Veers' Extension to Non-neutral Incoming Winds (VENTI)

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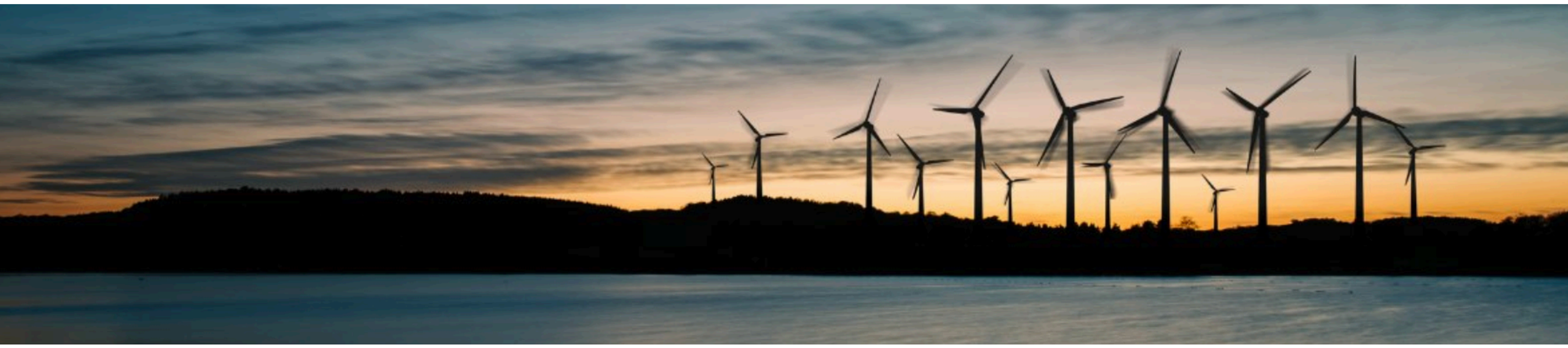
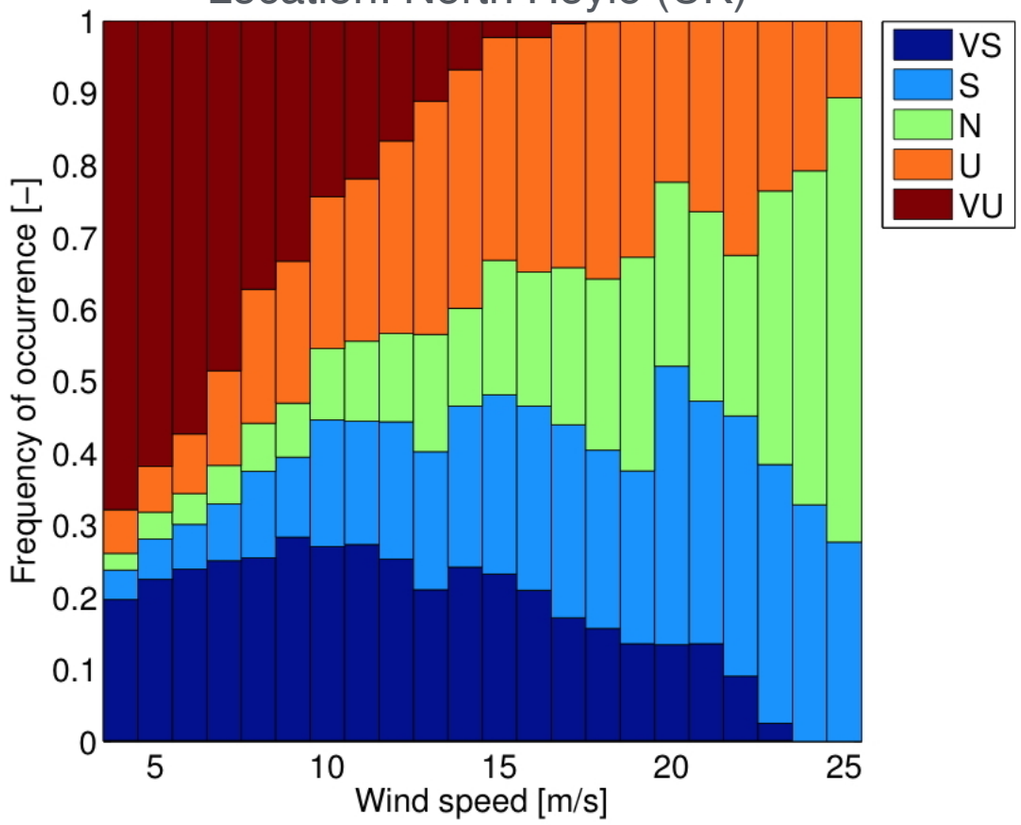
Supergen ORE - Flex Funding - First Call (2019)



