Numeric Modelling

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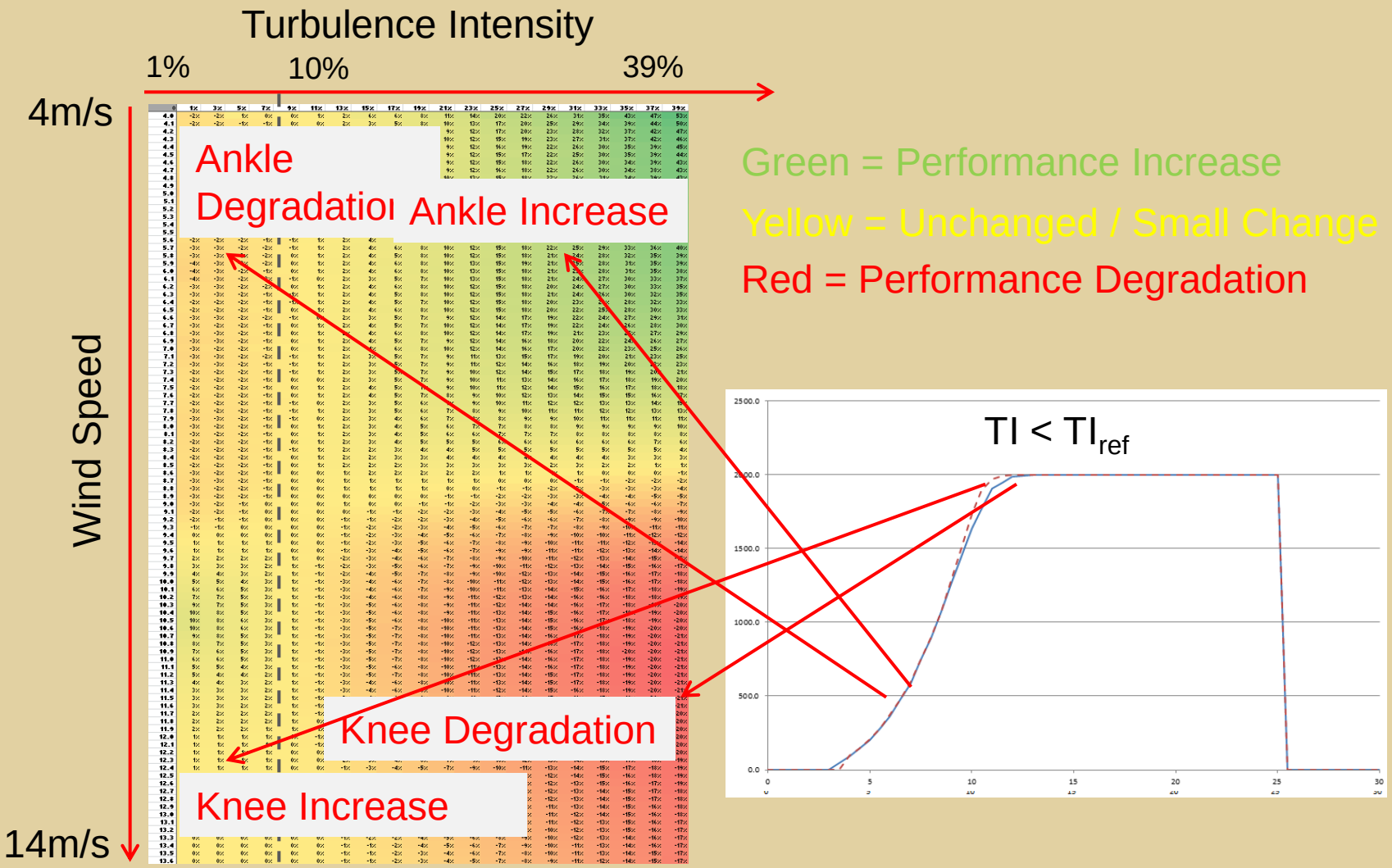
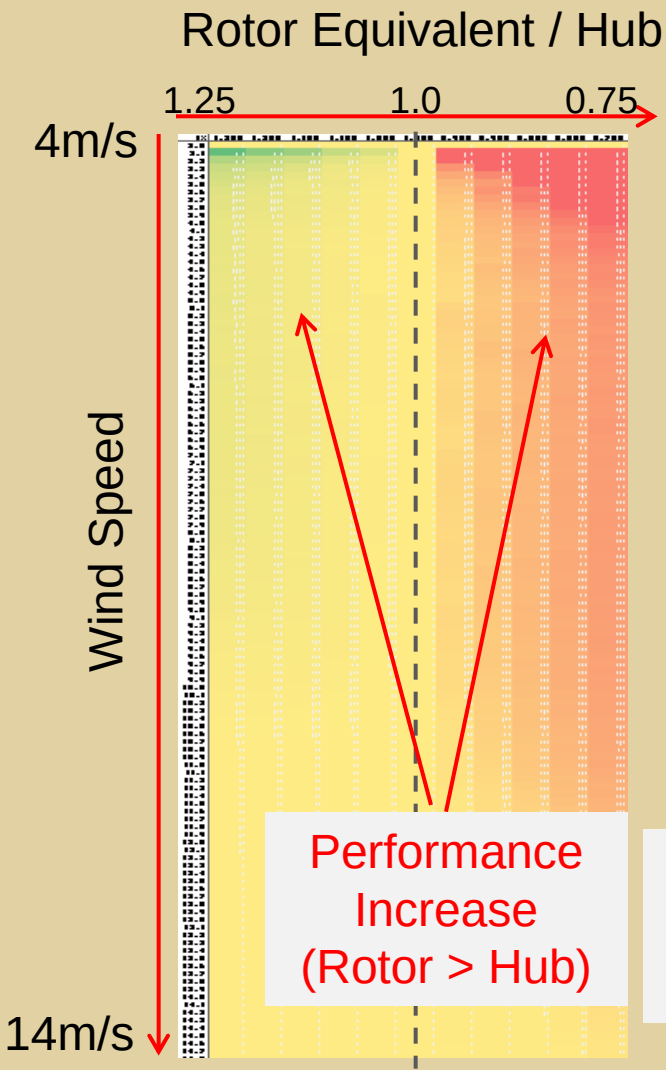
Thursday 19th September 2013

