WE ARE VENTIENT ENERGY

Useful life estimation and turbulence model impact

WindSim User Meeting – 21st June 2023

Ryan Kyle, Wind and Site Engineer
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PhD, OpenFOAM and floating wind turbine simulations — < 2020

Natural Power, wind EYAs and site assessments — 2020 - 2022

Ventient Energy, leading in-house wind and site assessments — 2022+

Agenda

1. Who we are and what we do
2. How WindSim fits into lifetime assessment
3. Case study – how turbulence model selection changed life predictions

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Who are Ventient Energy?

- One of Europe's leading independent owners / operators of wind energy
- 2.8 GW of onshore wind capacity
- From 1,510 wind turbines
- Within 140 wind farms
- Covering 6 countries
- Actively **optimising aerodynamic performance** of our assets

- Interesting facts:
  - Currently 22 of our sites are older than 20 years old, accounting for 300 turbines
  - Our oldest site started operation in 1993, making it 30 years old and still going

What do we do about this?

Questions now faced by operators:

1. What to do at end of life?
2. When even is “end of life”?
3. What can we do to get the most out of our life / exploit excess life?
   - Aerodynamic upgrades: yield now is better than yield later.

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How can WindSim help?

All answers require **accurate site conditions assessments**

- We need a tool which gives us all key flow conditions at each turbine, within each wind direction sector and by wind speed.
- Many, if not all, of our sites have **complex terrain or forestry.**

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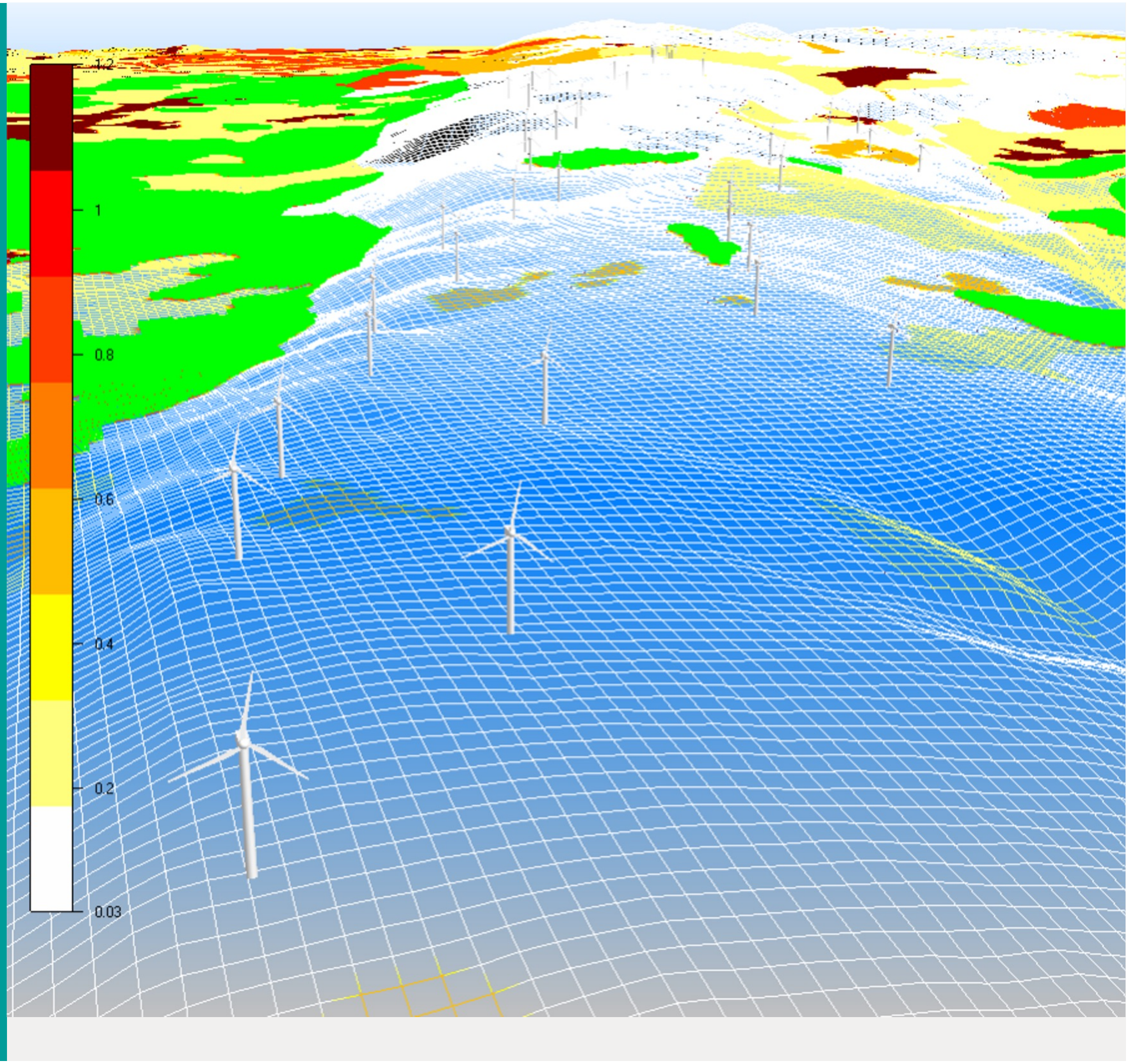
WindSim to the rescue…



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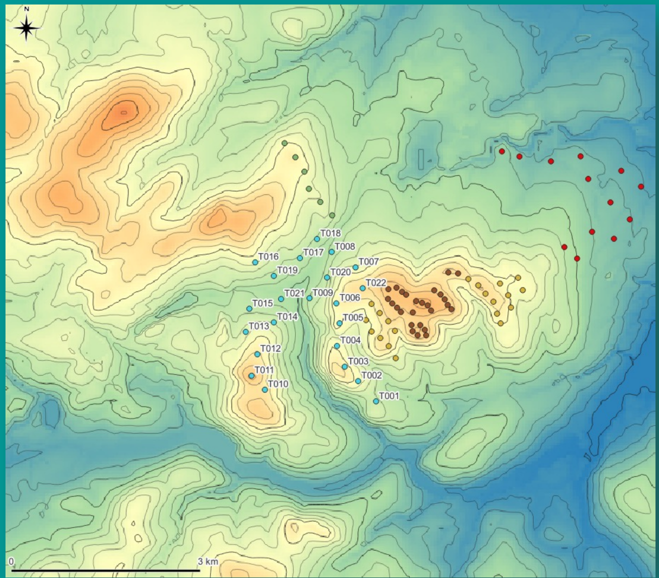
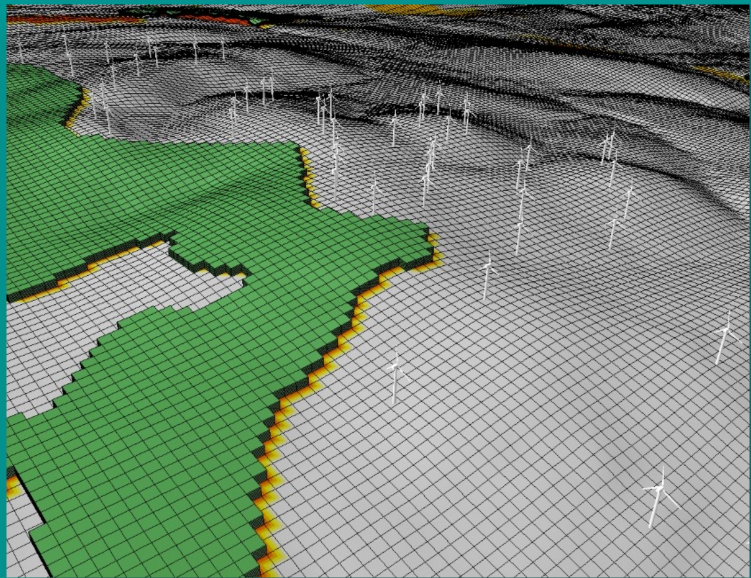
How do we use WindSim for this?



