Atmospheric Conditions at SWiFT for DOE Science Panel

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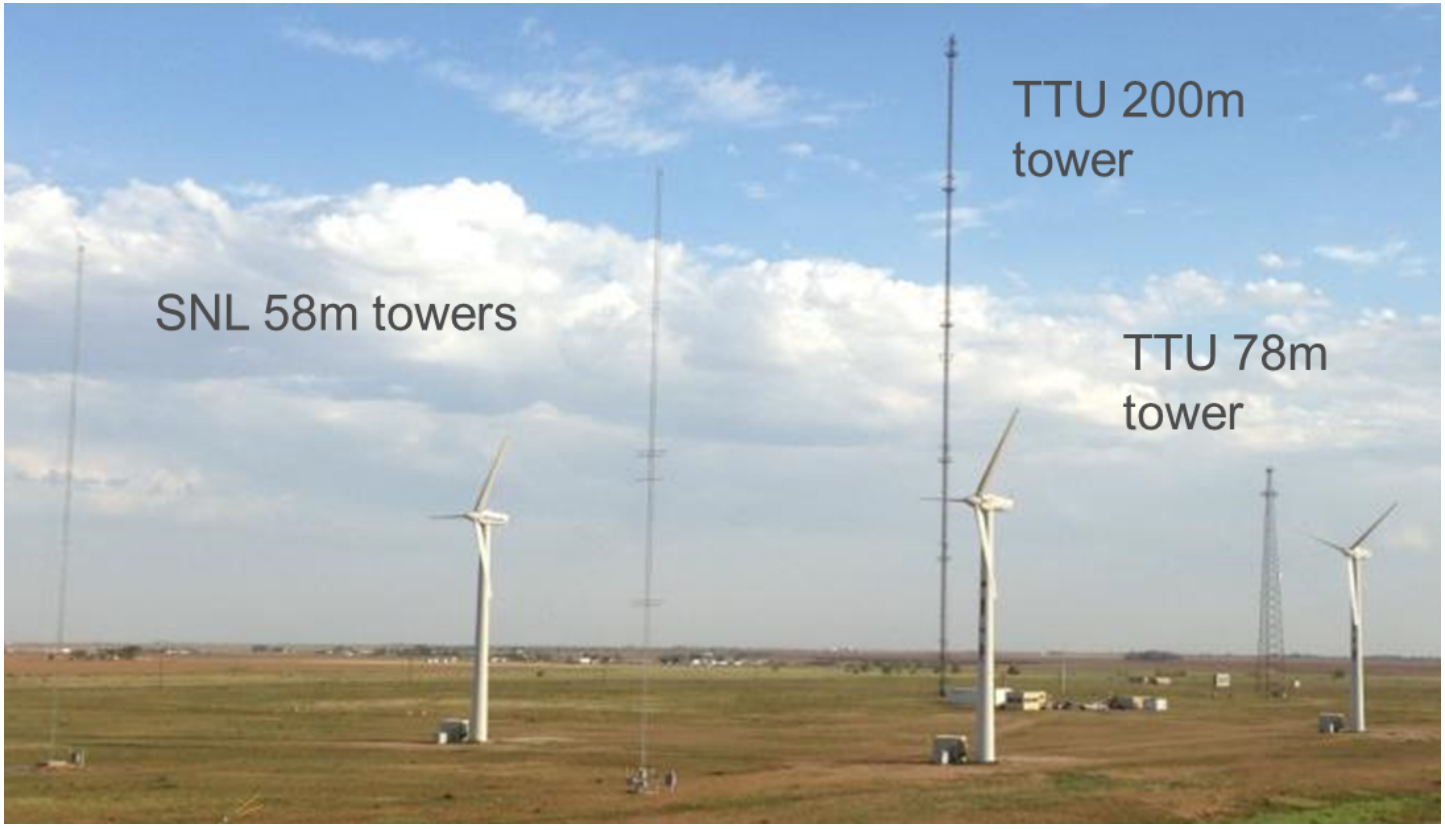
Goals

- Atmospheric sensors available
- Quantify statistics of wind at SWiFT
- Show to what extent SWiFT turbines experience the same range of inflow conditions as larger turbines

Meteorological Towers at SWiFT

- Sandia 58 m met towers
- TTU 78 m met tower
- TTU 200 m met tower



Additional Atmospheric Sensors On-site

- TTU 320 m sodar
- TTU Ka-band Mobile Doppler Radars
- TTU 6 km radar profiler

SWiFT Site Atmospheric Characterization

- Experimental data from TTU 200 m meteorological tower
- 2.5 years, June 2012 – December 2014
- Statistics based on 10 minute averages from 50 Hz data
- SAND–2016-0216

Texas Tech University 200 m Meteorological Tower

Table: TTU 200 m Sensors.