Problem and parameter space

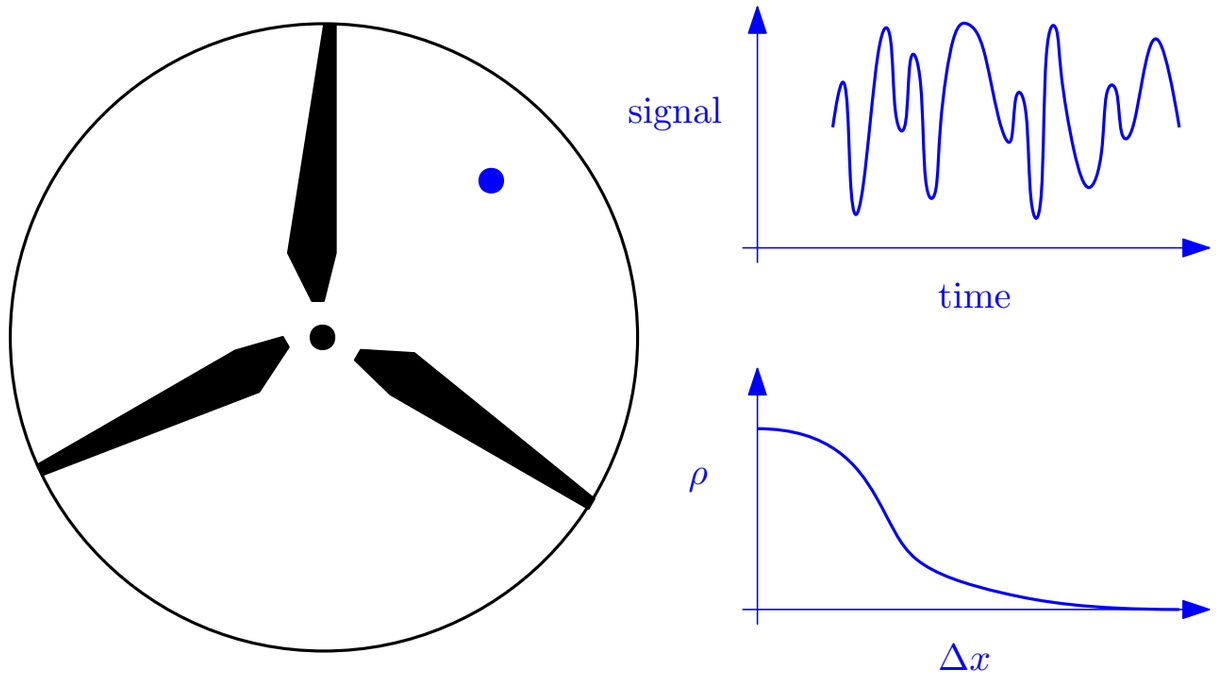
- The ABL is often not in neutral conditions
- We want simple methods to predict the wind resource availability (stability & WT)
- One approach is **Veers' method** - Sandia Lab (Veers 1984,1988)
- With atmospheric stability the parameter space is vast

Location: North Hoyle (UK)



Alblas, L, et al. (2014) J of Physics, Conf Series 555

Veers' Method (Veers 1984,1988)



Veers (1984, 1988) Sandia National Laboratories, Tech Reps SAND83-1909/ UC-60 & SAND88-0152/UC-261