Numerical Modelling: Impact of Turbulence



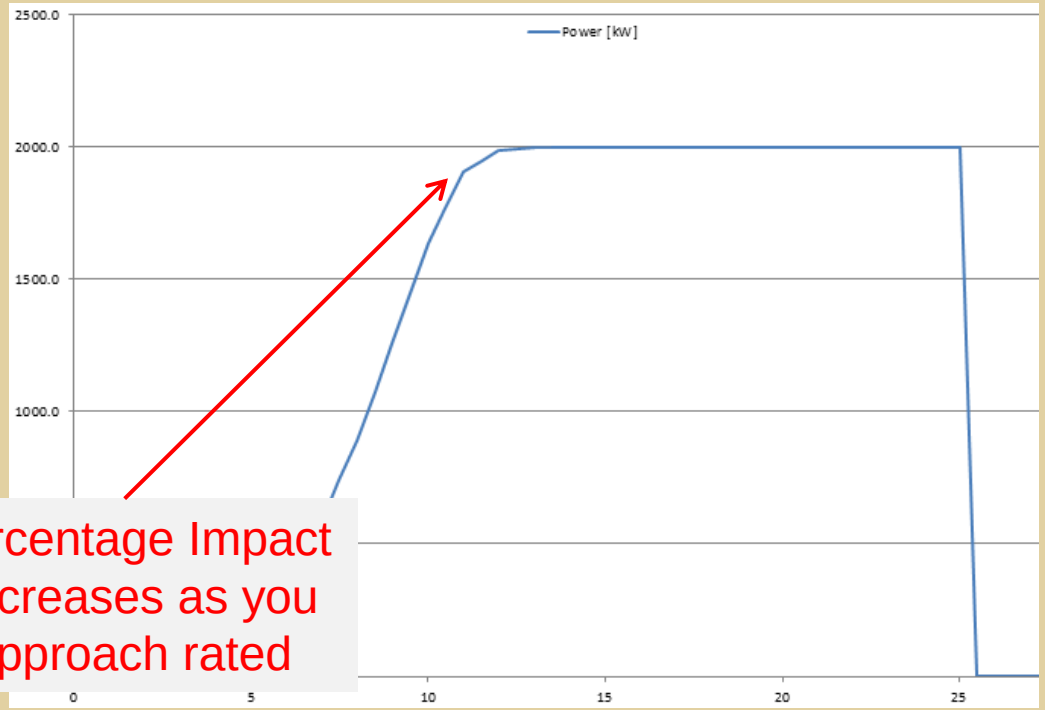
Numerical Modelling: Impact of Shear (Rotor Equivalent Wind Speed)



