### Wind Resources Assessment, Complex Terrain and Atmospheric Surface Stability

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SUPERGEN General Assembly



16<sup>th</sup> November 2017

#### **Outline**

- Wind energy research at Centre for Renewable Energy Systems Technology (CREST)
- Research aim
- Some CFD simulations Results
- Conclusion and Ongoing work



#### Wind Energy Research at CREST

- Condition Monitoring
  - Investigating SCADA data for condition monitoring
  - Developing algorithms for time frequency analysis to track the magnitude of fault signatures from electrical and vibration signals.



Extraction of the magnitude for the component at twice slip frequency in the electric power signal to reveal the degree of rotor unbalance over time



## Wind Energy Research at CREST cont'd

- Wind Resource Assessment
  - The effect of wind phenomena on offshore wind power as a result of sea/shore effect.



Atmospheric Gravity Waves (AGW) over Greater Gabbard. Satellite wind field processing by DTU Wind Energy.

RHS shows preliminary results for AGW CFD solution over a near-coastal wind farm

- Wake effect in large offshore wind farms
- Significance of atmospheric stability in wind resource assessment of complex terrain sites



#### What do I aim to achieve?

- To see if considering the atmospheric stability of a site help improve the accuracy of the simulation results.
- To look at the possibility of using real analysis data to infer stability

## **Assumption!**

- I want to assume that we all know what atmospheric stability is. If not,
  - It is the ability of the atmosphere to resist vertical motion or suppress existing turbulence
  - Or as Wikipedia defines it, it is a measure of the atmosphere's tendency to encourage or deter vertical motion



### **CFD Simulation**

• Series of simulations have been carried out using ANSYS CFX solver through the WindModeller front end solving the following model equations:





#### **Simulated Site**



Contour plot of height

- Domain radius of 10 km (site is 1.5 km)
- Domain height of 4 km
- Peripheral extension of 5 km
- Included stability by using potential temperature offsets of -4, 0, and 4 K (ground relative to air).
- Used reference wind speed of 10 m/s at 70 m height
- Result presented for 300 degree direction sector



#### **Simulation Results**



Velocity contour plots for T-4, T0, and T4 respectively. The figures are positioned to the north. T4 show streaks in the horizontal wind speed distributions, aligned with the flow direction



#### **Roll vortices?**



Low wind speed in regions of updraft and higher wind speeds in regions of downdraft

Not sure if this phenomenon is transient or steady-state as RANS model cannot truly determine this

This is suspected to be longitudinal roll vortices but cannot be verified due to time and computational requirement of LES

Image of the vector plot displaying a phenomenon that is yet to be ascertained



#### **Streaks persistent**



Velocity contour plots of 300 degree direction sector at 70 m above ground level for temperature offset of 4, 3, 2, and 1

- Shows that the streaks reduces as the potential temperature offset is reduced
- Using five stability classification:

T4 = Very unstable, T3 = Very unstable, T2 = Very unstable, T1 = Unstable Therefore, it could be said that this phenomenon only occurred in a very unstable atmospheric condition



Velocity contour plots of T4 at 300 degree direction sector and at 70, 300, 700, and 1000 m above ground level

The Streaks also reduces with height. From the figure on the RHS, it has a depth of up to 1 km.



## Conclusion

- Atmospheric stability can significantly affect wind flow in complex terrain sites.
- Modelling with atmospheric stability included can help reveal some flow features that would normally not be seen if modelled neutrally. Hence, It can provide important information that can help improve the siting of wind turbines thereby reducing operation and maintenance cost.

## **Ongoing work**

- To use reanalysis data to infer stability and see if it improves the accuracy of the simulation results.
- To carry out CFD simulations on other complex terrain sites to determine the importance to of including stability
- To determine the reliability of the reanalysis data in inferring stability
- To try and validated the simulation results with field measurements



# Thank you!

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