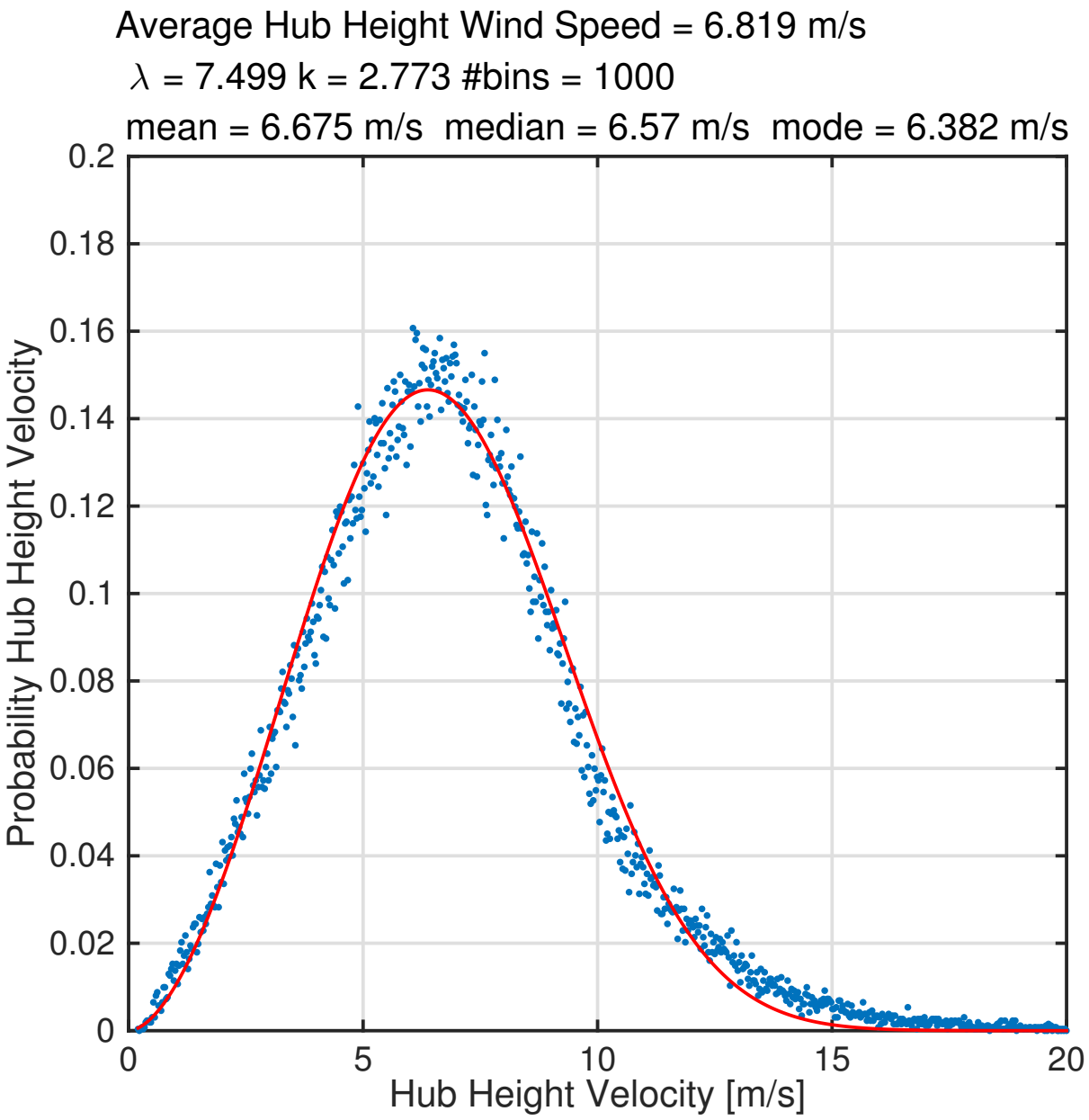
Sensor	TTU Raw Channels	[units]	TTU Processed Channels
3d Sonic Anemometer	*SonicU_NNft*	mph	*Sonic_North_NNft*
	SonicV_NNft	mph	*Sonic_West_NNft*
	SonicW_NNft	mph	*Sonic_Vert_NNft*
	SonicT_NNft	deg F	
Temperature	*Temp_NNft*	deg F	
Relative Humidity	*RH_NNft*	%	
Barometric Pressure	*BP_NNFt*	in Hg	
Propeller Anemometer*	*U_NNft*	mph	*UVW_North_NNft*
	V_NNft	mph	*UVW_West_NNft*
	W_NNft	mph	*UVW_Vert_NNft*

*Propeller anemometers are not mounted at the two lowest tower heights; (3,8)

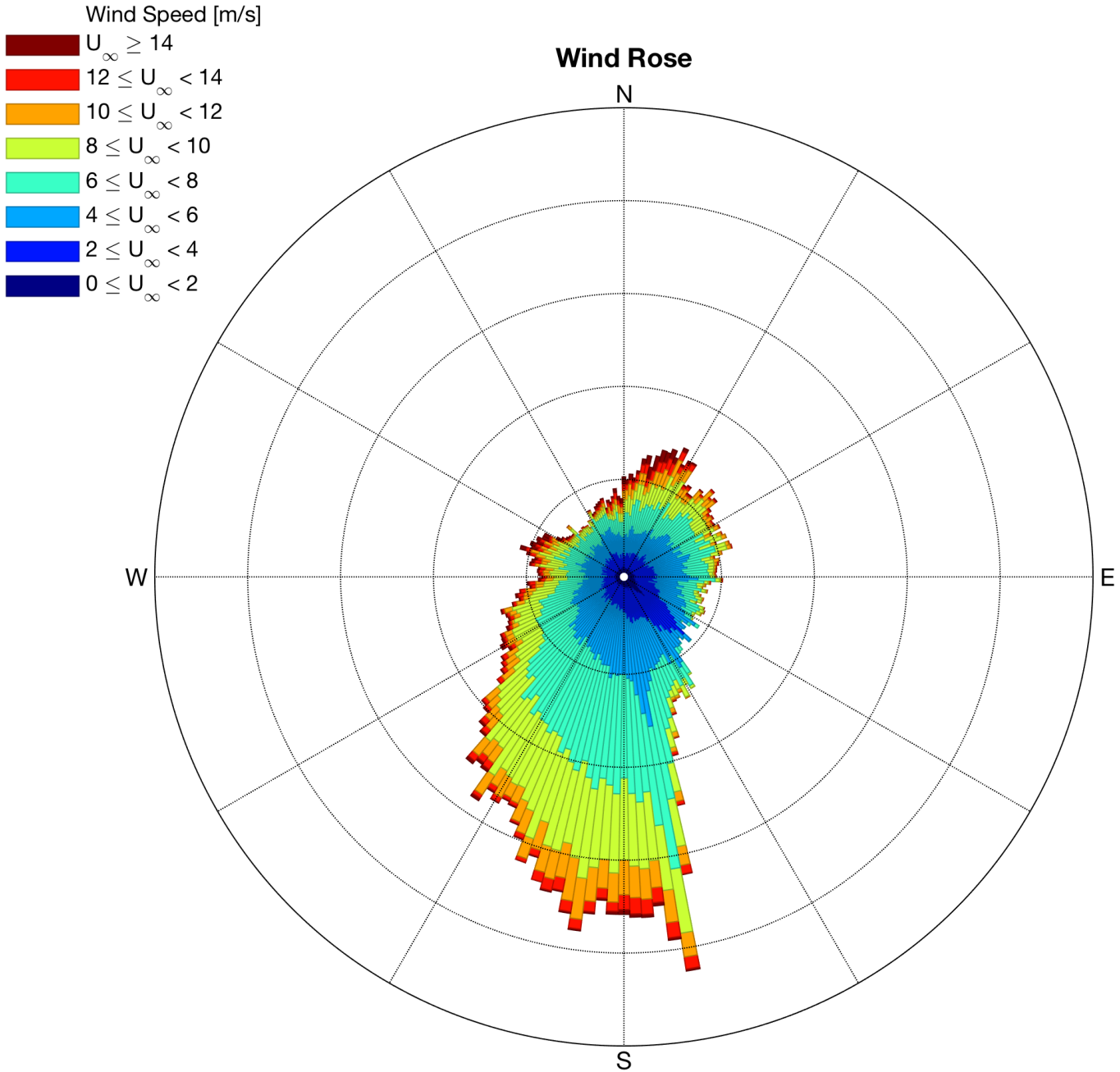
Table: TTU 200 m Tower Stations.

