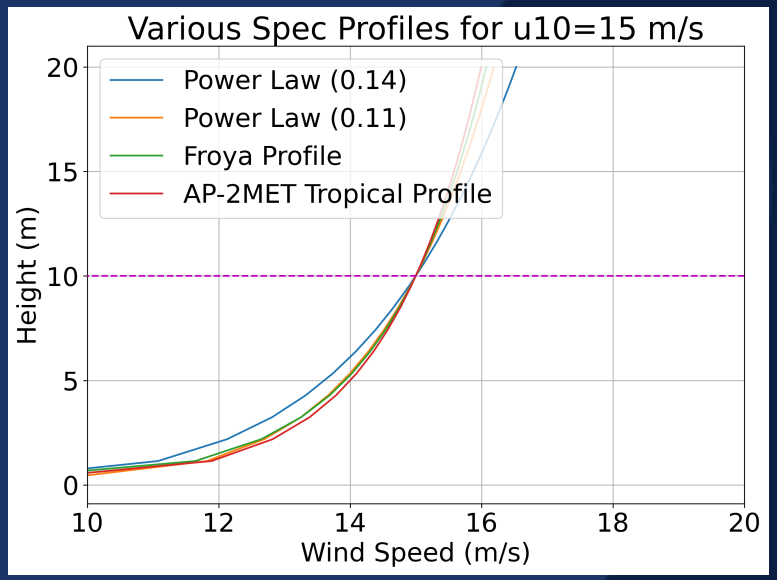
1. Introduction

1.1 Wind fields

10-meter neutral (mean) wind speeds

- Response model source term formulations
- Assumptions in offshore design standards



Marine winds

Over water we expect the winds to be a marine-equivalent exposure; roughness length $z_0(U)$

$$U_z = \frac{U_*}{\kappa} \ln \frac{z}{z_0(U_*)}$$

$$z_0 = \frac{a_c}{g} \left(\frac{\kappa U_z}{\ln \frac{z}{z_0}} \right)^{0.5}$$

1.2 Conventions in available data

Model-Obs. comparison requires consistent WS convention - 10m reference height

Neutral stability, "raw" exposure

- ERA5

Dynamic stability, "raw" exposure

- CFS/CFSv2
- WRF

Neutral stability, marine exposure

- OWITropPBL & USACE MORPHOS tropical cyclone models
- Satellite measurements

1.3 In-situ measurements

Offshore stations

- Height varies
- Marine exposure

Nearshore and coastal land stations

- Height varies; mixed or land exposure
  - **Upwind surface roughness lengths (z_0) from land-use/cover (LULC)**
- influenced by orographic effects from local topography

