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# The modeling and observation of the long-term offshore vertical wind profile and wind shear

**Alfredo Peña**, Sven-Erik Gryning, Torben Mikkelsen,  
Charlotte Hasager and Mark Kelly

DTU – Technical University of Denmark  
DTU Wind Energy, Risø campus – Department of Wind Energy

EWEA 2012 – Copenhagen, Denmark

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# Outline

- 1 Background
- 2 NORSEWInD project
- 3 The challenge
- 4 Long-term analysis
- 5 Results
- 6 Summary

## Background (1/2)

Knowledge of the vertical wind speed profile and wind shear is important when, i.a.:

- predicting winds at higher/lower levels (somehow done)
- predicting wind power outputs (almost not done)
- predicting loads (almost not done)
- predicting wake effects (almost not done)
- performing power curve measurements (on the way)
- performing thrust curve measurements (almost not done)

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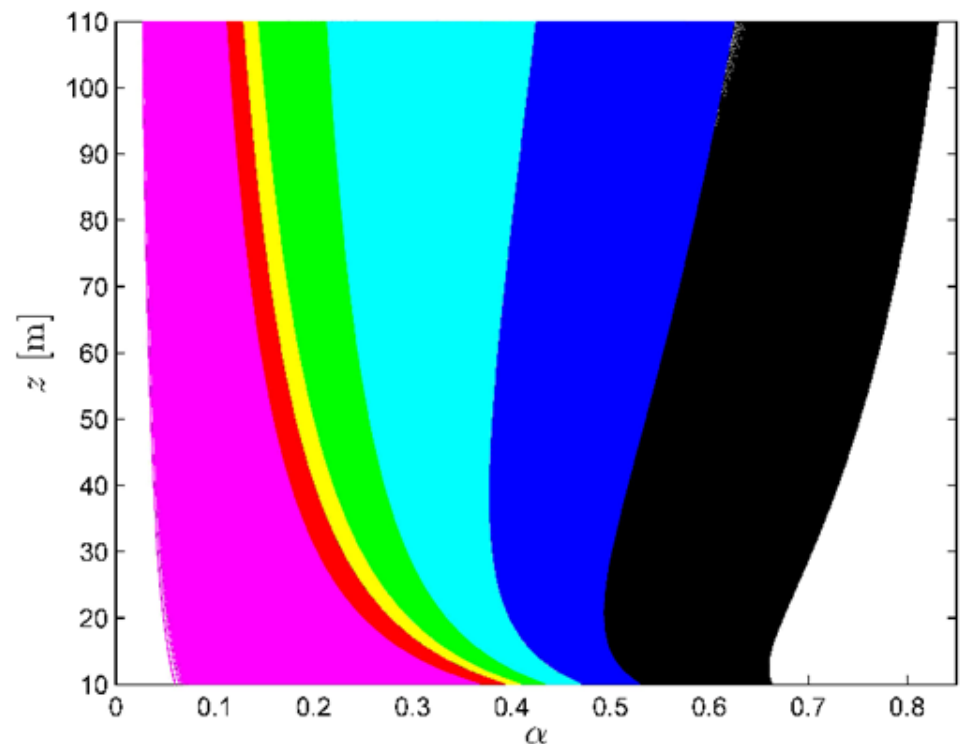
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## Background (2/2)