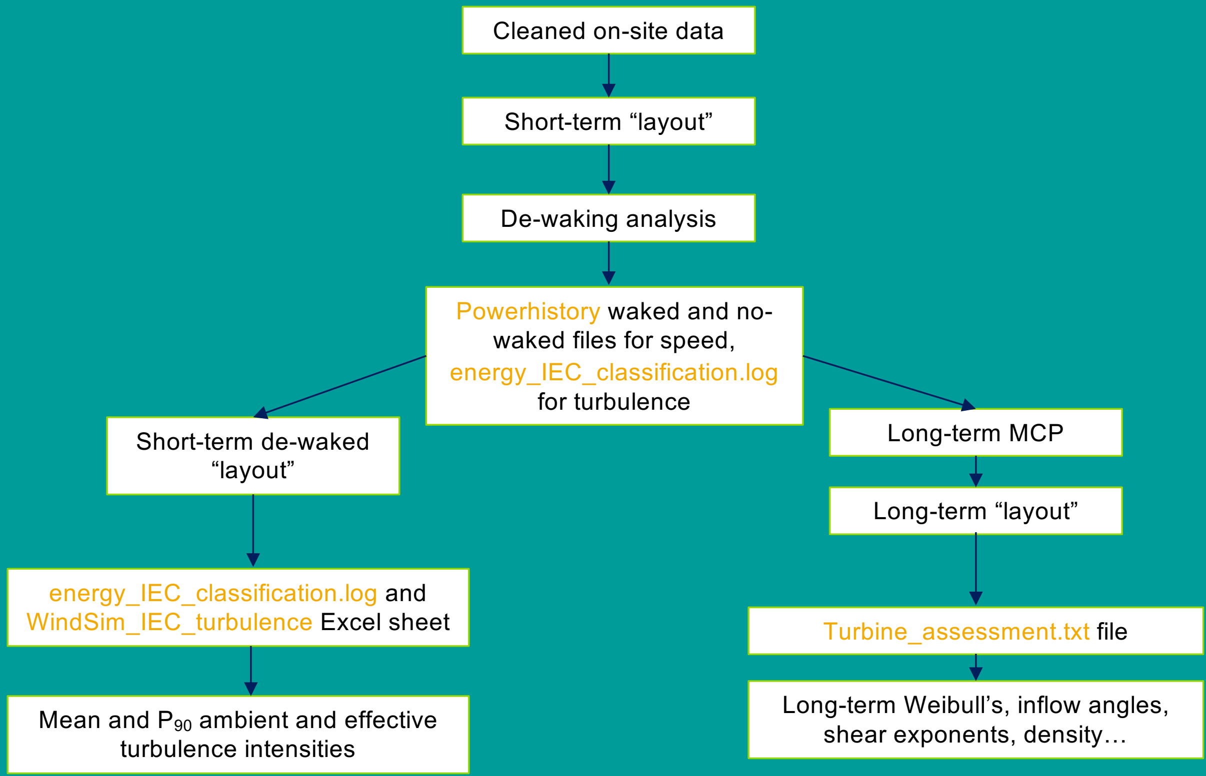
Terrain elevation
LiDAR scans, SRTM, AW3D30, OS…

Terrain roughness and forestry
Corrine Land Cover (CLC)…



Meshing and solving through
the Accelerator

How do we use WindSim for this?



Lots of valuable information at all of our turbines!

How do we do assess life?

1. Perform **relative analysis:**
   - Compare design against real turbine loading to predict fatigue life

Can we exploit excess turbine life?

Is it safe to keep running?

Image is Candeeiros Wind Farm, from Ventient LinkedIn post, May 2023: https://www.linkedin.com/posts/ventient-energy_oursites-ventientway-windpower-activity-7052234124123619328-PpM7?utm_source=share&utm_medium=member_desktop

So, what about this turbulence modelling

Indicative – further investigations underway

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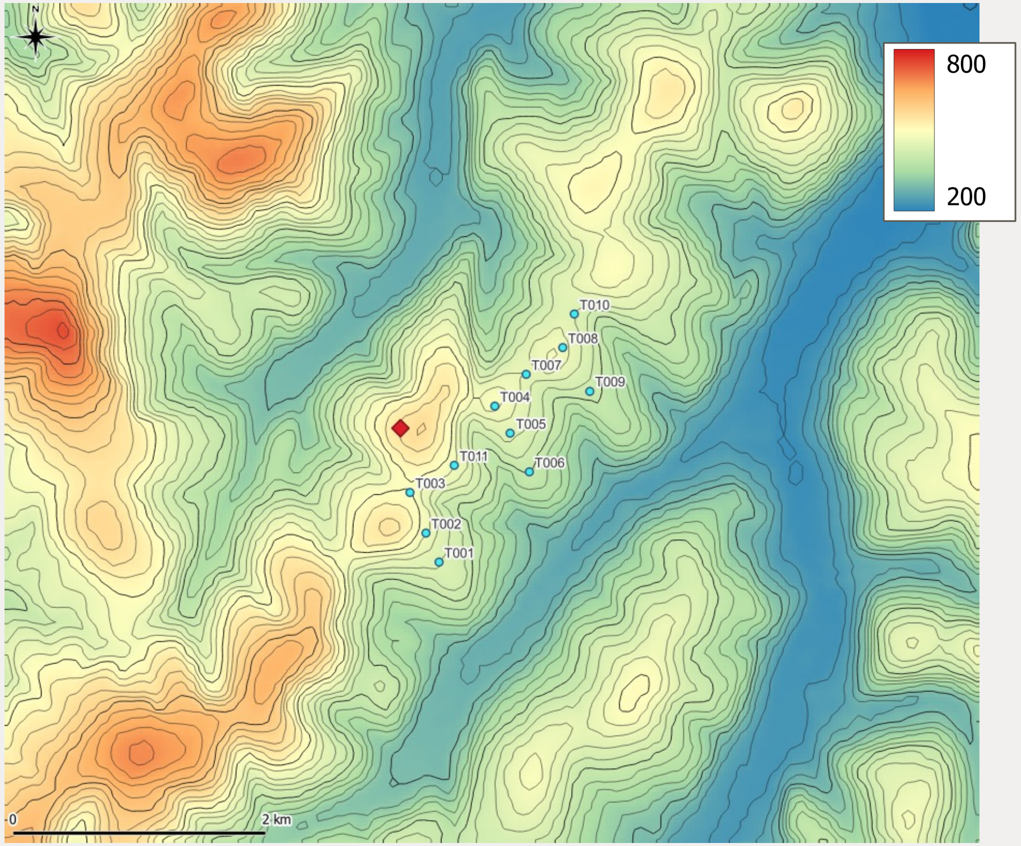
Case study, influence of turbulence model