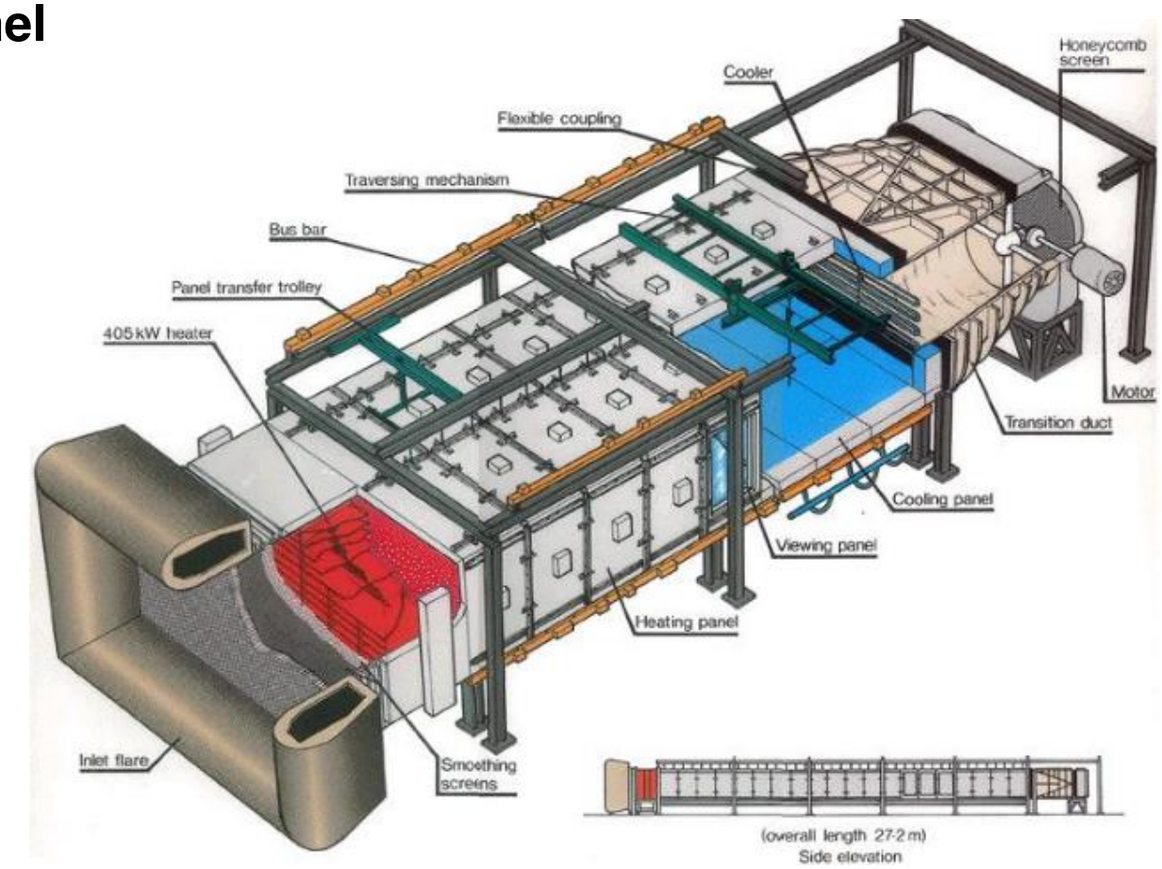
Experimental facility and setup

EnFlo – NCAS & NWTF meteorological wind tunnel

- Large working section: 20 m x 3.5 m x 1.5 m
- Velocity: 1.5 m/s ($P \propto V^3$)

- Heating: 15 layers, 405kW inlet heater
  $(dT/dz)_{max}$=80C/m
- Floor cooling: 1 kW/m^2, 10 ˚C