Sensor Group	1			2			3			4
Height [m]	0.9	2.4	4.0	10.1	16.8	47.3	74.7	116.5	158.2	200.0
Height [ft]	3	8	13	33	55	155	245	382	519	656
Sensor Package	partial	partial	full	full	full	full	full	full	full	full

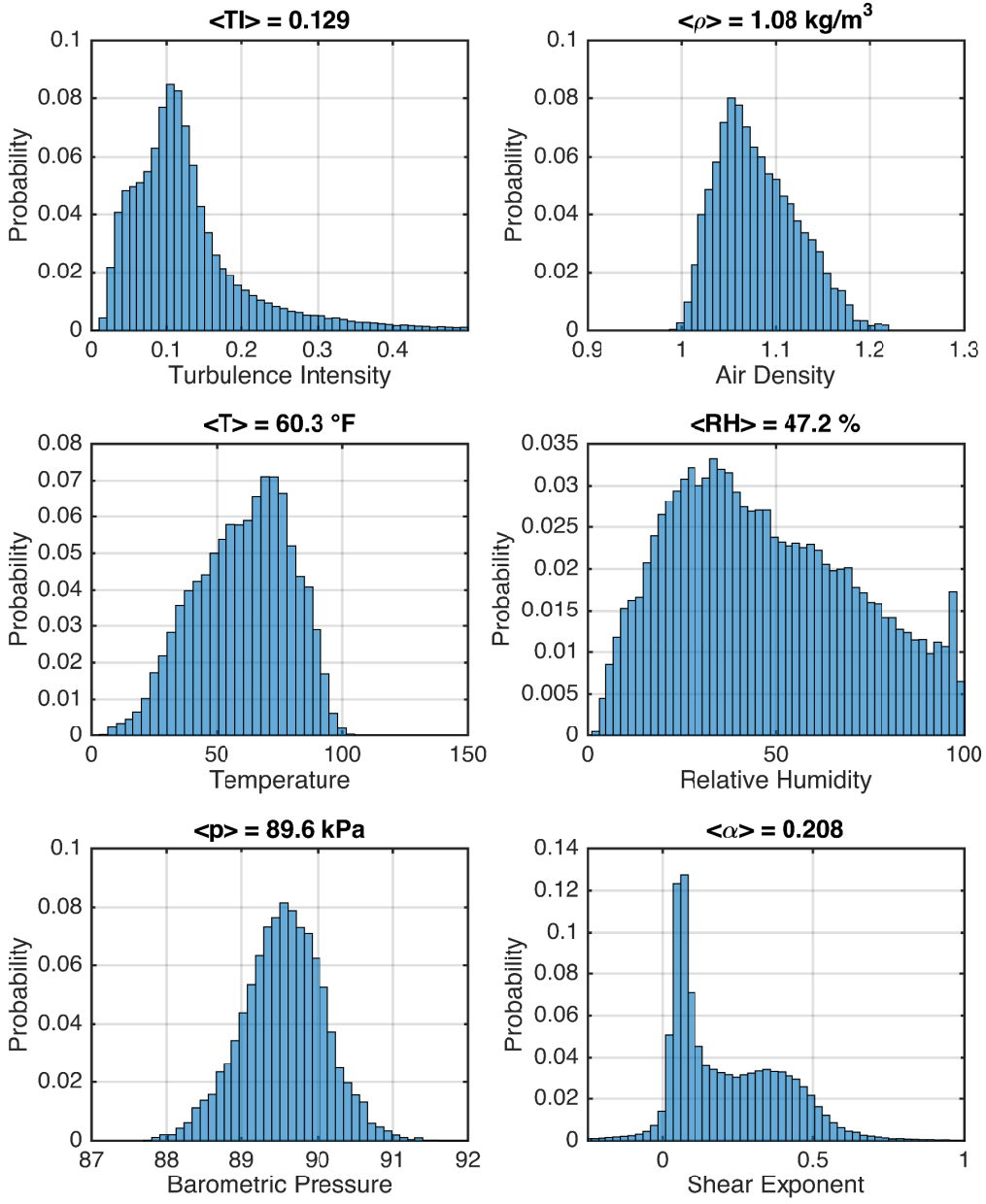
SWiFT Hub Height Wind Speed (32 m)