- Site in Scotland:
  - Twelve 2 MW turbines
  - Forestry nearby but nothing extreme
  - Moderately complex terrain

- CFD set up:
  - 8.3 million cells
  - 20 m cell resolution (in refinement region)
  - SRTM terrain
  - CLC2018 roughness lengths, modified
  - Forest modelled explicitly
  - Using standard $k - \varepsilon$ turbulence model



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Case study, influence of turbulence model

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  - Twelv
  - Fores
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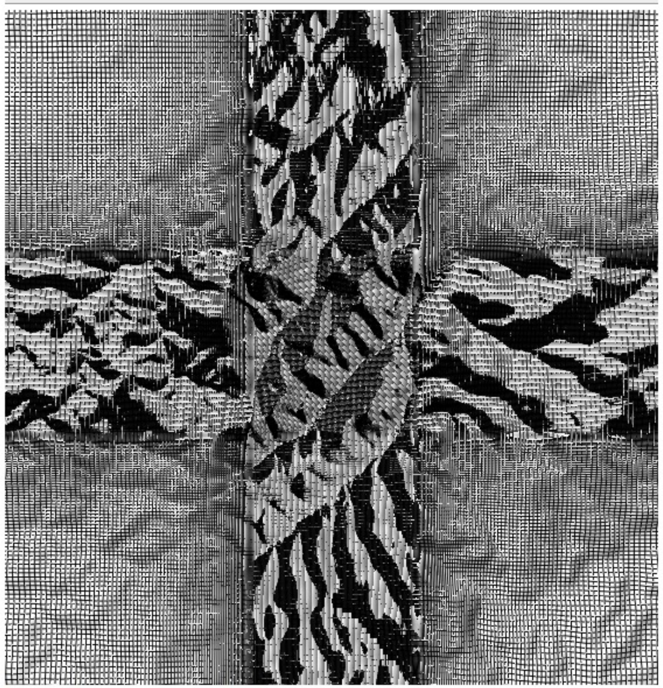


Fig 1. Digital terrain model - Grid (xy).

Body fitted co-ordinates (BFC) are used in grid generation. The above plot displays the resolution at ground level.

	x	y	z	total
Grid spacing, min - max (m)	20.1 - 178.7	20.0 - 181.5	Variable	-
Number of cells	394	419	50	8254300

Table 1. Grid data.

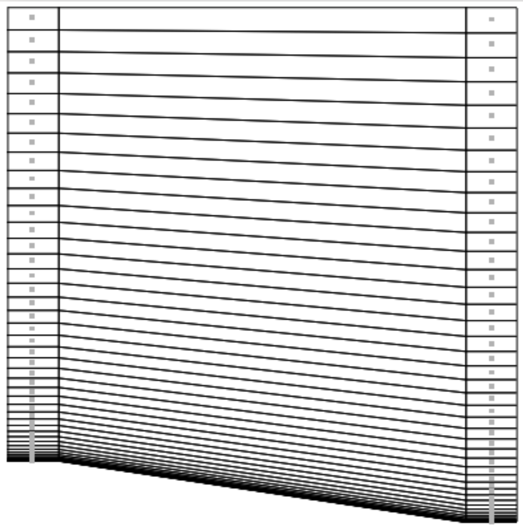
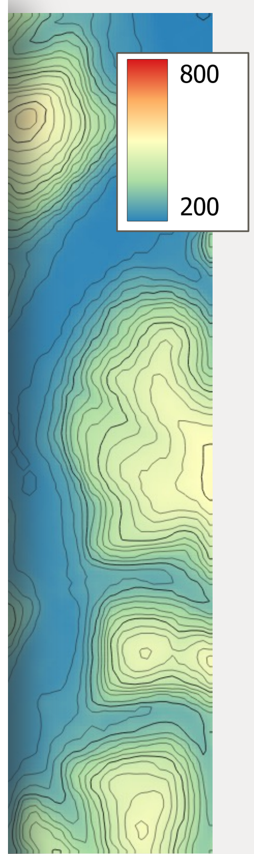


Fig 1. Digital terrain model - Grid (z).

The grid extends 4901.9 (m) above the point in the terrain with the highest elevation. The grid is refined towards the ground. The left and right columns display a schematic view of the distribution at the position with maximum and minimum elevation respectively. The nodes, where results from the simulations are available, are situated in the cell centers indicated by dots.

.	1	2	3	4	5	6	7	8	9	10
z-dist. max (m)	0.8	2.5	4.2	5.8	7.5	9.2	11.2	13.8	16.2	18.8
z-dist. min (m)	0.8	2.5	4.2	5.8	7.5	9.2	11.2	13.8	16.2	18.8
.	11	12	13	14	15	16	17	18	19	20
z-dist. max (m)	21.3	26.8	38.5	56.4	80.3	110.4	146.6	189.0	237.4	292.0
z-dist. min (m)	21.4	27.8	41.0	61.3	88.5	122.7	163.8	211.9	266.9	328.9
.	21	22	23	24	25	26	27	28	29	30
z-dist. max (m)	352.8	419.6	492.6	571.7	656.9	748.3	845.8	949.4	1059.1	1175.0
z-dist. min (m)	397.9	473.8	556.7	646.5	743.3	847.1	957.8	1075.5	1200.1	1331.7

Table 1. Distribution of the first 30 nodes in z-direction, relative to the ground, at the position



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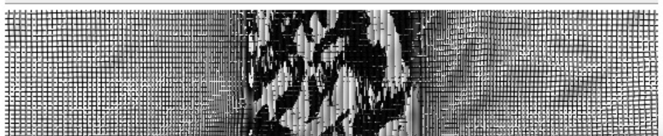