- 2 overhead 3-axis traverses



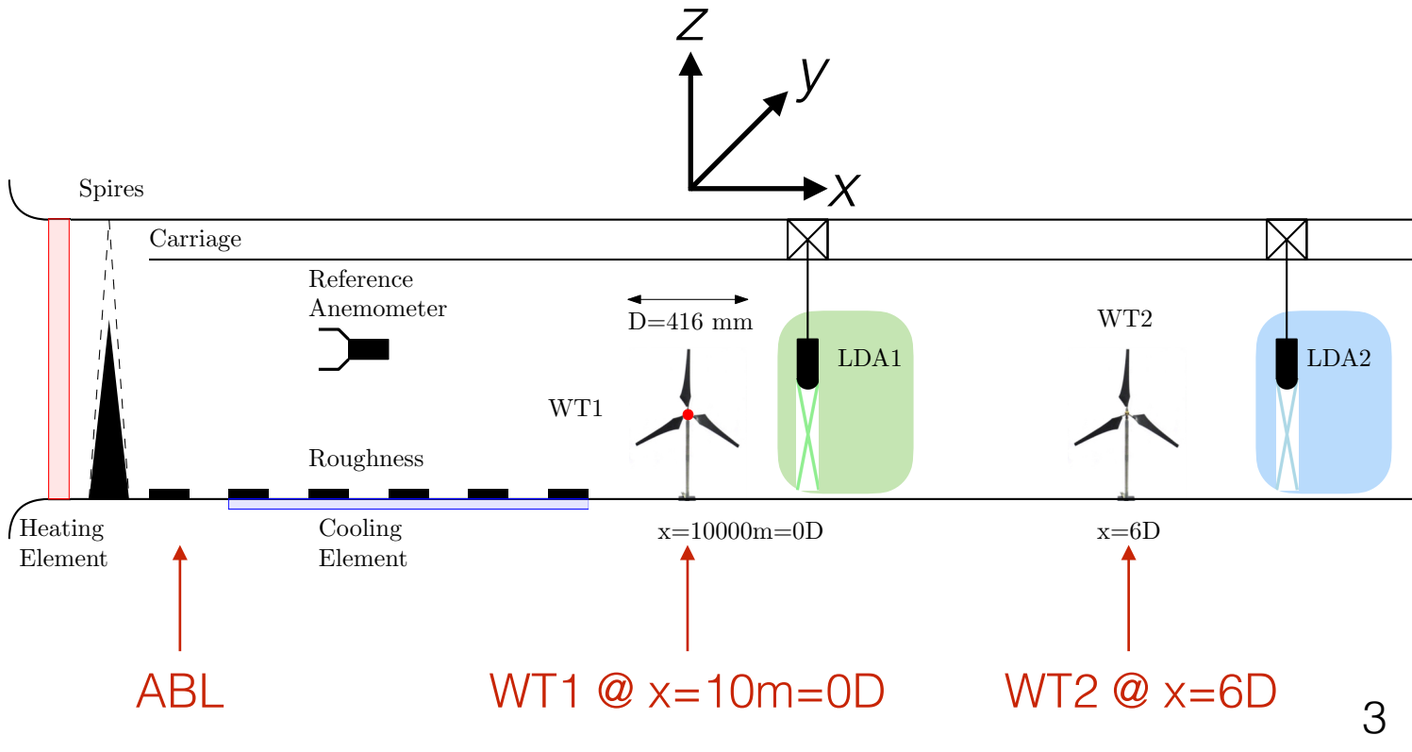
Experimental setup

- Spires & roughness to induce a suitable ABL

- Aerodynamic parameters to match field data

- 2-point simultaneous LDA

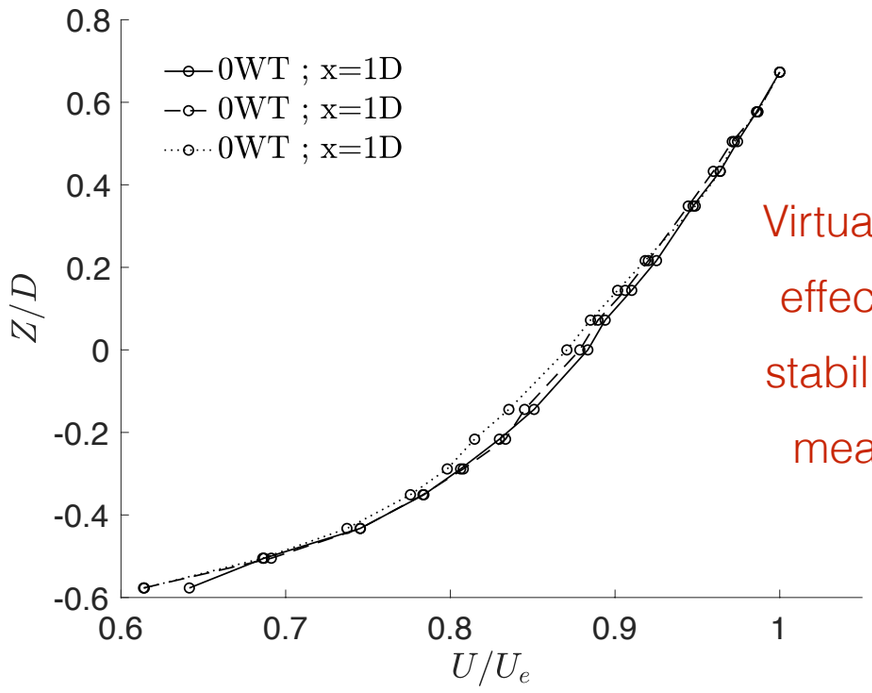
- 3 stability conditions: Neutral, moderately stable, moderately stable (+ inversion)