Green = Performance Increase

Yellow = Unchanged / Small Change

Red = Performance Degradation



Numerical Modelling: Impact of Shear and Turbulence

- Combine shear and turbulence effects for discrete wind speed bins.

Turbulence	Rotor Equivalent Wind Speed										
0.8%	1.050	1.040	1.030	1.020	1.010	1.000	0.990	0.980	0.970	0.960	0.950
29.00%	0%	0%	0%	0%	0%	-7%	-7%	-8%	-8%	-8%	-8%
27.00%	0%	0%	0%	0%	0%	-6%	-6%	-6%	-6%	-6%	-7%
25.00%	0%	0%	0%	0%	0%	-5%	-5%	-5%	-5%	-5%	-6%
23.00%	0%	0%	0%	0%	0%	-3%	-3%	-4%	-4%	-4%	-4%
21.00%	0%	0%	0%	0%	0%	-2%	-2%	-3%	-3%	-3%	-3%
19.00%	0%	0%	0%	0%	0%	-2%	-2%	-2%	-2%	-2%	-2%
17.00%	0%	0%	0%	0%	0%	-1%	-1%	-1%	-1%	-1%	-1%
15.00%	0%	0%	0%	0%	0%	0%	0%	-1%	-1%	-1%	-1%
13.00%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
11.00%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
9.00%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
7.00%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
5.00%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
3.00%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1.00%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Rated Wind Speed (11m/s)

- Models only capture ‘Type 1’ effects (available energy).
- Type 2 effects (degradation of conversion efficiency) would manifest in corners.

Rotor Equivalent Wind Speed proxy

- Rotor Equivalent wind speed (using LiDARs) is potentially the ideal way to characterise the performance degradation due to shear, however most existing power performance measurements do not include LiDAR measurements.

- Examine existing measurements using shear (lower tip to hub) and turbulence, but keep in mind how this relates to rotor equivalent wind speed.

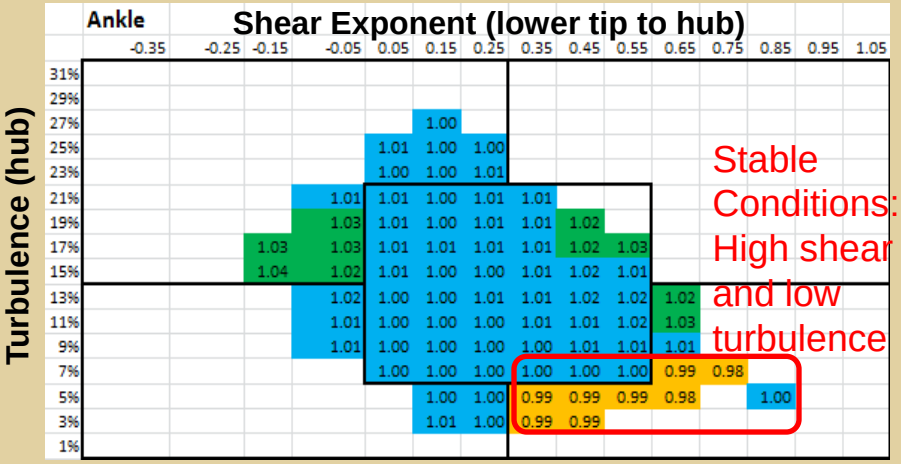
- Using RR Dataset 1 examine relationship between shear, turbulence and rotor equivalent wind speed.

- Current analysis only considers wind speed element of rotor equivalent wind speed (no veer).