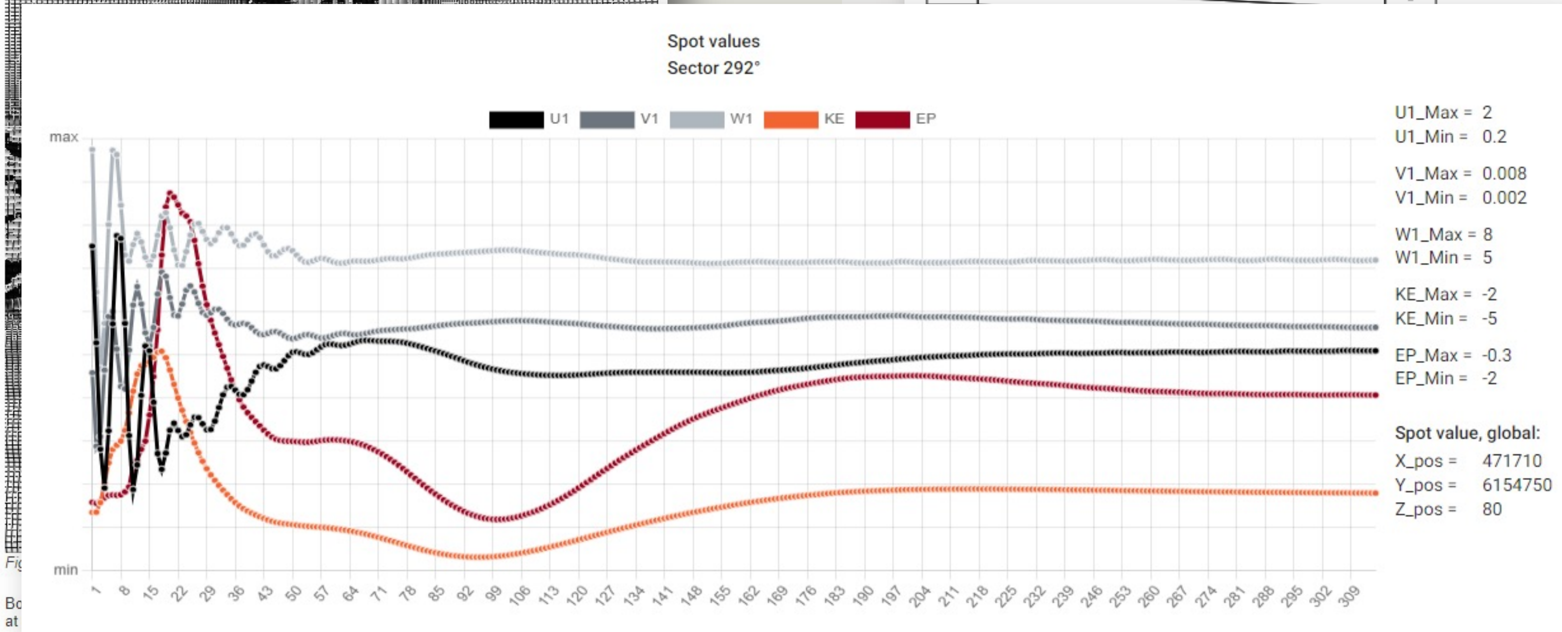

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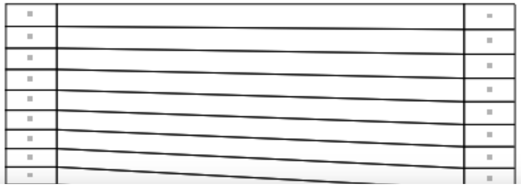

The grid is ... des, where ... dots.

										20
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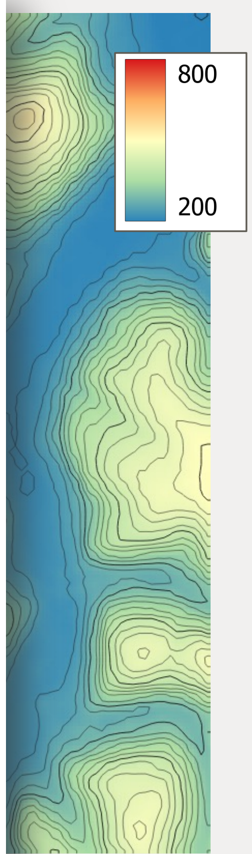

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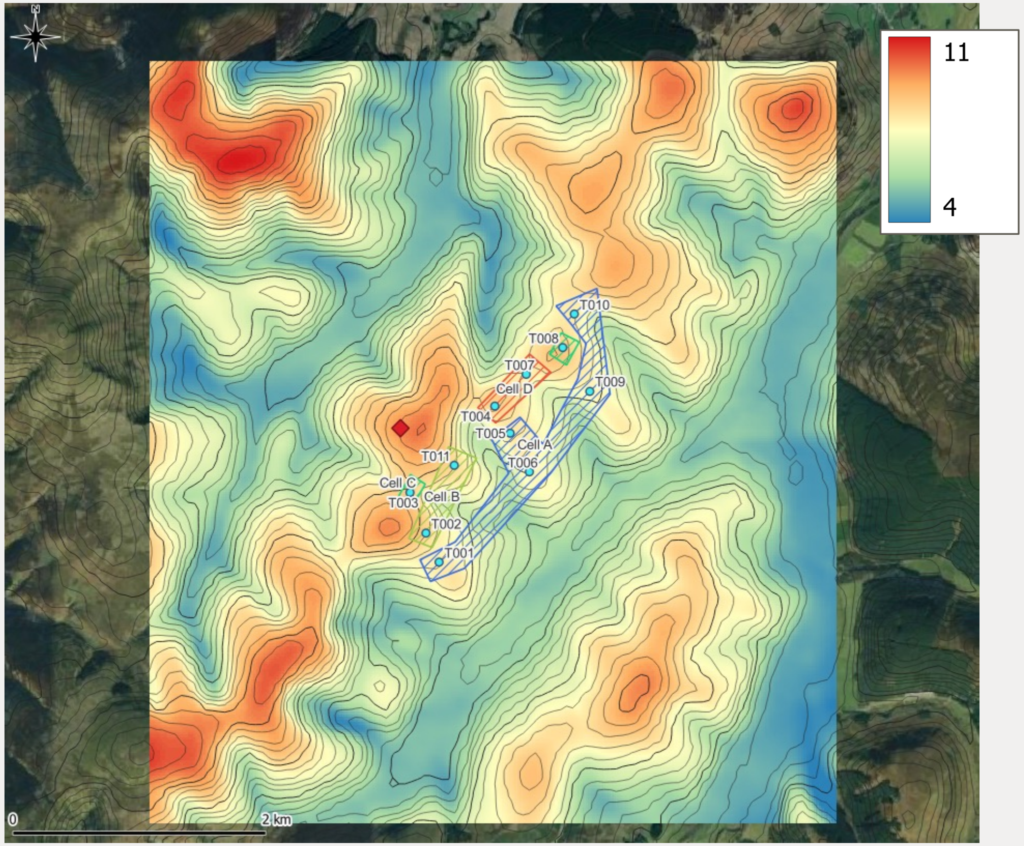