1.4 Legacy Solutions

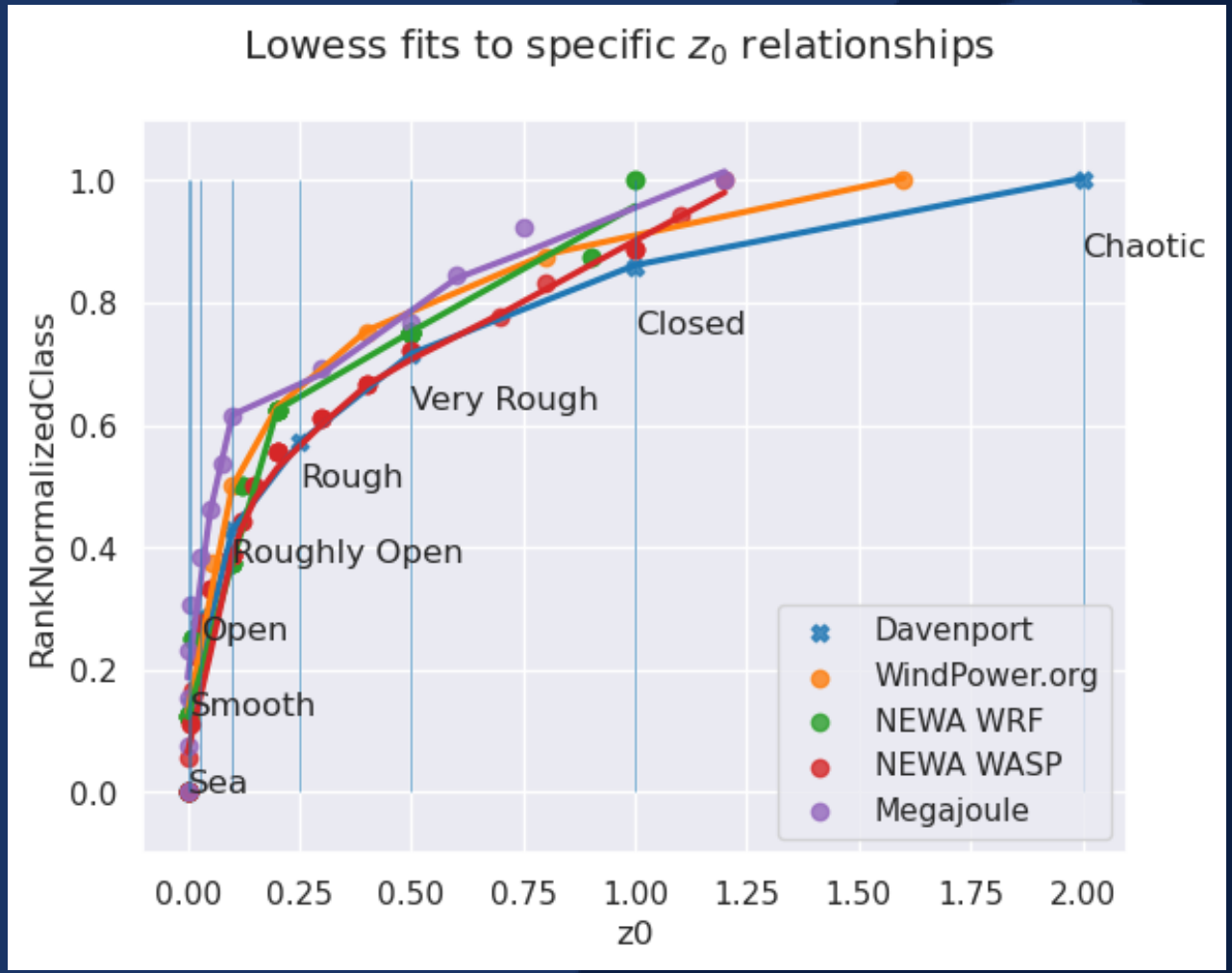
- Manual estimation from imagery using Davenport classes
- Available model domain coverage including directional z_0
  - ADCIRC
  - WRF
- Site-specific research/papers

2. Modern Global Approach

2.1 Semantic relationships

Many LULC systems

Few accepted mappings to z_0



2.2 Classification mapping to z_0

Dataset	Temporal Coverage	Resolution	Classification System
ESA WorldCover	2020-2021	10-meter	ESA-WorldCover subset of UN-LCCS
Impact Observatory (IO)	2017-2022	10-meter	ESRI simplification of IO's system

Class	Description	z0 (m)	ESA-WorldCover	ESRI
1	Urban fabric	1.2	50	7
2	Forests	0.75	10/95	2/4
3	Green urban areas; transitional woodlands/shrub; burnt areas	0.6	20	
4	Industrial, commercial and transport units	0.5		
5	Heterogeneous agricultural areas	0.3		
6	Permanent crops	0.1	40	5
7	Industrial commercial and transport units	0.075		
8	Arable land and marine wetlands	0.05	90	
9	Pastures	0.03	30/100	11
10	Mine, dump and construction sites	0.005		
11	Ice and snow	0.001	70	9
12	Wetlands	0.0005		
13	Open spaces with little or no vegetation	0.0003	60	8
14	Water bodies	0.0	80	0/1/3/6/10

Wetlands:

Coastal marshland $(z = 0.05)$

Mangroves $(z = 0.75)$

Megajoule Paper:
Silva, Julieta & Ribeiro, Carla & Guedes, Ricardo & Rua, Megajoule-Consultants & Ulrich, Frederico. (2007). Roughness length classification of Corine Land Cover classes. Proceedings of EWEC 2007.