Effect of **stability** on ABL stats

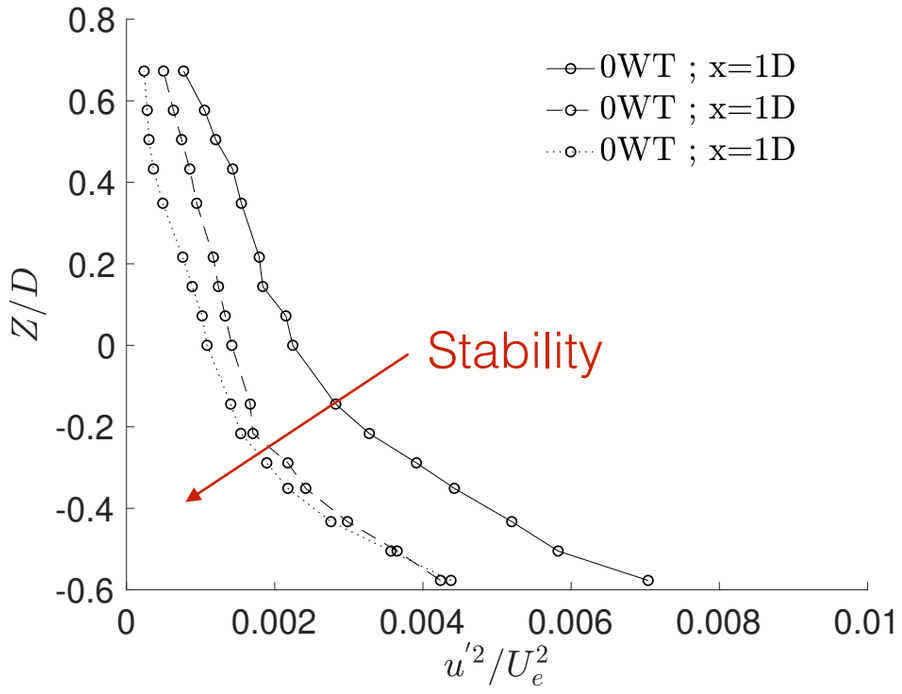
Stability effect - no WT

Stability on mean velocity

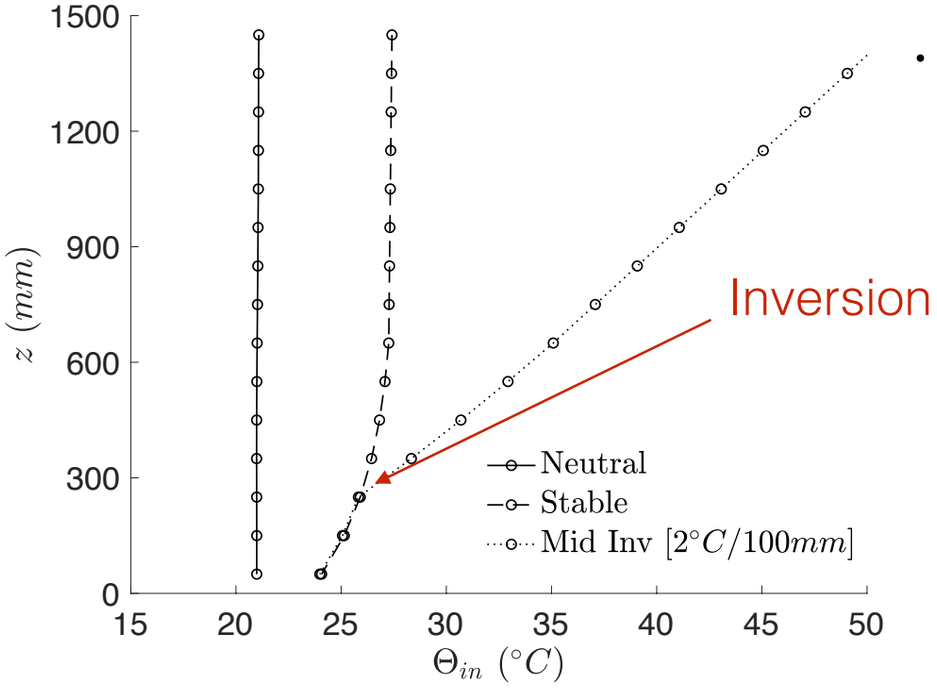


Virtually no effects of stability on mean U

Stability on Reynolds stresses



Θ upstream (heaters)