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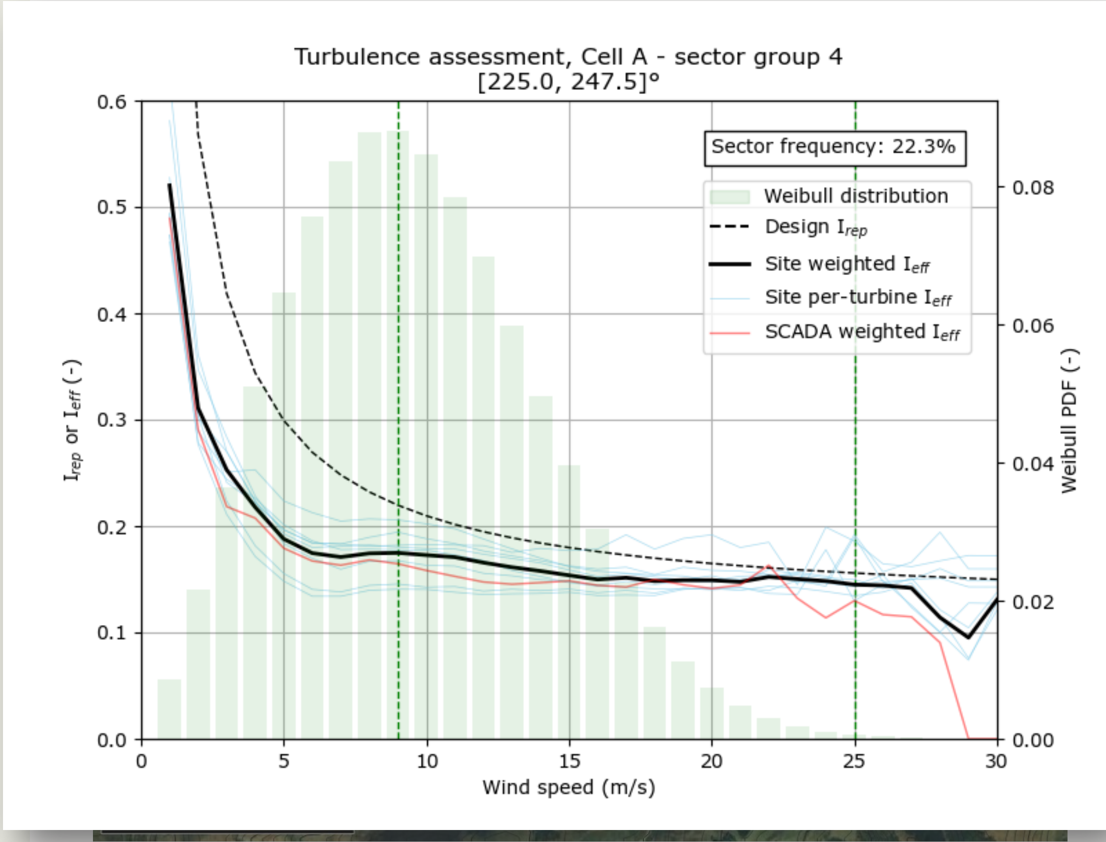

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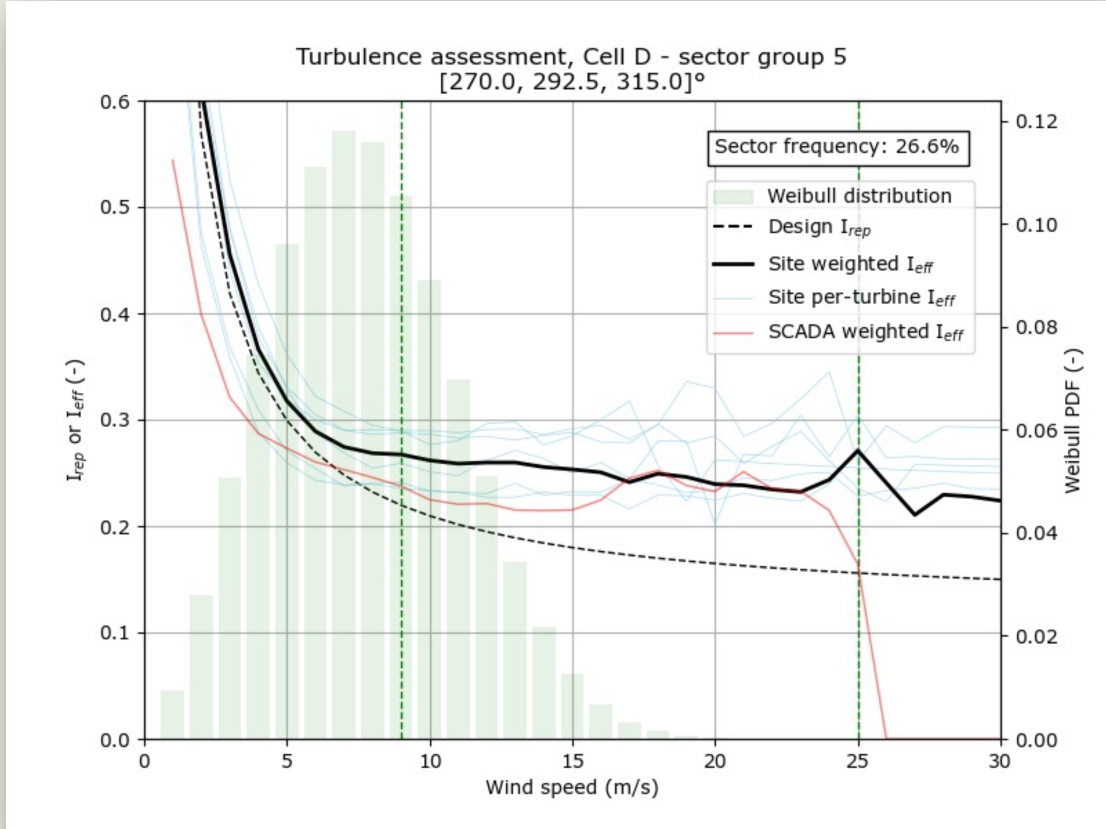