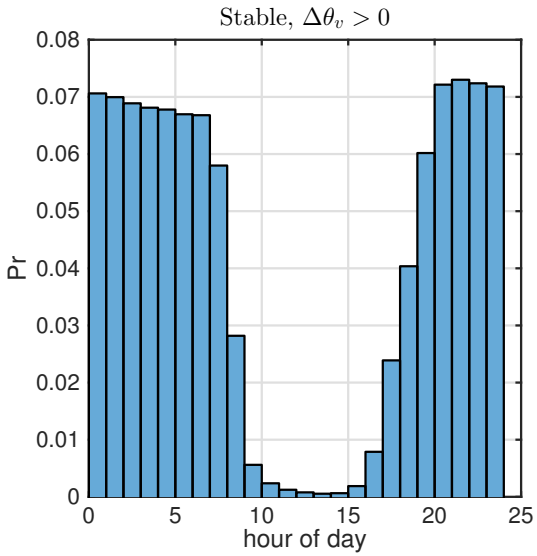
SWiFT Hub Height Wind Direction

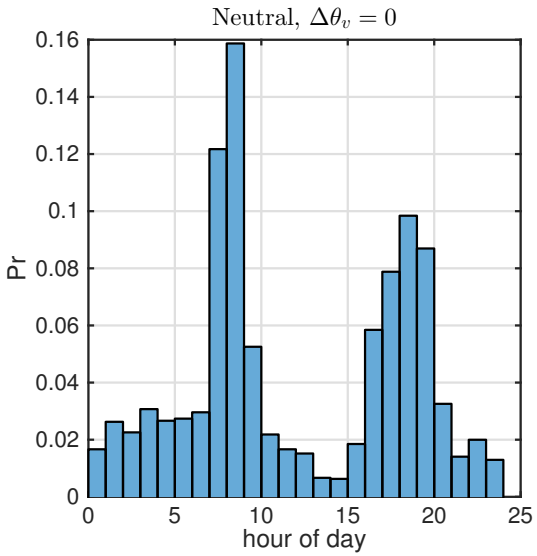


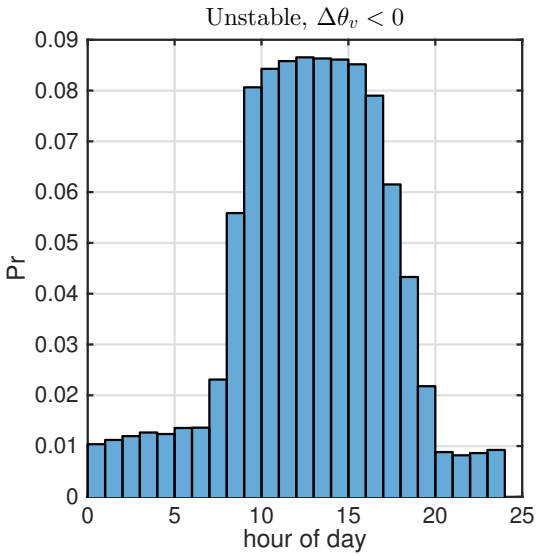
SWiFT Hub Height Statistics



Stability

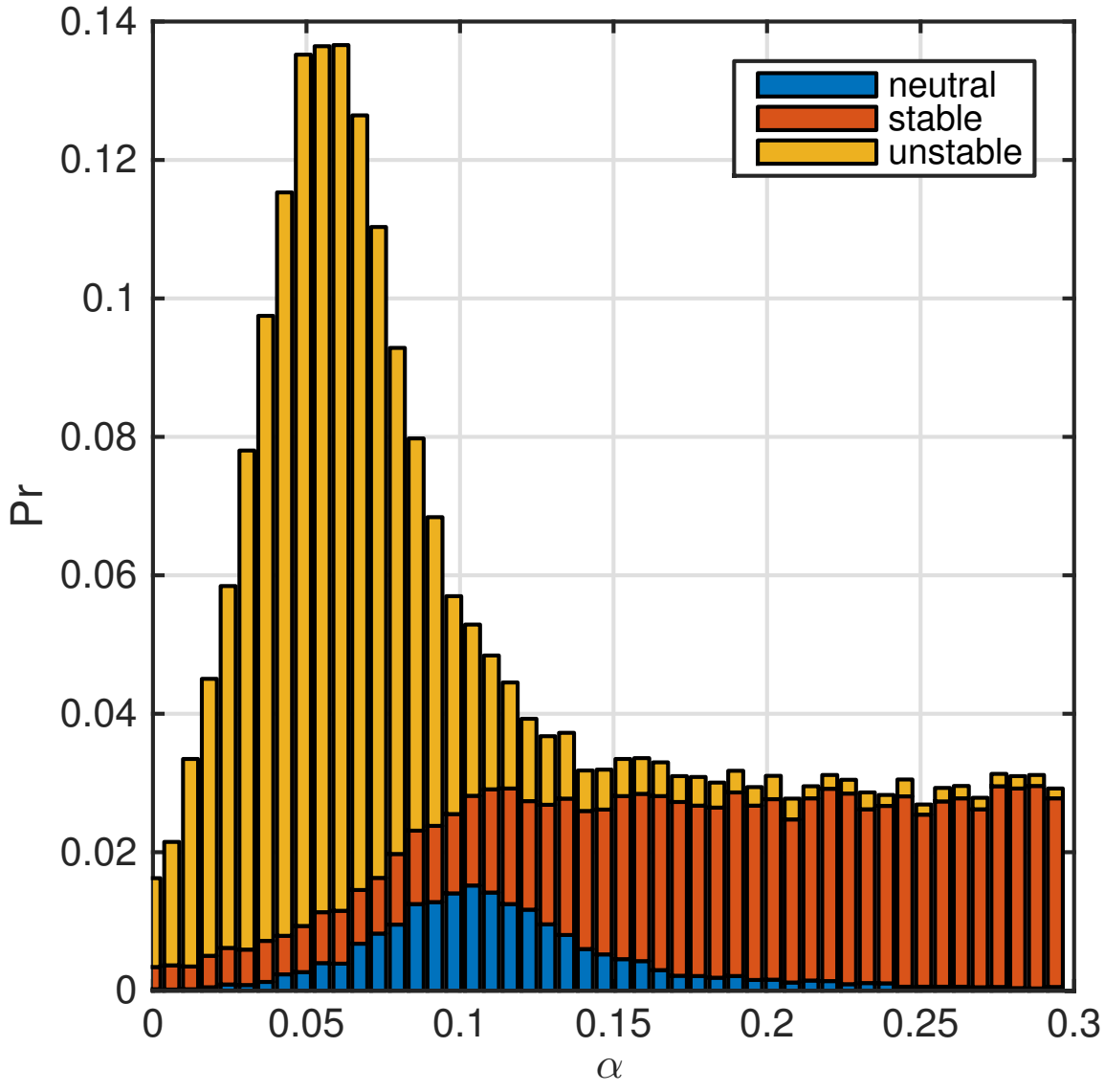


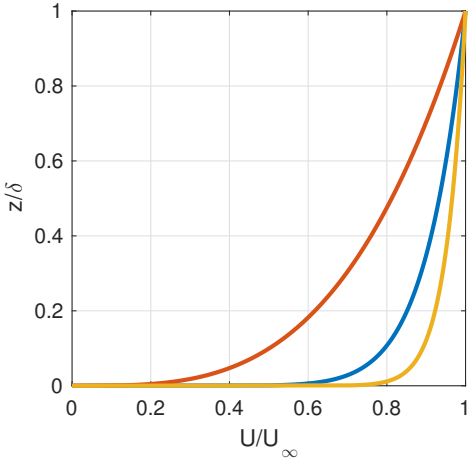




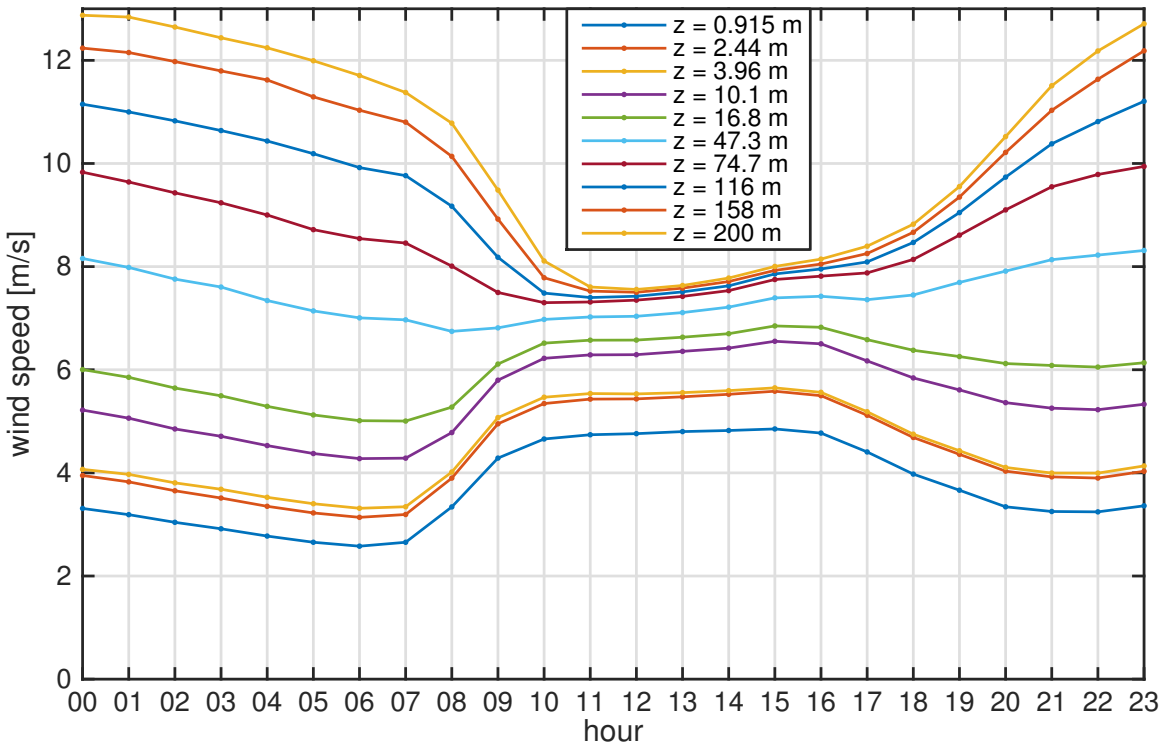
Stability Class	Stable	Neutral Transition	Unstable	Neutral Transition
Time of Day	20:00–08:00	08:00–10:00	10:00–18:00	18:00–20:00