Neutral

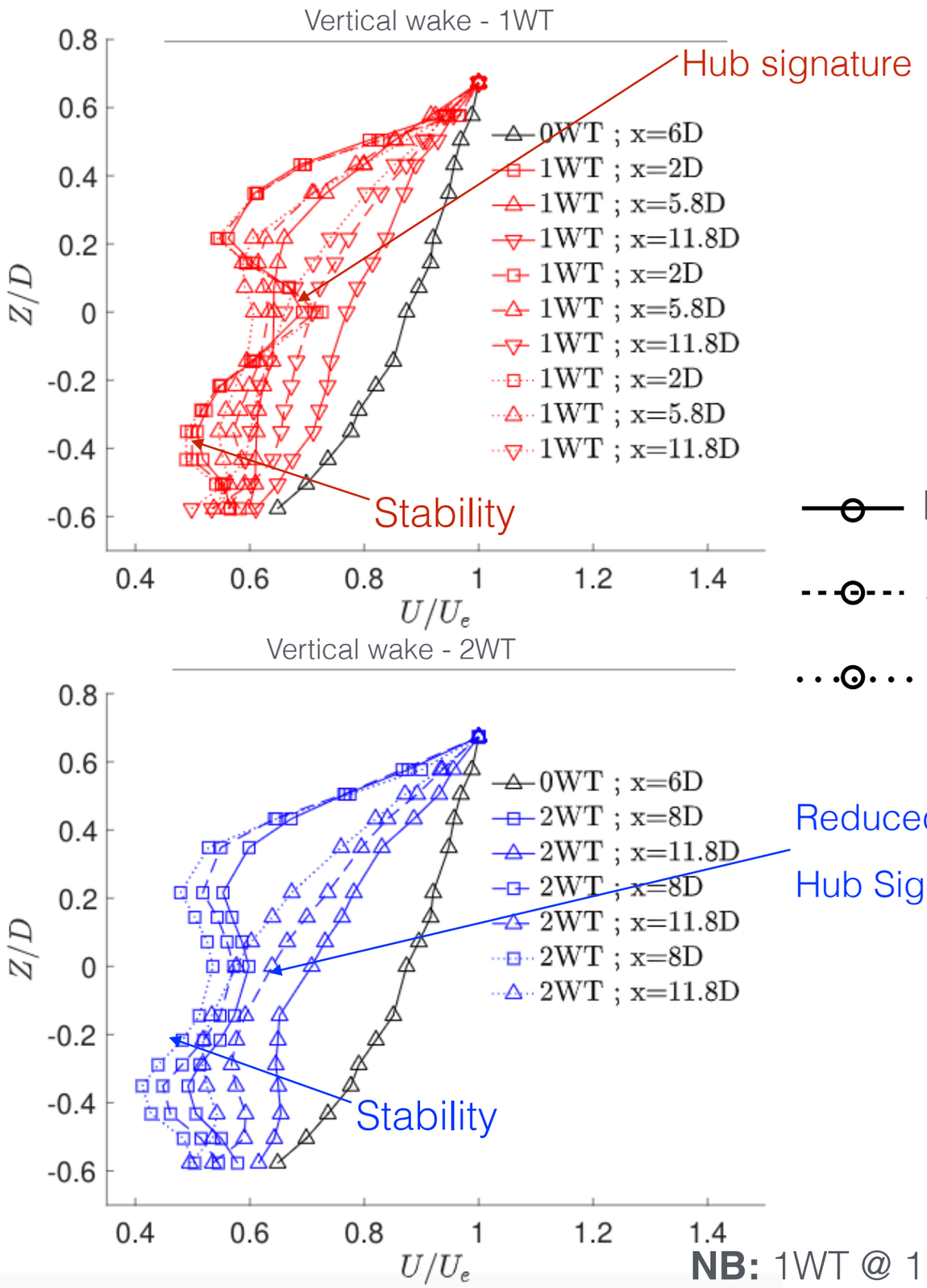
Stable

Mid Inv

- Moderate atmospheric **stability** (with or without inversion) has virtually **no effect** on the **mean velocity** profiles
- Stability, as known, **inhibits** the turbulence **fluctuations**

Effect of **stability & WT** on velocity

Combined effects

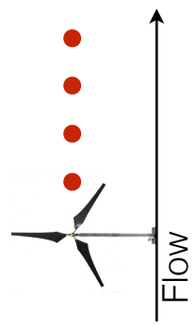


Neutral — 0WT

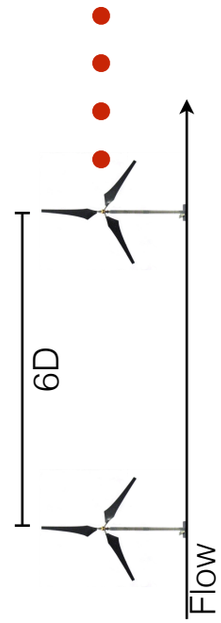
Stable — 1WT

Mid Inv — 2WT

- The **stronger** the **stability,** the **slower** the wake **recovery**



- **Wake recovery affected by stability** (same as above)
- **Snaking/meandering of the wake** evident from lateral profiles (not shown on this slide)