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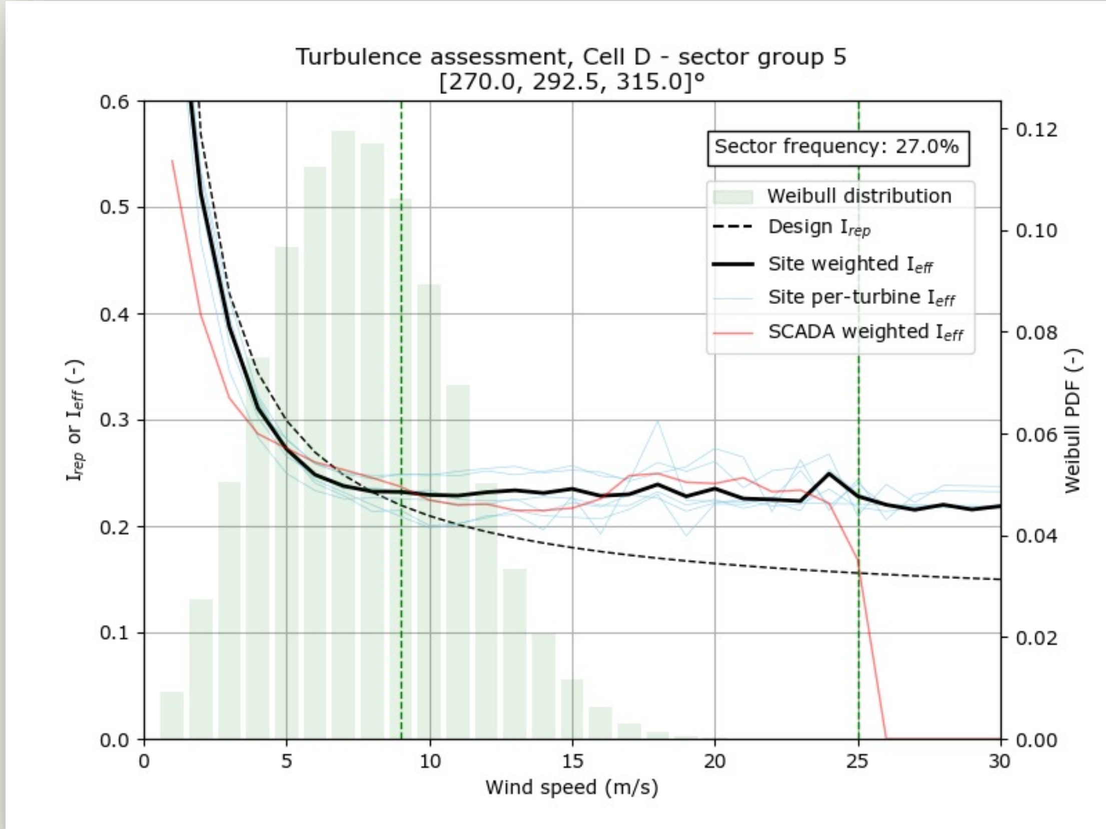
- Using $k - \varepsilon$ RNG, useful life:
  ~23 years (blade bolts)



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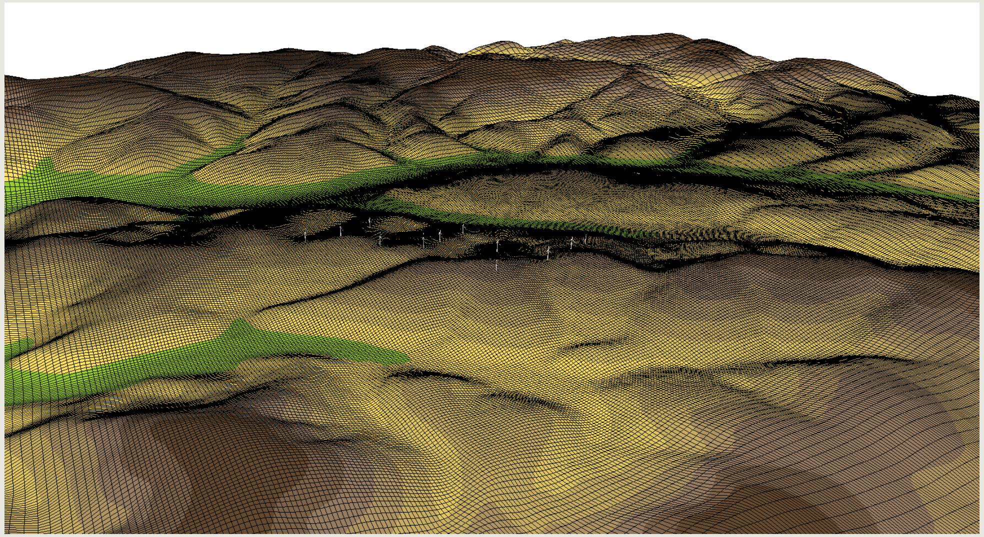
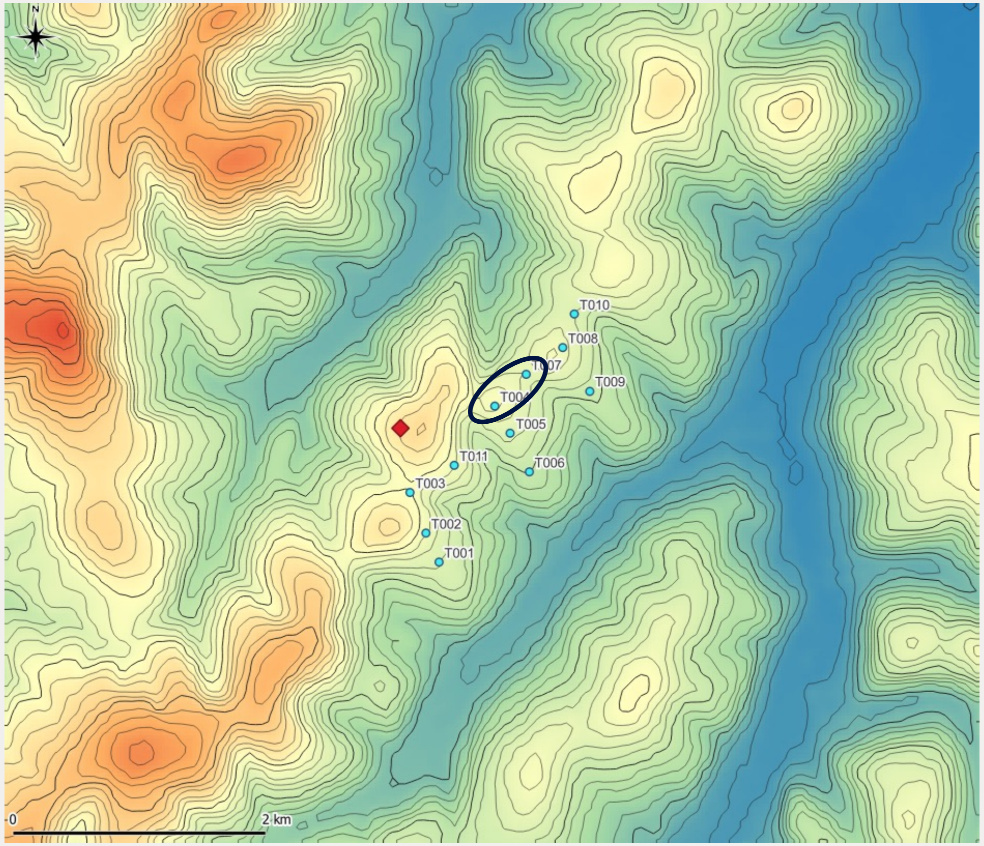
Why the difference?