Combining the power law  
with MOST, i.e,

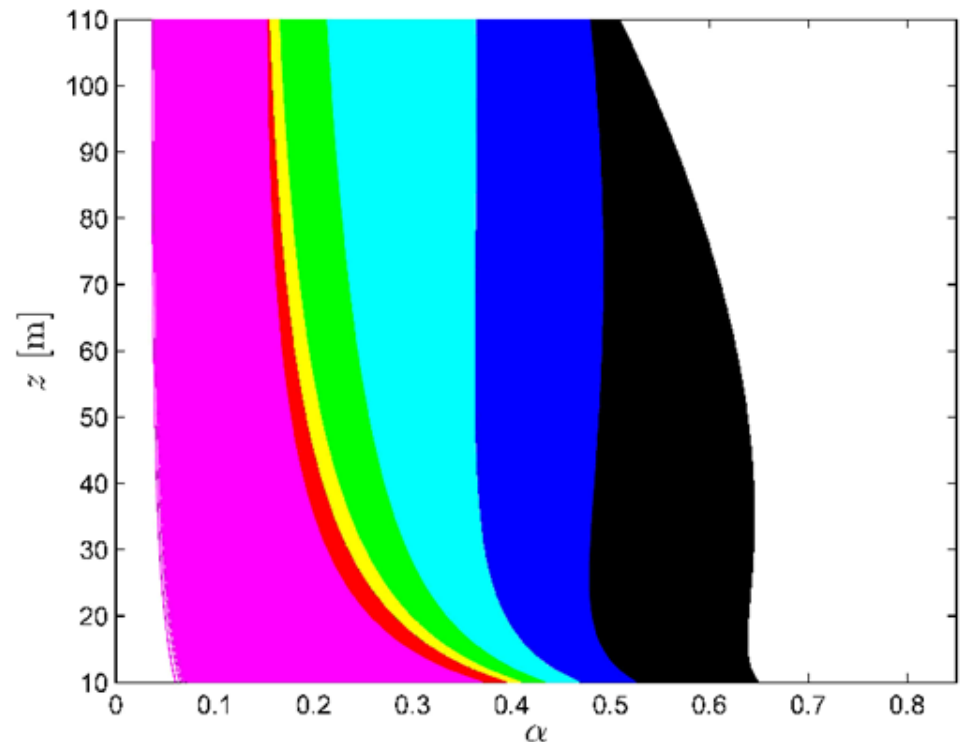
$$u = u_r \left( \frac{z}{z_r} \right)^\alpha +$$
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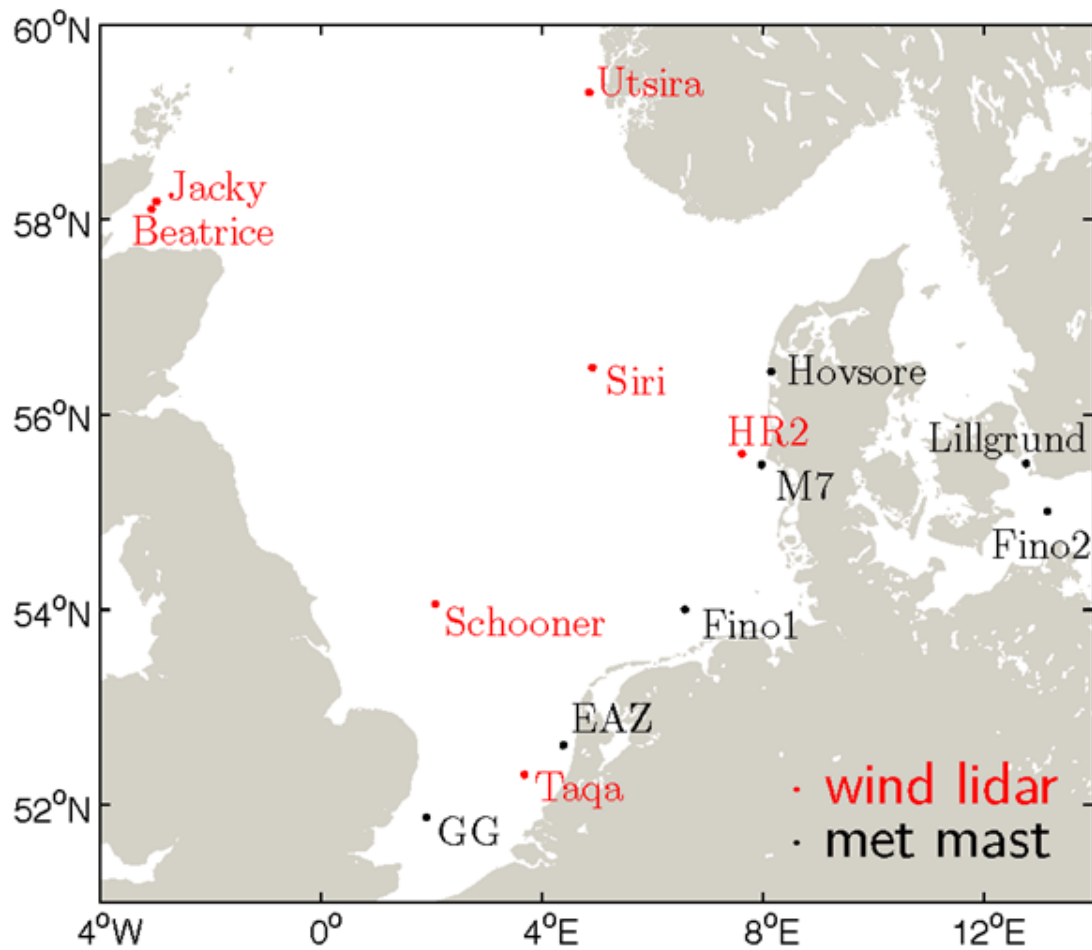
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# NORSEWInD network