Rotor Equivalent Wind Speed proxy

Turbulence \ Rotor Equivalent Wind Speed	1.050	1.040	1.030	1.020	1.010	1.000	0.990	0.980	0.970	0.960	0.950
-50.4%											
29.00%	38%	33%	28%	23%	23%	17%	13%	13%	10%	5%	5%
27.00%	36%	32%	26%	21%	21%	16%	11%	11%	8%	3%	3%
25.00%	34%	30%	23%	19%	19%	14%	9%	9%	5%	1%	1%
23.00%	33%	27%	22%	16%	16%	12%	7%	7%	3%	-1%	-1%
21.00%	31%	25%	20%	15%	15%	10%	5%	5%	1%	-3%	-3%
19.00%	29%	23%	18%	13%	13%	8%	3%	3%	-1%	-5%	-5%
17.00%	27%	21%	16%	10%	10%	6%	1%	1%	-2%	-7%	-7%
15.00%	25%	19%	14%	9%	9%	4%	0%	0%	-4%	-8%	-8%
13.00%	23%	18%	12%	7%	7%	2%	-2%	-2%	-6%	-10%	-10%
11.00%	21%	16%	11%	6%	6%	1%	-3%	-3%	-7%	-11%	-11%
9.00%	20%	15%	10%	5%	5%	0%	-4%	-4%	-8%	-12%	-12%
7.00%	19%	14%	9%	3%	3%	-1%	-5%	-5%	-9%	-13%	-13%
5.00%	18%	13%	8%	3%	3%	-2%	-6%	-6%	-10%	-13%	-13%
3.00%	18%	13%	7%	2%	2%	-2%	-7%	-7%	-10%	-14%	-14%
1.00%	18%	13%	7%	2%	2%	-3%	-7%	-7%	-10%	-14%	-14%

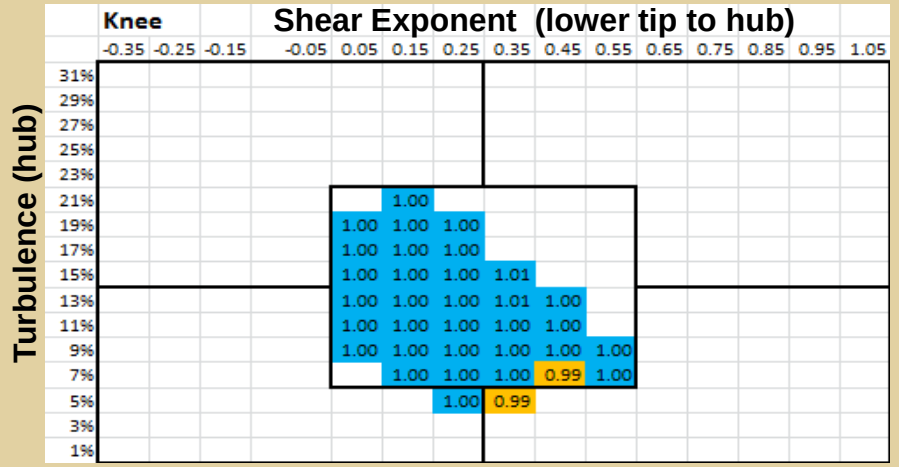
Ankle Wind Speed (7m/s)



Rotor Equivalent Speed / Hub Wind Speed

Turbulence \ Rotor Equivalent Wind Speed	1.050	1.040	1.030	1.020	1.010	1.000	0.990	0.980	0.970	0.960	0.950
-39.2%											
29.00%	-13%	-14%	-14%	-15%	-15%	-16%	-17%	-18%	-19%	-20%	-21%
27.00%	-11%	-12%	-13%	-13%	-14%	-14%	-16%	-17%	-18%	-19%	-20%
25.00%	-10%	-11%	-11%	-12%	-13%	-13%	-14%	-16%	-17%	-18%	-19%
23.00%	-8%	-9%	-10%	-10%	-11%	-12%	-13%	-14%	-15%	-16%	-17%
21.00%	-6%	-8%	-9%	-9%	-9%	-10%	-11%	-13%	-14%	-15%	-16%
19.00%	-5%	-6%	-7%	-7%	-8%	-8%	-10%	-11%	-12%	-13%	-15%
17.00%	-3%	-5%	-5%	-6%	-6%	-7%	-8%	-9%	-11%	-12%	-13%
15.00%	-1%	-3%	-3%	-4%	-4%	-5%	-6%	-7%	-9%	-10%	-12%
13.00%	0%	-1%	-2%	-2%	-2%	-3%	-4%	-6%	-7%	-8%	-10%
11.00%	2%	1%	0%	0%	0%	-1%	-2%	-4%	-5%	-7%	-8%
9.00%	3%	2%	2%	2%	1%	1%	0%	-2%	-3%	-5%	-6%
7.00%	5%	4%	4%	3%	3%	3%	1%	0%	-1%	-3%	-4%
5.00%	5%	5%	5%	5%	5%	5%	3%	2%	1%	0%	-2%
3.00%	5%	5%	5%	5%	6%	6%	5%	4%	3%	2%	0%
1.00%	5%	5%	5%	5%	6%	6%	5%	5%	4%	4%	2%