- Standard $k - \varepsilon$ = 16 years
- RNG $k - \varepsilon$ = 23 years





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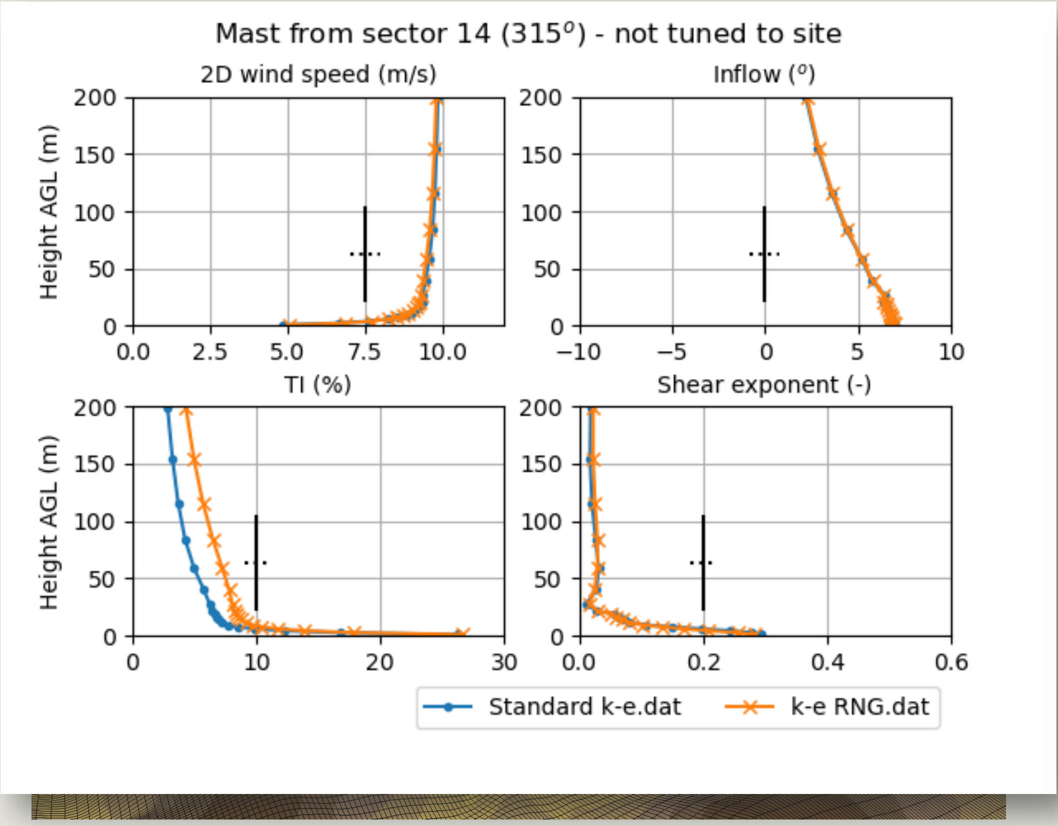