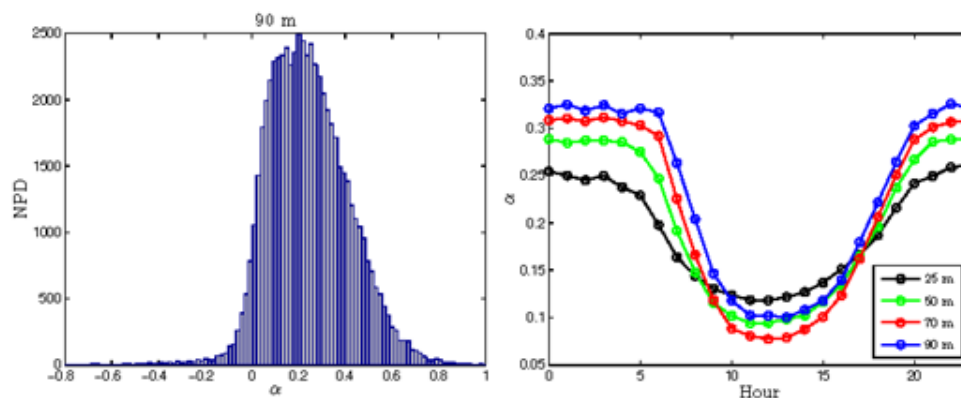
For wind shear analysis



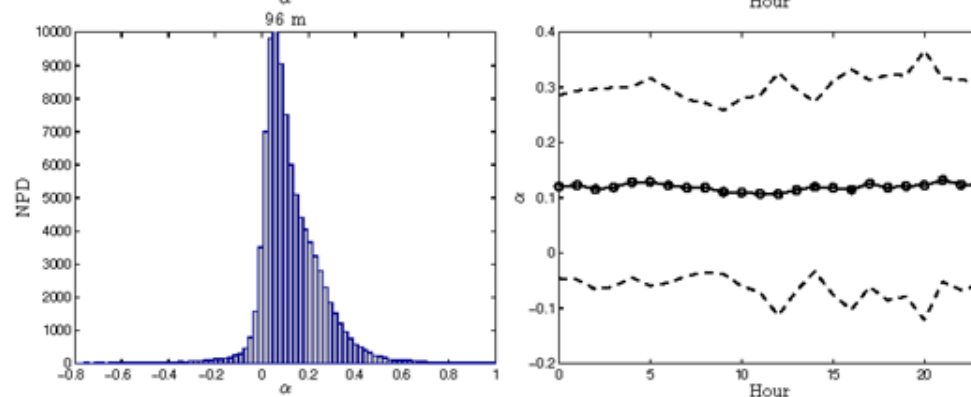
# The challenge – facts

- No measures of stability at NORSEWInD lidar nodes
- Not all mast nodes have means to derive stability
- Offshore shear values similar to onshore but different behavior:

Hovsore



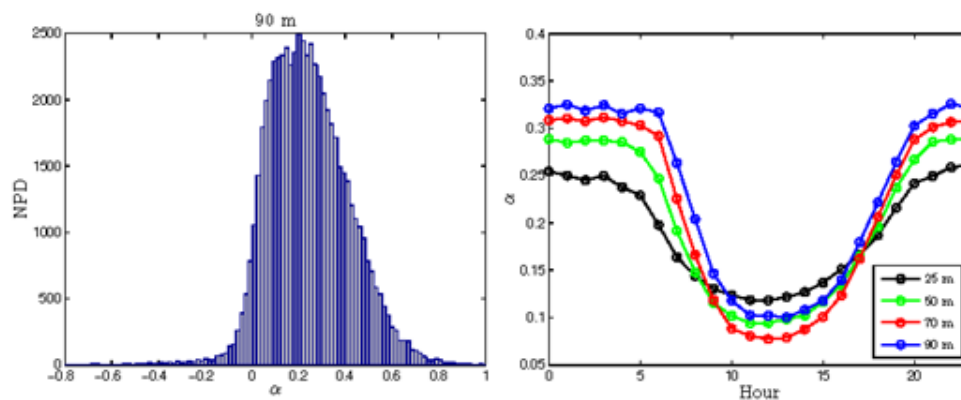
Horns Rev II



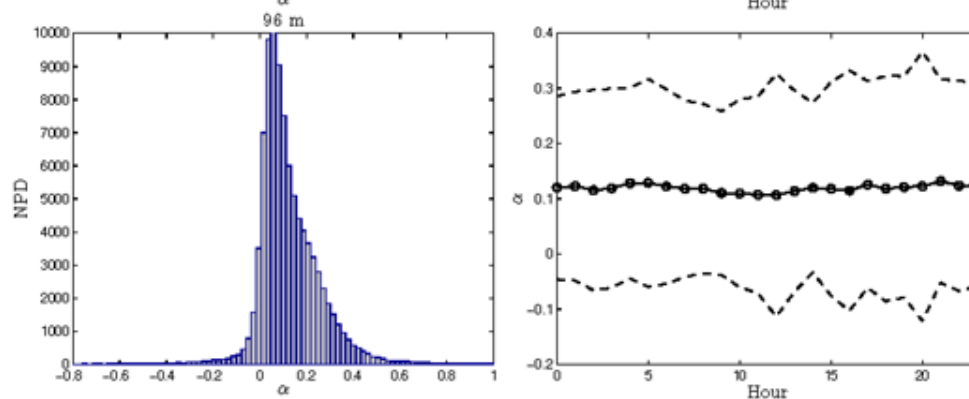
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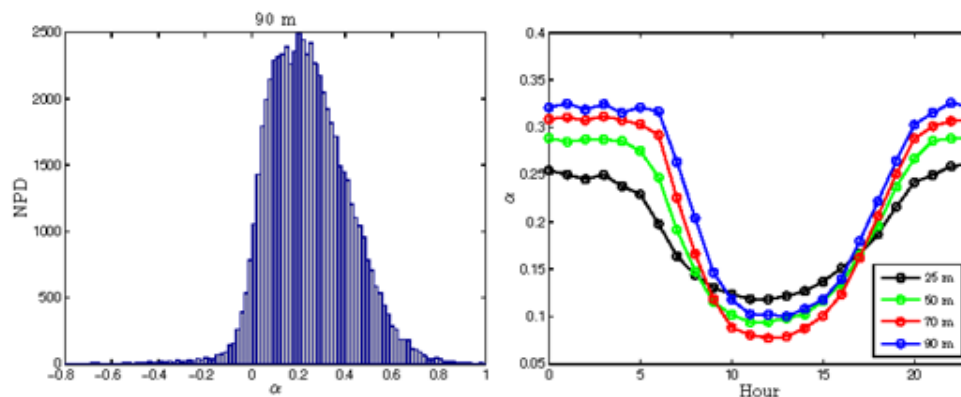
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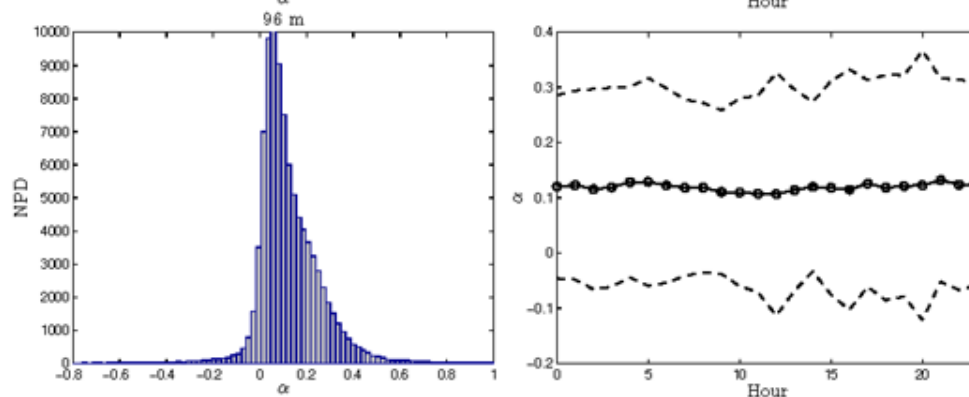
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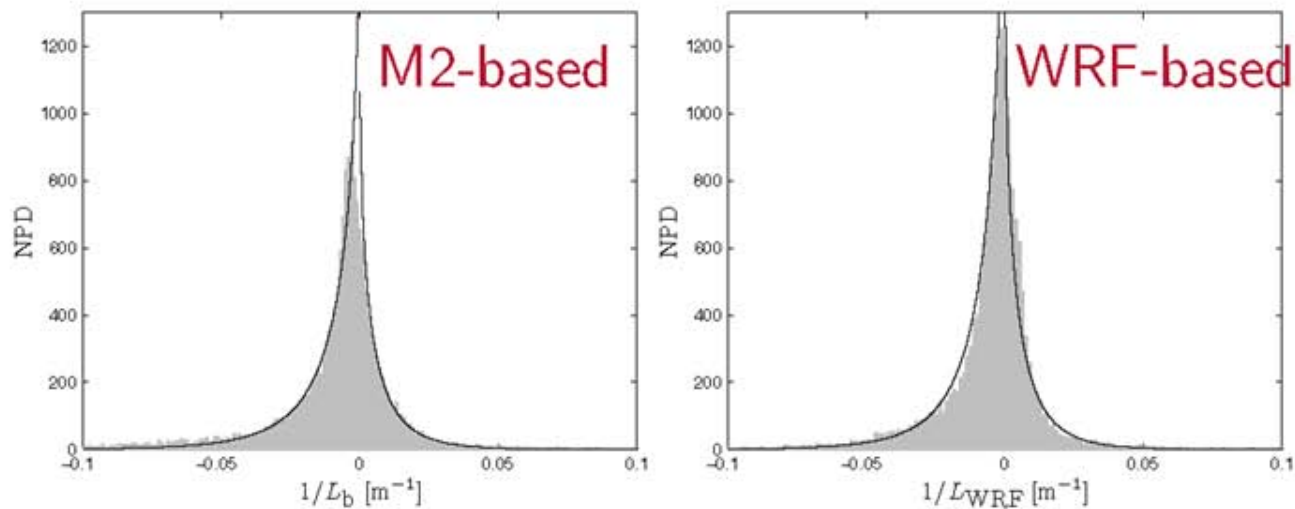
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# Long-term analysis – Horns Rev I (M2) + WRF