Knee Wind Speed (11m/s)



Rotor Equivalent Speed / Hub Wind Speed

Numerical Model vs Observed (Ankle)

Substitute observed relationship between rotor equivalent wind speed and shear and turbulence into numerical model.

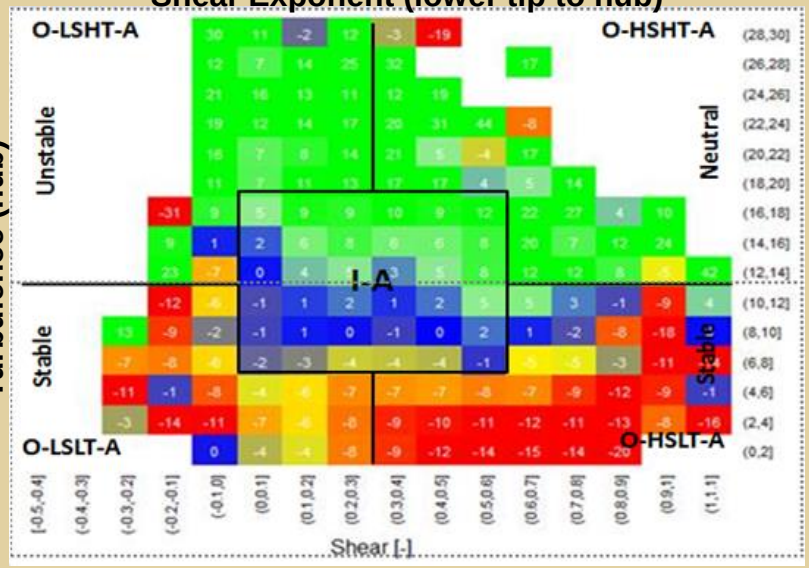
Shear Exponent (lower tip to hub)

1.2%	-0.45	-0.35	-0.25	-0.15	-0.05	0.05	0.15	0.25	0.35	0.45	0.55	0.65	0.75	0.85	0.95	1.05
31.00%	####															
29.00%	####															
27.00%	####						16%									
25.00%	####					14%	14%	14%								
23.00%	####					12%	12%	16%								
21.00%	####				15%	10%	10%	10%	10%							
19.00%	####				18%	13%	8%	8%	13%	18%						
17.00%	####			16%	16%	10%	6%	6%	10%	16%	16%					
15.00%	####			19%	14%	4%	4%	4%	9%	9%	9%					
13.00%	####				7%	2%	2%	2%	7%	7%	7%	7%				
11.00%	####				6%	1%	1%	1%	6%	6%	6%	11%				
9.00%	####				0%	0%	0%	0%	0%	0%	5%	5%				
7.00%	####					-1%	-1%	-1%	-1%	-1%	-1%	-5%	-5%			
5.00%	####						-2%	-2%	-2%	-6%	-6%	-10%		-2%		
3.00%	####						2%	-2%	-7%	-7%						
1.00%	####															

Turbulence (hub)

Ankle Wind Speed (7m/s)

Shear Exponent (lower tip to hub)



Turbulence (hub)

Ankle Wind Speed (Range)

Compare to observed performance for different turbine (results from REPower). Colour schemes are different and comparison is approximate.