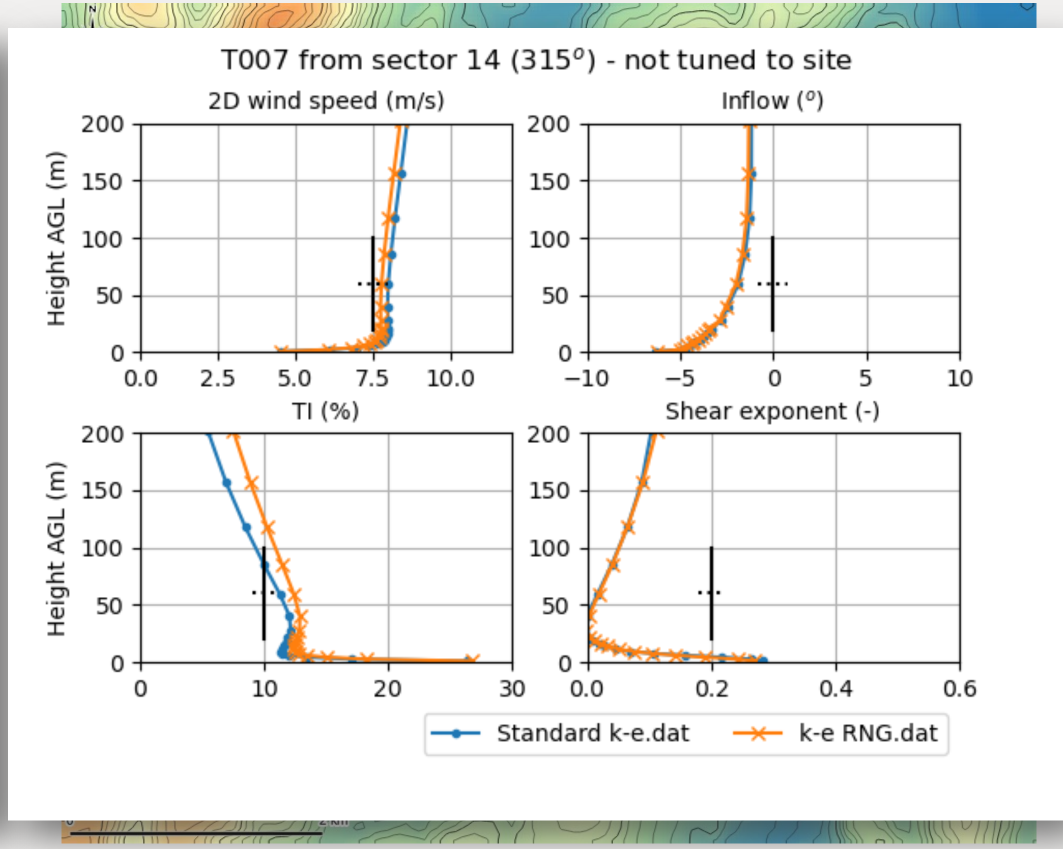

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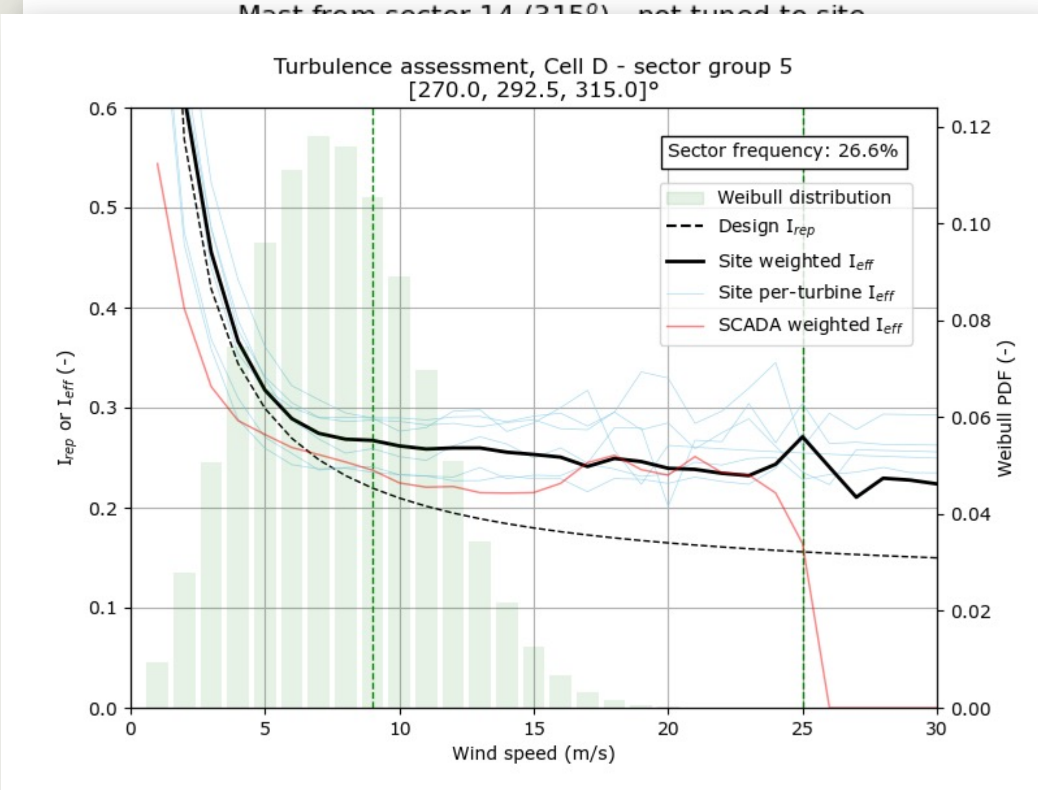
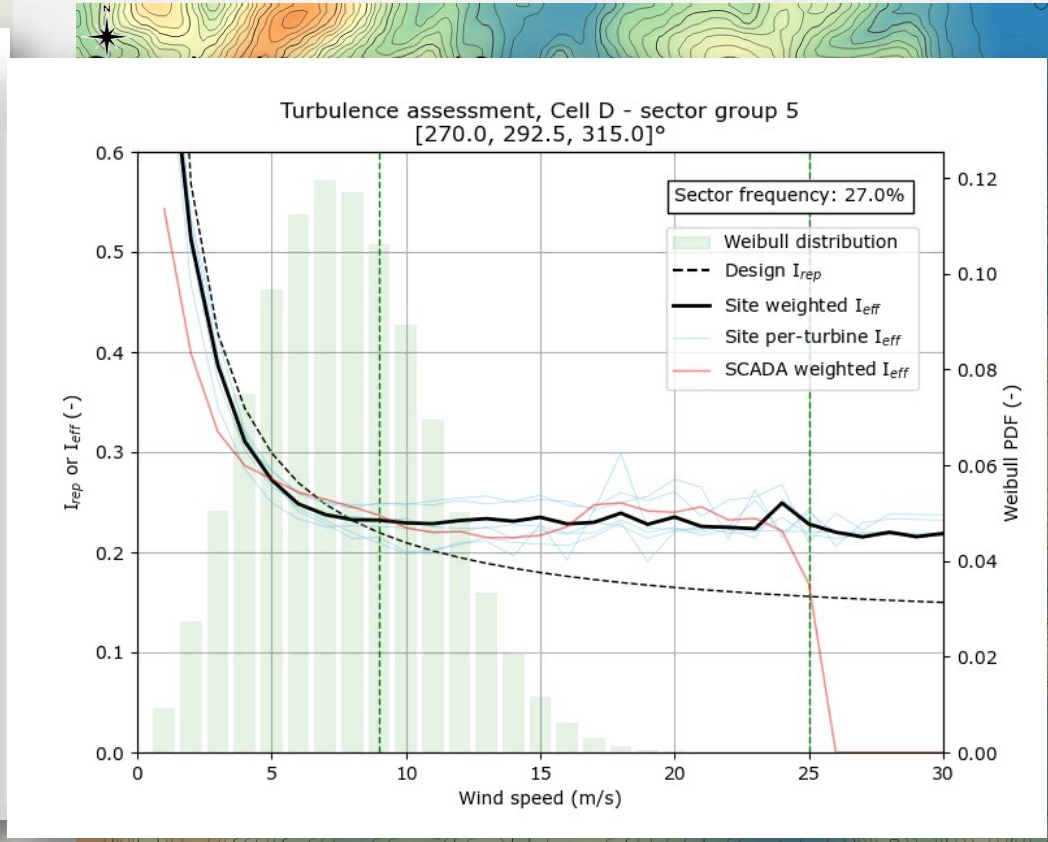
Why the difference?

Mast from sector 14 (315º) – not tuned to site





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Conclusion

- Ongoing learning process…
- $k - \varepsilon\ RNG$ adjusts the turbulence dissipation rate based on strain rate (?)
  - Improvements in rapidly strained flow
  - Improvements in flow with streamline curvature
- **Not intending to scare! Intending to encourage thought on turbulence model selection…**

$$u_j \frac{\partial u_i}{\partial x_j} = -\frac{1}{\rho}\frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j}\left[\nu\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right) - \overline{u_i u_j}\right] + \frac{1}{\rho}(S_{1,i}+S_{2,i}) \qquad i=\{1,2\},$$

$$d\left(\frac{\rho^2 k}{\sqrt{\varepsilon\mu}}\right) = 1.72\frac{\hat{v}}{\sqrt{\hat{v}^3-1-C_v}}d\hat{v}$$

$$\frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + G_k + G_b - \rho\epsilon - Y_M + S_k$$

$$\frac{\partial}{\partial x_i}(\rho\varepsilon u_i) = \frac{\partial}{\partial x_j}\left(\alpha_\varepsilon \mu_{eff}\frac{\partial \varepsilon}{\partial x_j}\right) + C_{1\varepsilon}\frac{\varepsilon}{k}(G_k + C_{3\varepsilon}G_b) - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} - R_\varepsilon + S_\varepsilon$$

Thanks for listening!

Ryan Kyle – Wind and Site Engineer
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