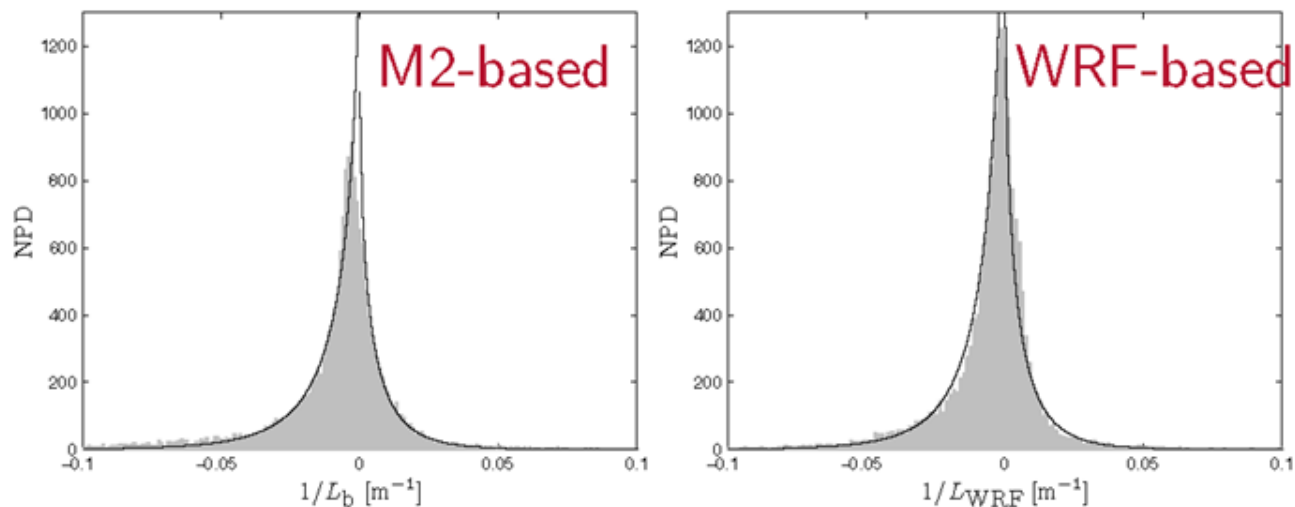


$$P = n_{\pm} \frac{C_{\pm} \exp \left[ - (C_{\pm} |1/L| / \sigma_{\pm})^{2/3} \right]}{\sigma_{\pm} \Gamma [1 + 3/2]}$$

$$\sigma_{\pm} = \frac{g}{\langle \bar{T} \rangle} \frac{\langle (\overline{w'\theta'_v} - \langle \overline{w'\theta'_v} \rangle_{\pm})^2 \rangle^{1/2}}{\langle u_*^3 \rangle}$$