2.3 Directional roughness dataset development

Effective roughness length by: point & upwind sector

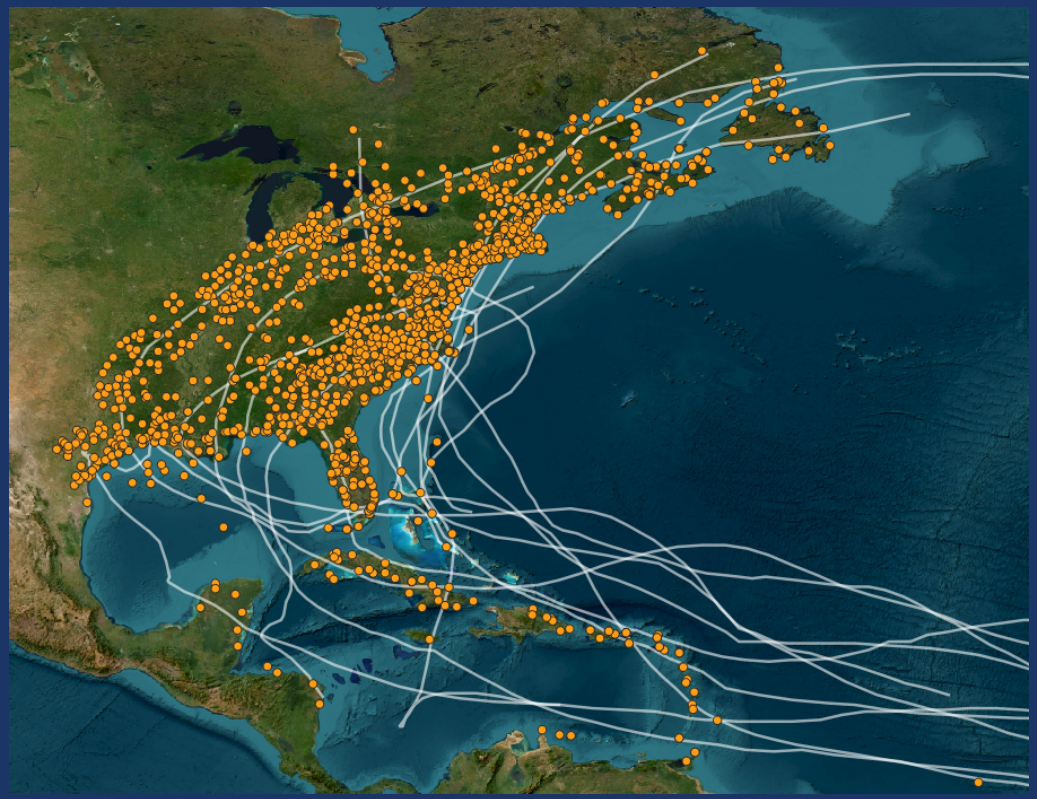
- Weighted mean upwind z_0: Rectangular ray from point (*Width x Distance*)

Parameter sweep testing

- Upwind ray distance (100-5000 m)
- Upwind ray width (30-500 m)
- # of directional sectors (8-16)