Stability

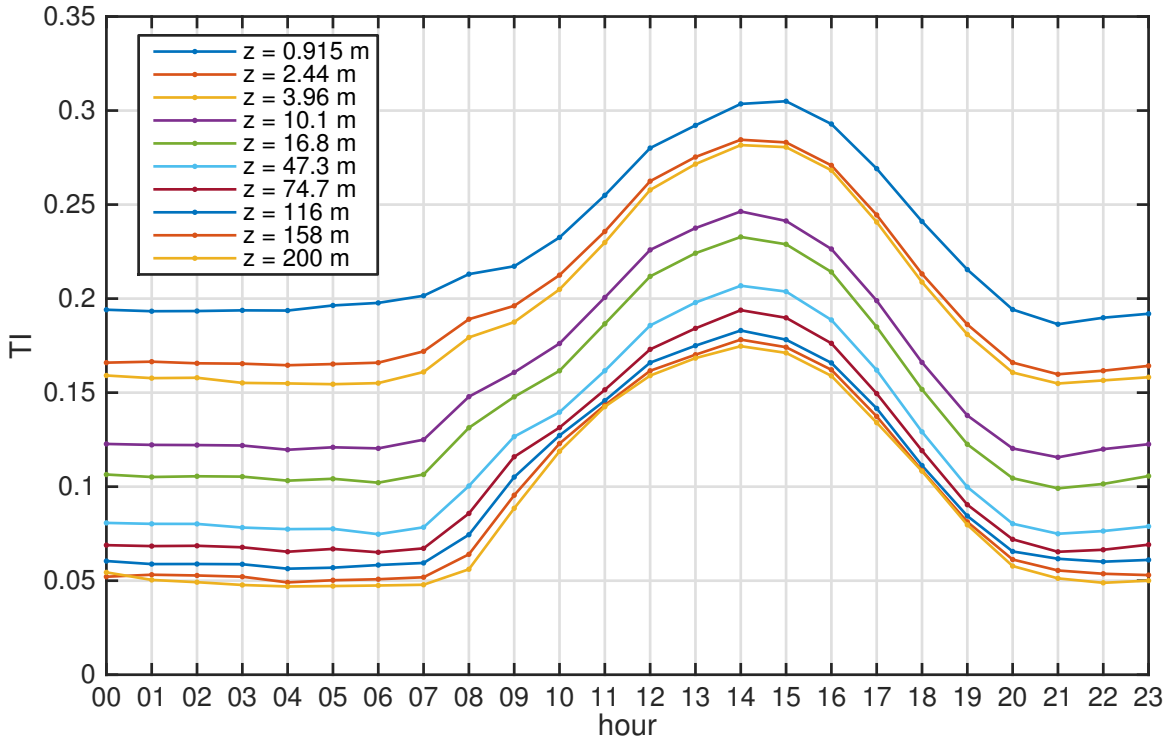

neutral
stable
unstable
Pr
α
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.05
0.1
0.15
0.2
0.25
0.3