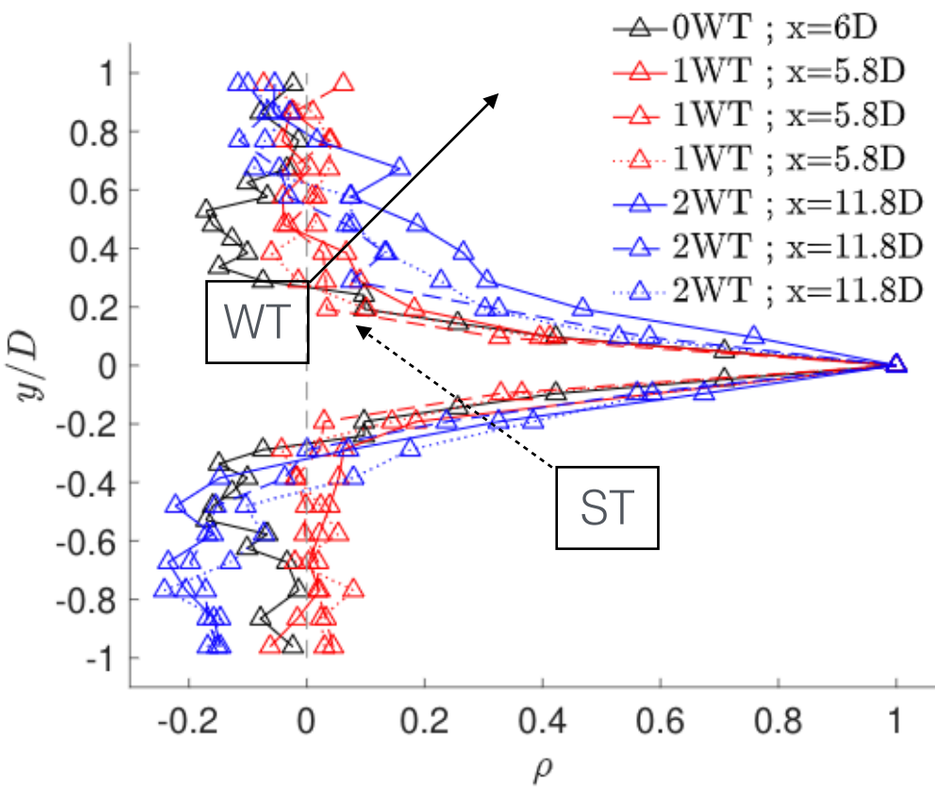


NB: 1WT @ 1D = 2WT @ 7D

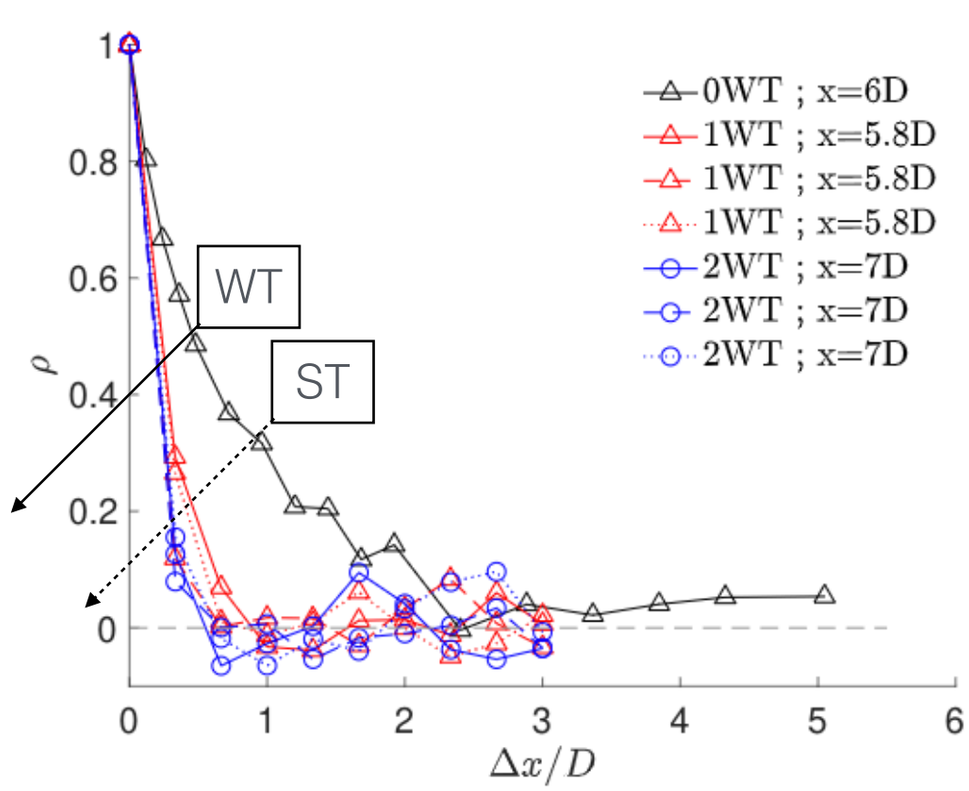
Effect of **stability & WT** on correlations