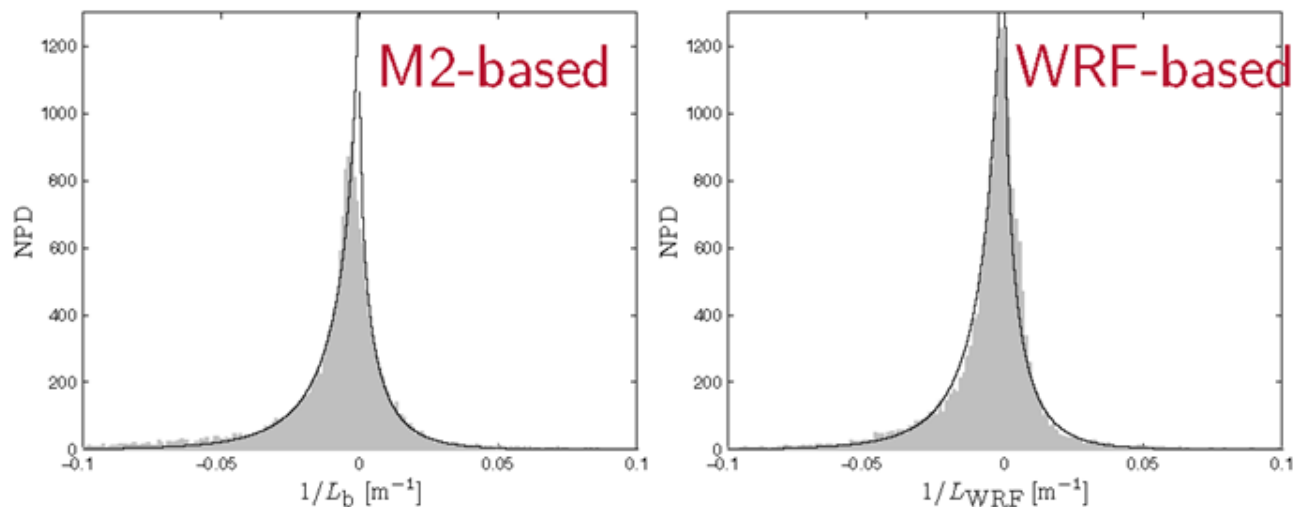
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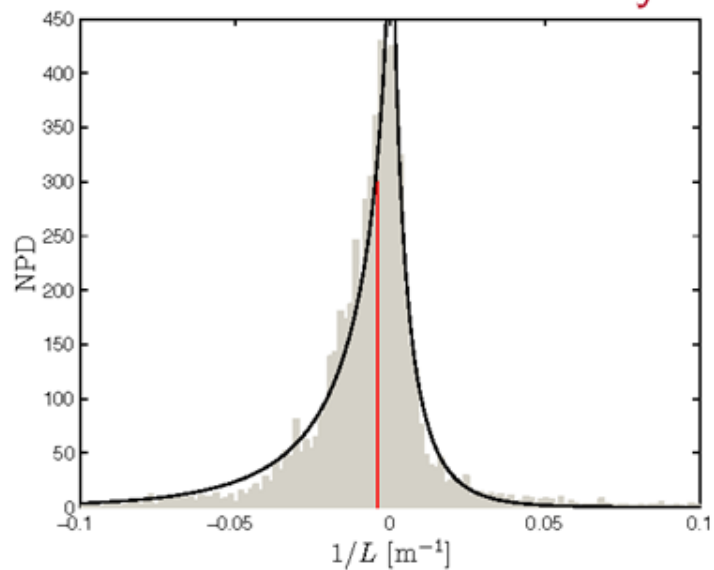
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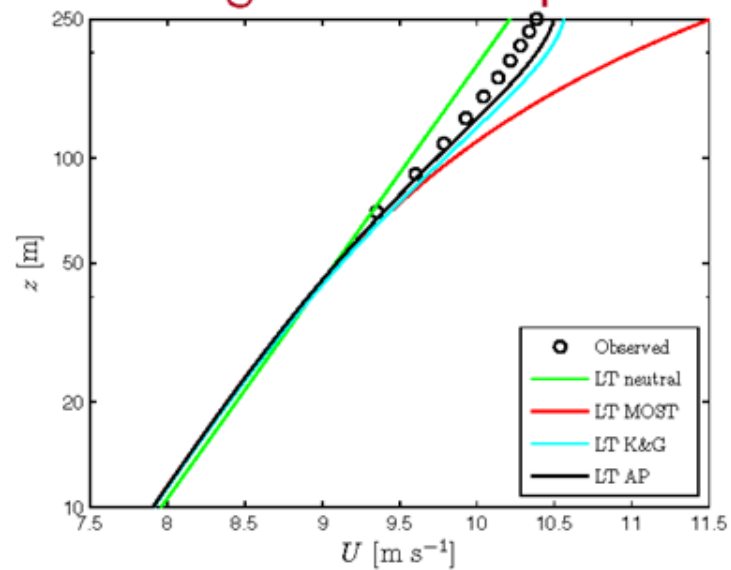
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# Results – Taqa (1 yr, 74%)

