How does measured stratification and classification behaves as function of height

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CV – Kurt S. Hansen – Senior Scientist

- Department of Wind Energy DTU ≥ 240 Employees
  - We educate 40-60 students on master level annually
  - My working area: research & education

- ≥ 40 years of experience within wind energy
  - Initial projects: (large) prototype wind turbines, design & testing.
  - Data analysis as part of research projects.
  - Flow analysis in onshore and offshore wind farms based on SCADA data
  - Analysis of structural loads on single wind turbines and turbines in clusters

- 15 years of experience with education of students of master level in wind turbine measurement technique.

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Outline

- Introduction
- Ex. 1; Identification of problem
- Ex. 2; Validation of results
- Conclusion
- Acknowledgements
What height(s) should be used for classification of the atmospheric stratification?

• Answer: Practical issues often determines the height of your equipment

• But this leaves you with a question: how reliable will your classification be?
Previous work and presentation

- Input for classification:
  - Wind speed
  - Air & water temp
  - AMOK (software)

Mean turbulence intensity

Horns Rev - M7: sector 0 - 180 deg

HR-M7: 2005-2009
Revised classification, 2019

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<th>Stability Class cL</th>
<th>Condition</th>
<th>Class description</th>
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1. experiment, how to classify stratification?
Ex1: Shear profiles, $U(109m) = 5 \pm 1 \text{ m/s}$

**Classification, sonic@100m**

**Classification, sonic@7m**
Ex1 Distribution of observations

Classification: $h=7 \ & \ 100m, U(109m)=5\pm1m/s$

Counts

Classification

$cL=-4 \  cL=-3 \  cL=-2 \  cL=-1 \  cL=0 \  cL=1 \  cL=2 \  cL=3 \  cL=4$

- 100m/96h
- 7m/92h
Ex 1. Classification of wind speed & turbulence

Classification of wind speed, $h=38\text{m}$, $U(109\text{m})=5\pm1\text{m/s}$

Classification of turbulence, $h=38\text{m}$, $U(109\text{m})=5\pm1\text{m/s}$
Ex 2. Layout of Risø Campus

V52-mast, h=70m located at Risø Campus, DTU

- 70 m
- 57 m
- 44 m
- 31 m
- 18 m

Cup anemometer
3D-Sonic anemometer
Thermometer

Appr. 120m
Ex.2 from V52 met mast at Risø Campus

V52 met mat: classification of shear; $U_{70m} = [6;7]$ m/s

Classification reference: 3D-sonic@h=18m

Classification reference: 3D-sonic@h=44m

Classification reference: 3D-sonic@h=70m
Ex2 Distribution of observations

V52 met mat: Stratification; $U_{70m} = [6;7]$ m/s
Ex2 Classification of wind speed at 70, 44 & 18m

V52 met mat: Stratification; $U_{70m} = [6;7]$ m/s
Ex2 Classification of Turbulence at 70, 44 & 18m

V52 met mat: Turbulence; $U_{70m} = [6; 7]$ m/s

Stability class vs. Turbulence - m/s

- TI70/s70m
- TI70/s44m
- TI70/s18m
- TI44/s70m
- TI44/s44m
- TI44/s18m
- TI18/s70m
- TI18/s44m
- TI18/s18m
Conclusion

1. The distribution of MB-L recordings seems height sensitive.

2. A sonic at 7 m seems more reliable than at 100 m.

3. The classification seems less sensitive for reference height between 18-70m (coastal site).

4. Strange behaviour of wind speed and turbulence for extreme stable conditions, which need further investigation.
Acknowledgements

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2) DTU Wind Energy