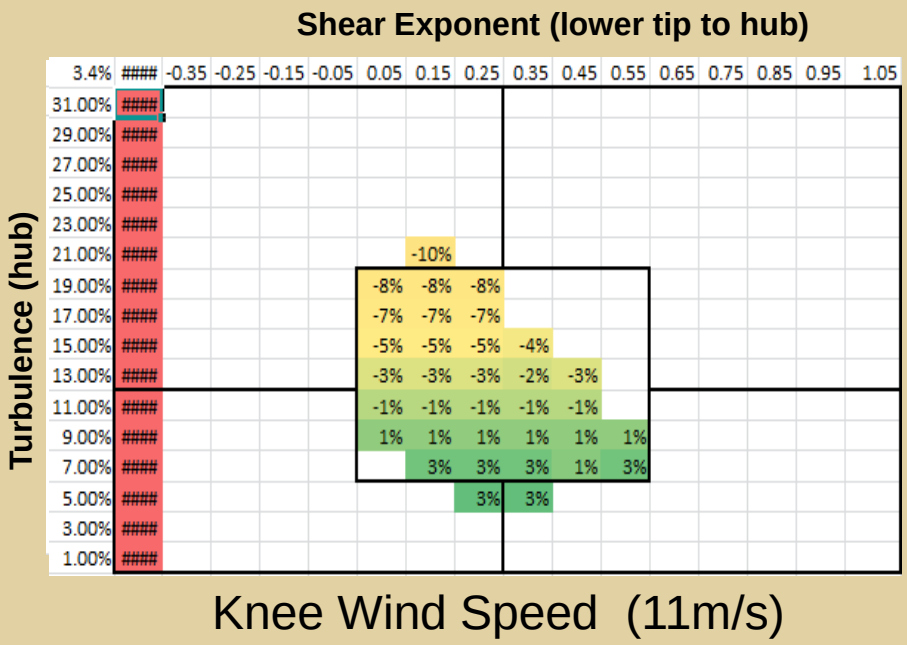
Next Steps

- Extend analysis of historic power performance data (dependence on shear and turbulence) to other machines. This is a key opportunity for group collaboration.
- Examine dependence of rotor equivalent wind speed to hub ratio w.r.t. lower tip shear and turbulence for more datasets. How much does this relationship vary across sites?
- Perform further comparisons of models and observations.
- Please join in!

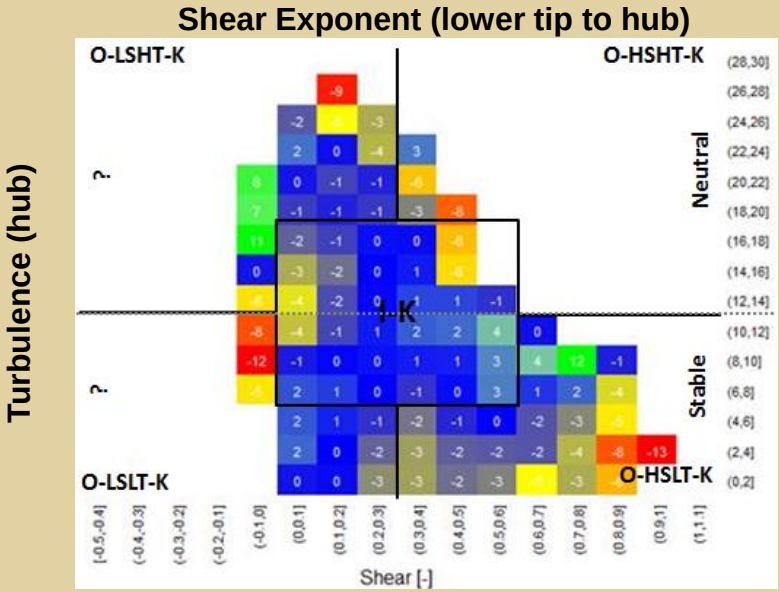

power for good

Numerical Model vs Observed (Ankle)

Substitute observed relationship between rotor equivalent wind speed and shear and turbulence into numerical model.



Knee Wind Speed (11m/s)



Ankle Wind Speed (Range)

Compare to observed performance for different turbine (results from REPower). Colour schemes are different and comparison is approximate.