## WRF-PDF of stability

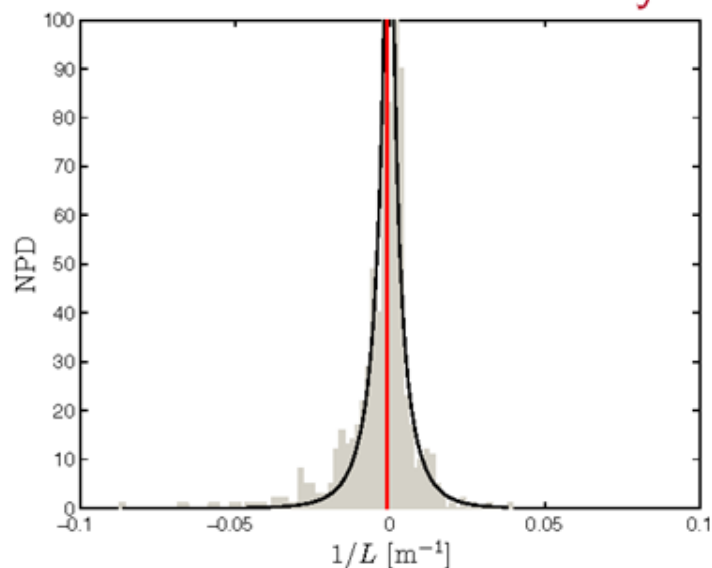


## Long-term wind profile

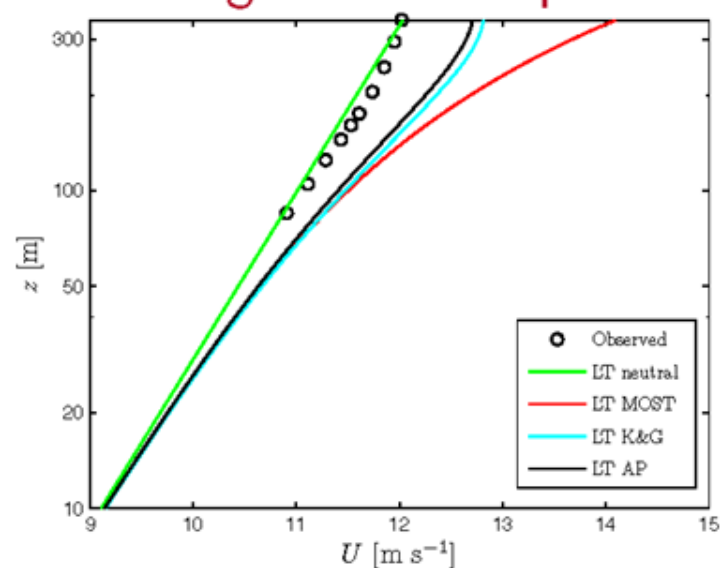


# Results – Siri (1 year, 12%)

## WRF-PDF of stability



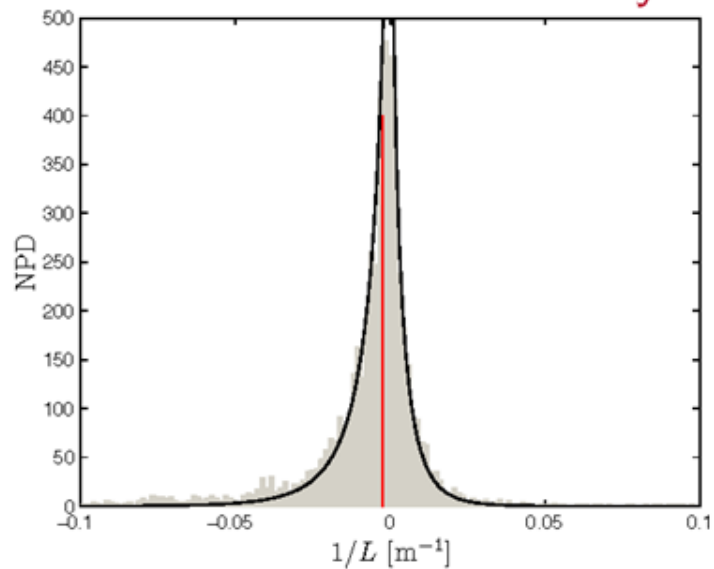
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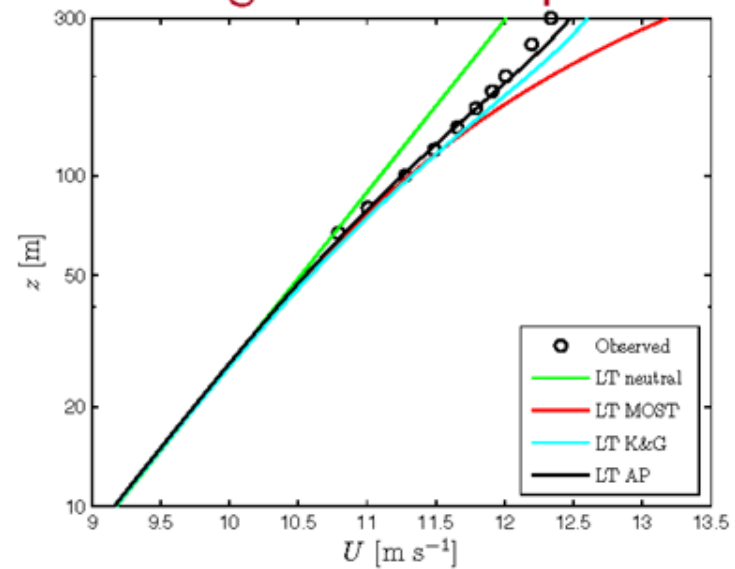