z/δ
U/U∞
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1

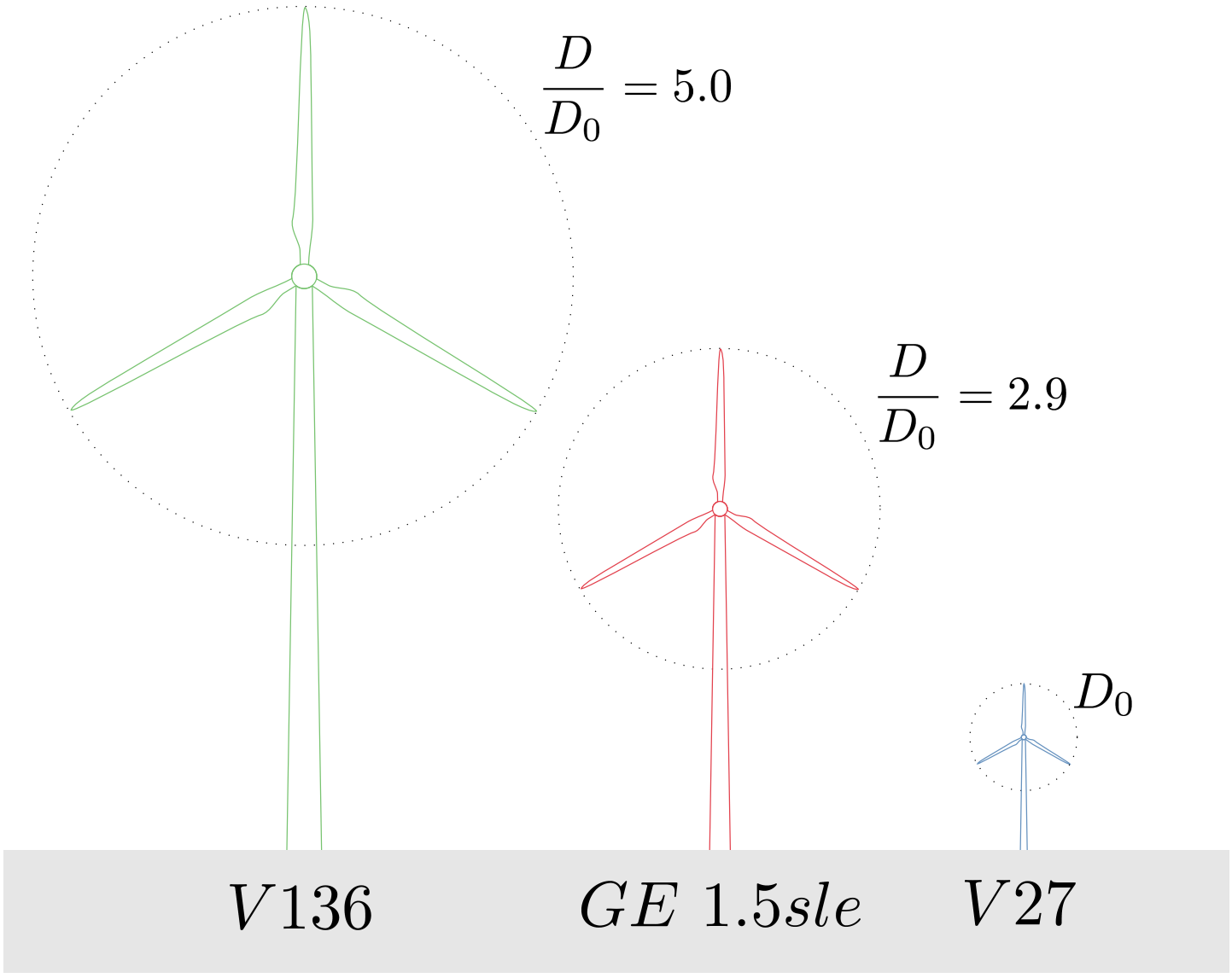
Average Day Wind Speed



Average Day Turbulence Intensity



Inflow Conditions for Different Size Turbines



Dimensionless Quantities

shear

$$\tau^* = \frac{U_t - U_b}{U_h} \tag{1}$$

turbulence intensity