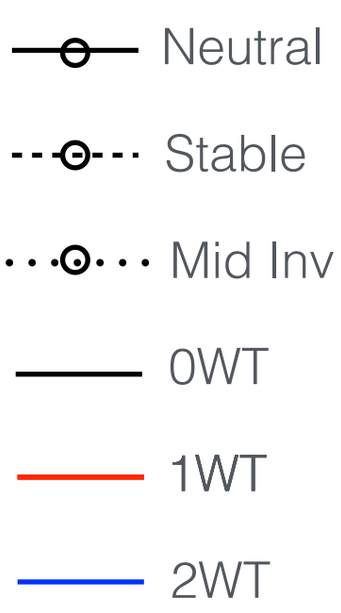
Combined effects

Lateral correlations @ $z=z_h$



Longitudinal correlations @ $z=z_h$





- <u>Lateral correlations:</u> presence of **WTs and stability seem to have competing effects** (widening vs. narrowing)

- <u>Longitudinal correlations:</u> both **WTs and stability reduce longitudinal lengthscales**

Major findings to date

- The rate of longitudinal momentum recovery is affected by the thermal stability

- The effect of the wake flows with thermal stability on correlation lengthscales is complex

  - In the bottom part of the boundary layer, the vertical correlation is much more affected by the presence of the wake than by the change in atmospheric stability; the opposite is true in the top half of the layer

  - The longitudinal correlation is significantly reduced due to both the turbines and the thermal stability

    - The lateral correlations are widened by the turbulence in the wake flows, while the thermal stability seems to oppose this effect

- Thermal stability should be considered when expanding the approach of Veers to non-neutral winds as this can significantly affect the wind coherence function

Dissemination

Conference participation:

- **Placidi, Hancock (2021).** Veers' Extension to Non-neutral Incoming Winds (VENTI). *Presentation and panel discussion at the Supergen ORE Hub Annual Assembly: Offshore Renewable Energy and the Road to Net Zero. Online, Jan 18-21, 2021.*
- **Placidi, Hancock, Hayden (2021).** Wind power aerodynamics in non-neutral winds. *18th European Turbulence Conference, Dublin, Ireland, August 23-26 2021. (Cancelled)*
- **Placidi, Hancock, Hayden (2020).** Effect of wind turbines and atmospheric stability on turbulent boundary layers. *73rd Annual Meeting of APS DFD, Chicago, IL, November 22-24, 2020.*

Journal publication:

- **Placidi, Hancock, Hayden (2021).** Wind turbine wakes: two-point correlations and the effect of stable atmospheric stability*. To be submitted before the end of 2021.*

Further impact

Scholarships:

- This work was leveraged and shortlisted for **NERC SCENARIO Ph.D. scholarship in 2020 (Value: £65k)**. More info: https://www.findaphd.com/phds/project/scenario-the-effect-of-non-neutral-winds-on-wind-power-aerodynamics/?p126145. A candidate was shortlisted for this position - they, unfortunately, withdrew their application
- This work was leveraged and shortlisted for **NERC SCENARIO Ph.D. scholarship in 2021 (Value: £65k)**. Currently recruiting. More info: https://research.reading.ac.uk/scenario/apply/projects-for-2022-entry/

Media:

- This work was featured by the University of Surrey's media team, who issued **a Press Release**. See https://www.surrey.ac.uk/news/surrey-develop-tool-help-predict-efficiency-wind-farms

Grants:

- Project received University of Surrey's internal COVID-19 funded extension in Sept 2020. The extension **(value £43k)** aimed at counteracting the impact of COVID-19 on laboratory closure and personnel hire. This allowed VENTI to run until Sept 2021

- Findings and publications (upcoming) are being leveraged to develop a **multi-institution proposal** led by Surrey to EPSRC on topics related and complementary to those of VENTI **(value £800k)**

For any questions, please do contact

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This work is supported by:

- NCAS/EPSRC (National facility)
- EPSRC Flex Funding agreements within SUPERGEN Wind and ORE under projects VESABL and VENTI
- DNVGL and CATAPULT ORE as project partners