2.4 Evaluation of exposure adjustment

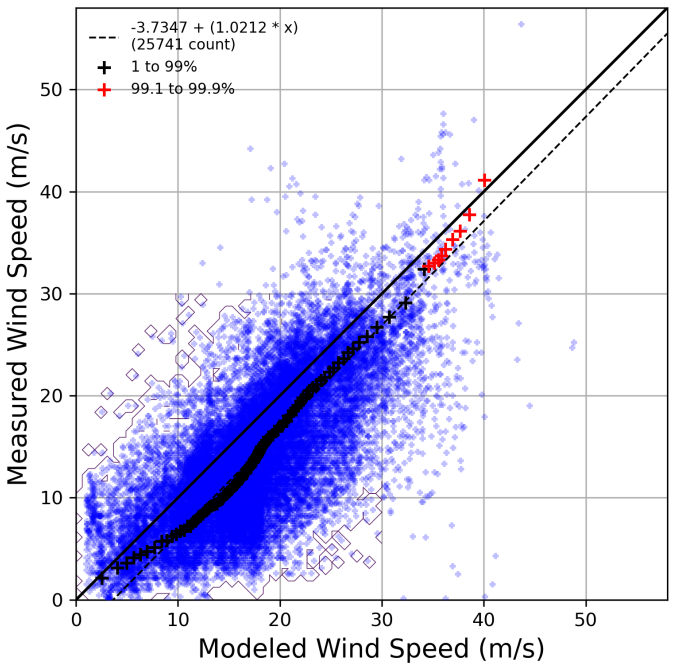
Using 5-year mean directional roughness from (ESRI/IO dataset)



Top 14 land-falling CONUS trop. cycl. (1985-2019)

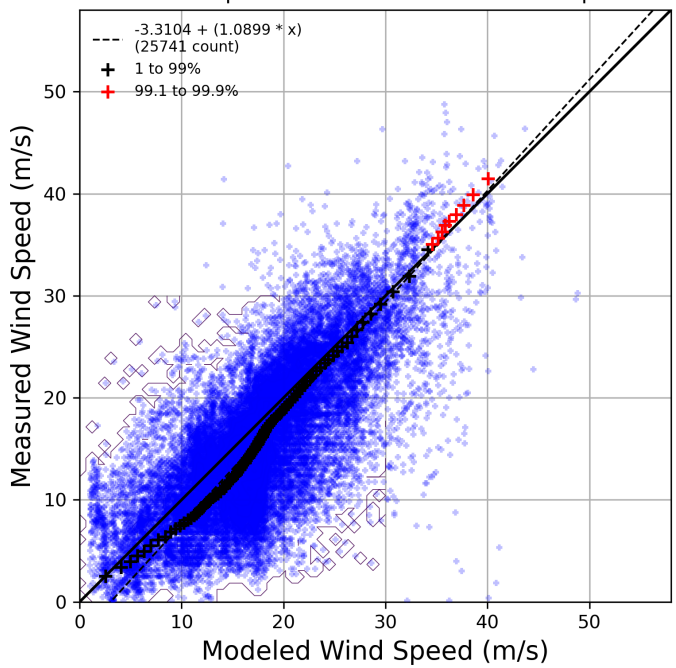
2.5 Result

Raw exposure obs.



Count	MeanMeas	MeanHind	Bias(H-M)	RMSE	StndDev	ScatIndex	Ratio	CorrCoeff
25741	13.88	17.23	3.35	5.98	4.95	0.36	0.78	0.71

Marine exposure obs.



Count	MeanMeas	MeanHind	Bias(H-M)	RMSE	StndDev	ScatIndex	Ratio	CorrCoeff
25741	15.49	17.23	1.74	5.19	4.89	0.32	0.64	0.74

Modeled tropical wind speed (WS) comparisons to 10m neutral measurements from land stations

2.6 Summary

- Standardized approach for normalizing coastal & land-based WS obs. for comparison to tropical storm modeling
- $z_0(\theta)$ best case: rect. upwind rays with a width of 300m & length of 1km
- Better comparison than unadjusted exposure & our original adjustments for the test storm/station population
- No explicit adjustment of obs. averaging periods, orographic impacts, or temporal trends/variation