$$TI = \frac{\sigma(U_h)}{\overline{U}_h} \tag{2}$$

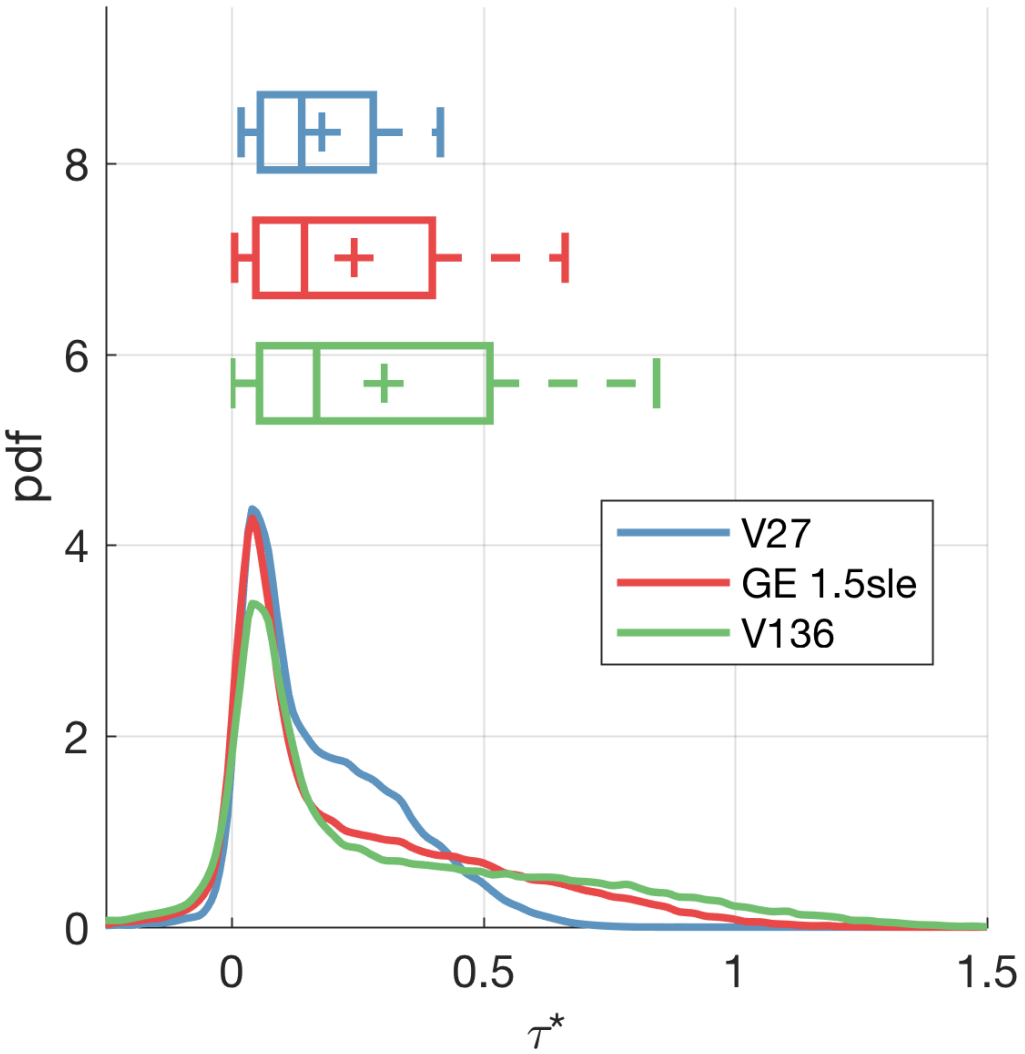
veer

$$Vr = \theta_t - \theta_b \tag{3}$$

lateral turbulence intensity

$$LTI = \frac{\sigma(\theta_h)}{\overline{\theta}_h} \tag{4}$$

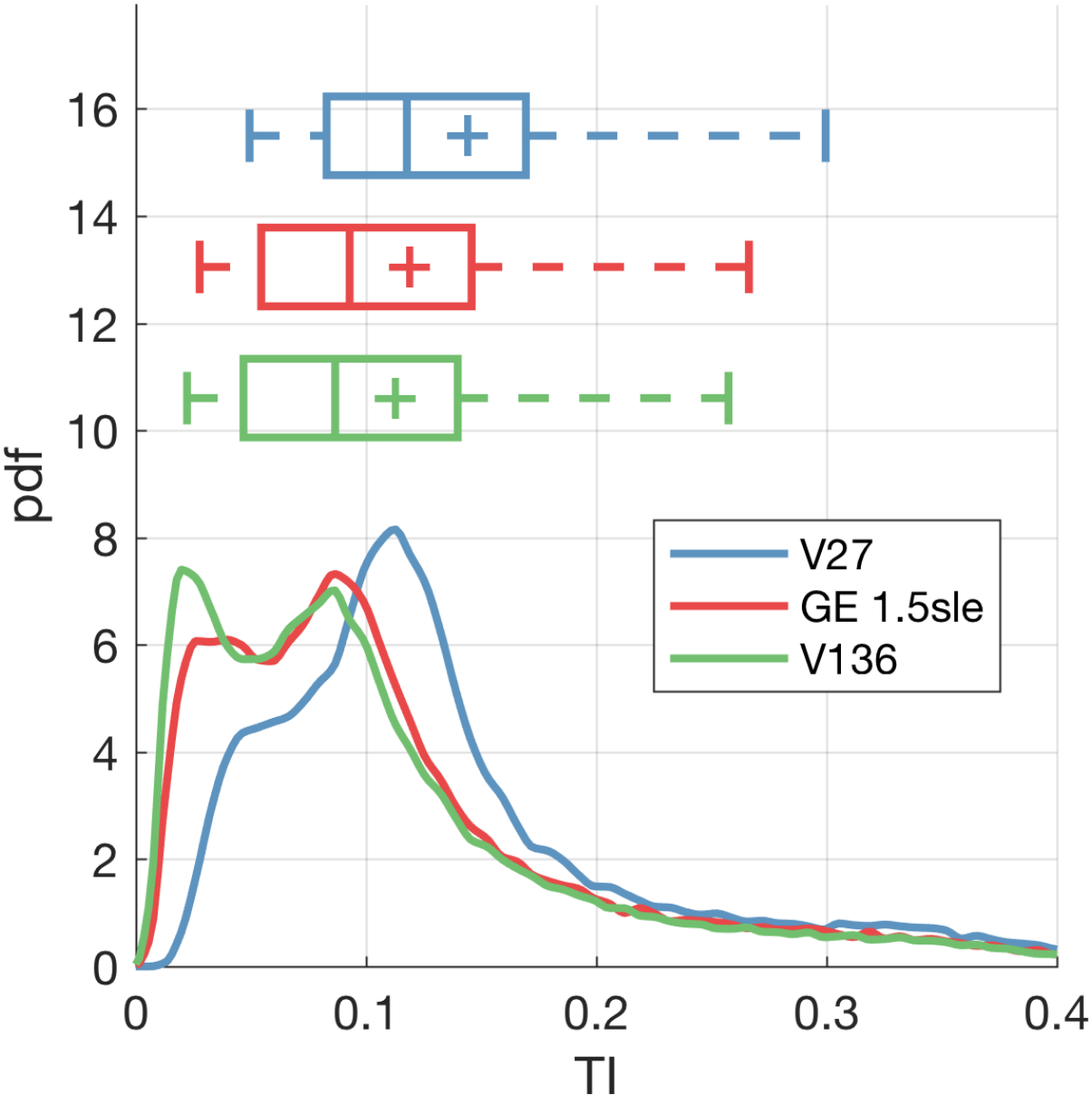
Shear



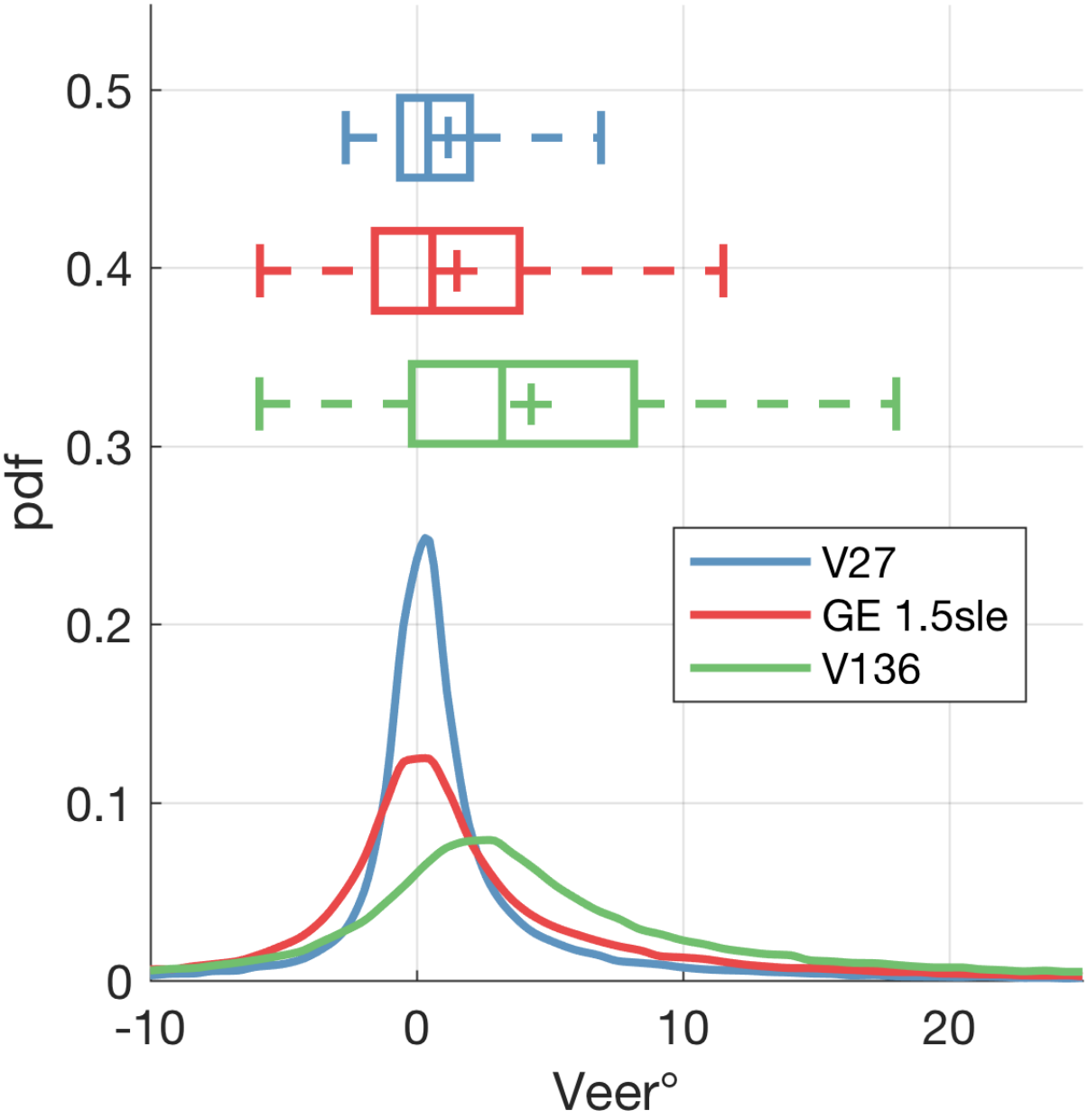
$Pr(\tau^* > 0.75) = 4.6\%$ for GE 1.5sle