# Results – Utsira (2 yr, 32%)

## WRF-PDF of stability

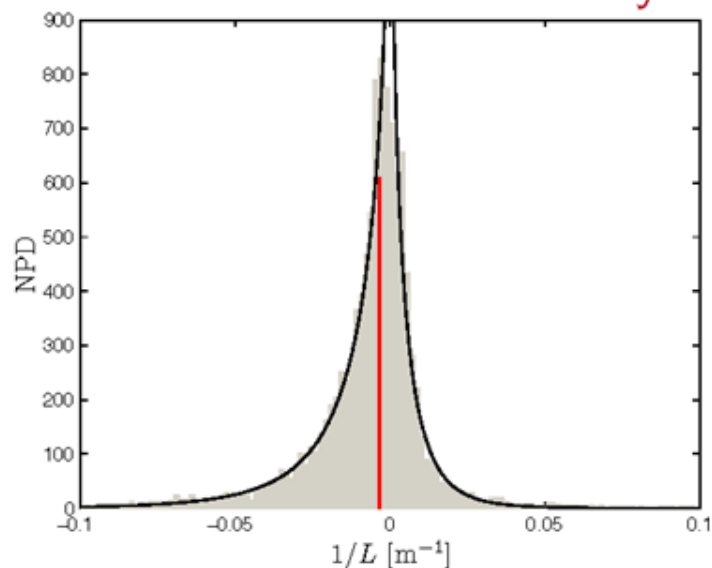


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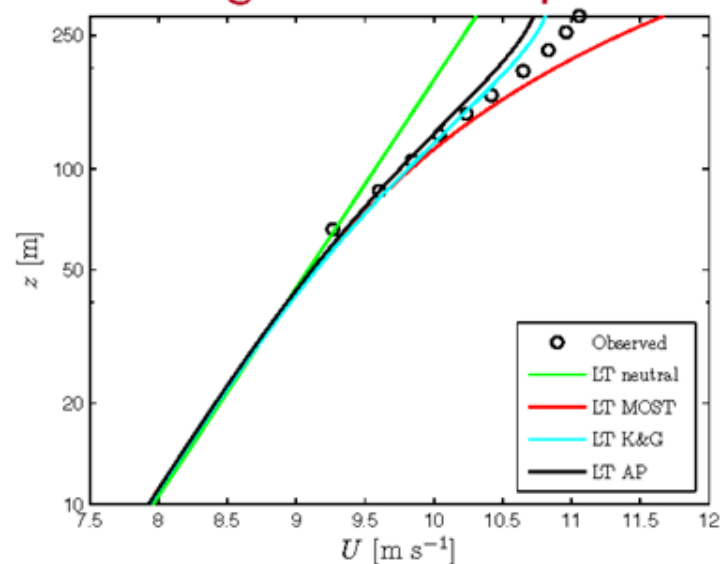


# Results – Horns Rev II (+2 yr, 62%)

## WRF-PDF of stability



## Long-term wind profile



# Summary

- We need observations of the wind profile/wind shear (not only at hub height)
- The wind shear is dependent on (in order) stability, roughness and height (among others)
- Offshore shear range close to onshore but different behavior (daily/monthly)
- $\text{PDF}(1/L) \Rightarrow \text{PDF}(\alpha)$
- In the long-term NWP models may provide means to estimate the long-term stability correction
- The long-term wind profile needs to be corrected with the long-term stability correction: predicting winds  $> 100$  m needs  $z_i$  and other parameters

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# Thanks for your attention!