$Pr(\tau^* > 0.75) = 11.4\%$ for V136

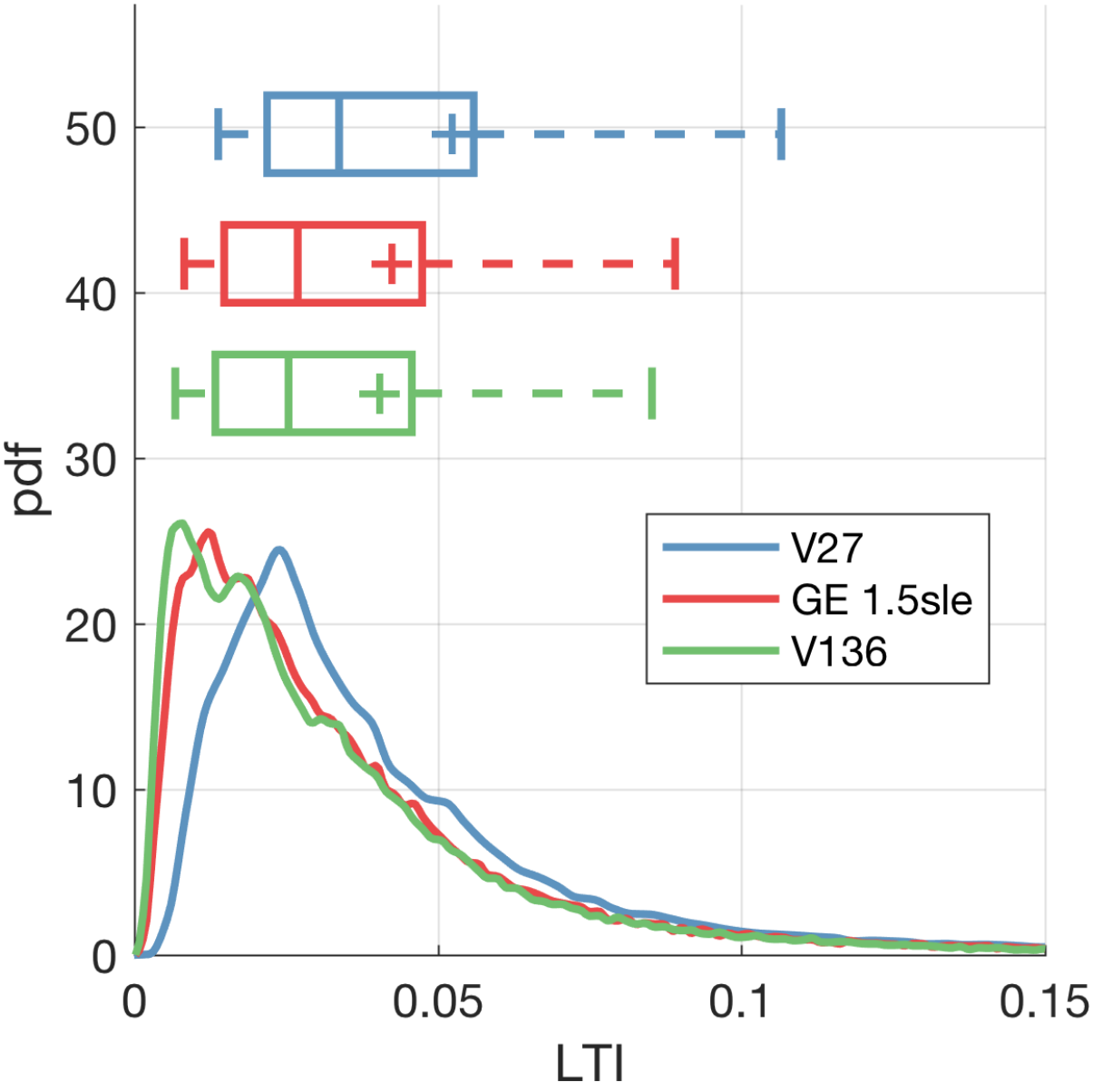
Turbulence Intensity



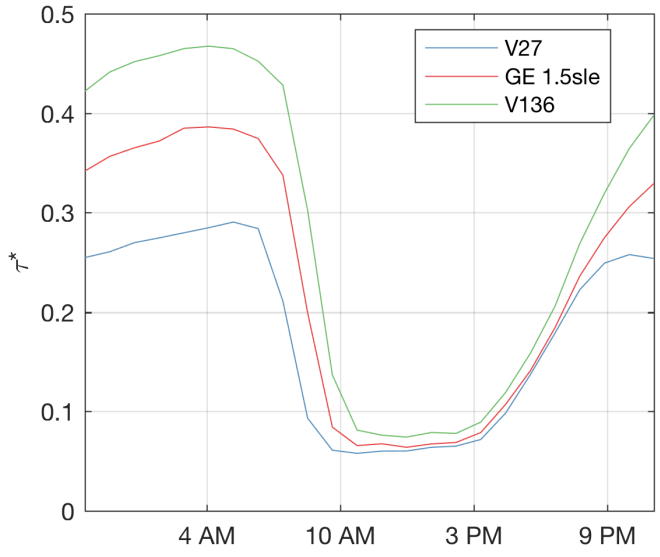
Veer

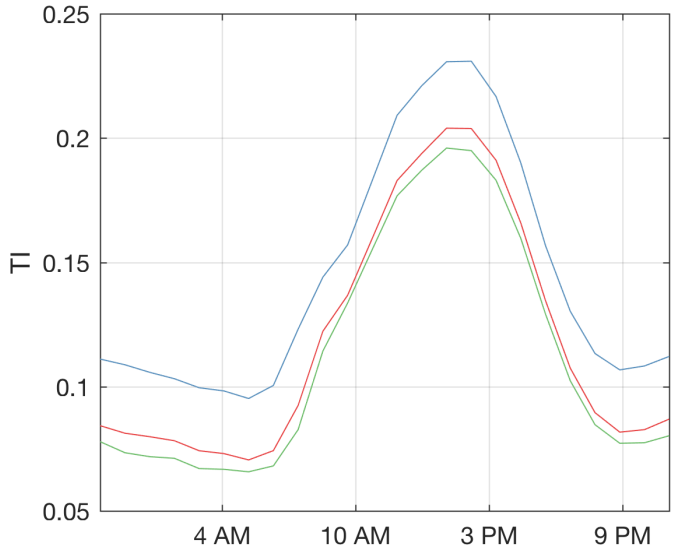


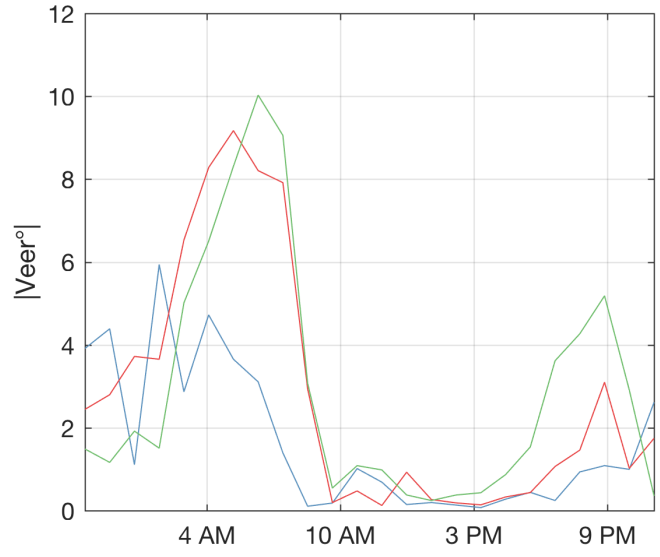
Lateral Turbulence Intensity

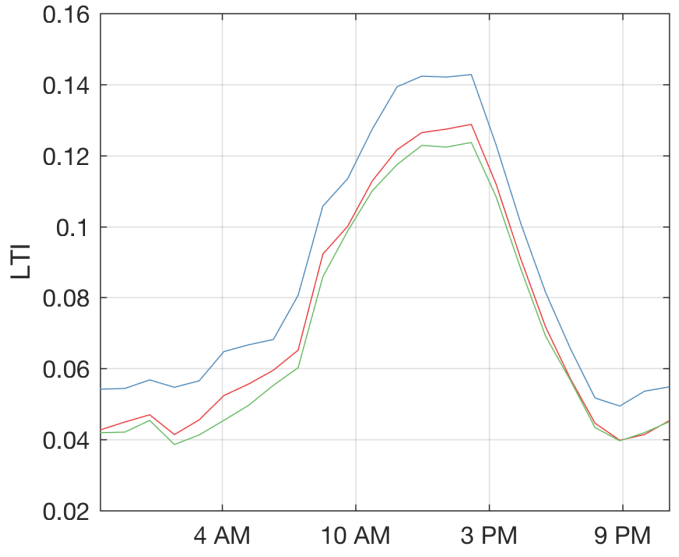


SWiFT Average Day









Inflow Conclusions

- Highly instrumented site
- Strong winds predominantly from the south
- Significant overlap of inflow conditions for V27 and V136
- Equal daytime shear
- Larger turbines see higher shear above 75% with a Pr = 11%