

TURBULENCE AND ITS IMPACT ON FATIGUE

Abhijit Chougule
University of Agder, Grimstad

NORCOWE CONFERENCE

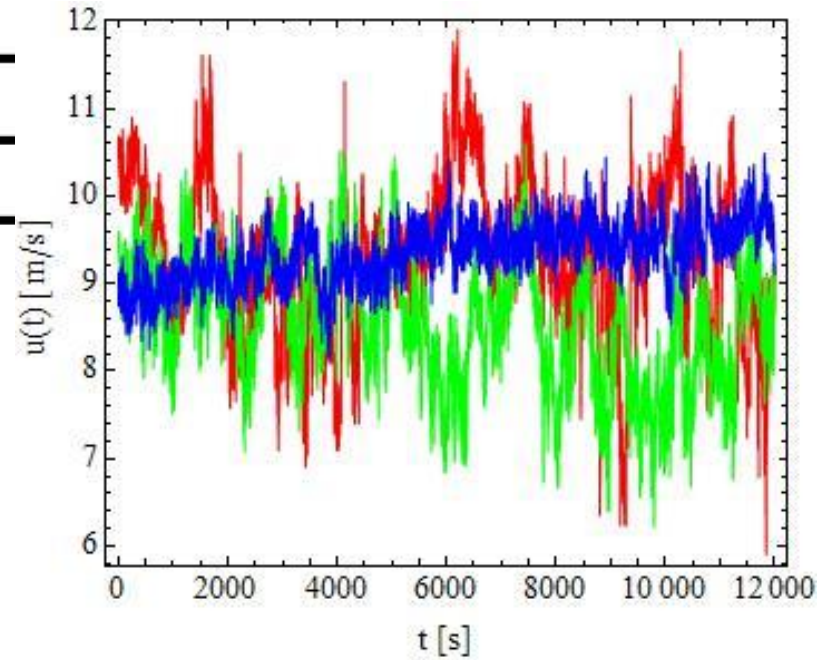
Bergen

14-16 Sept., 2016

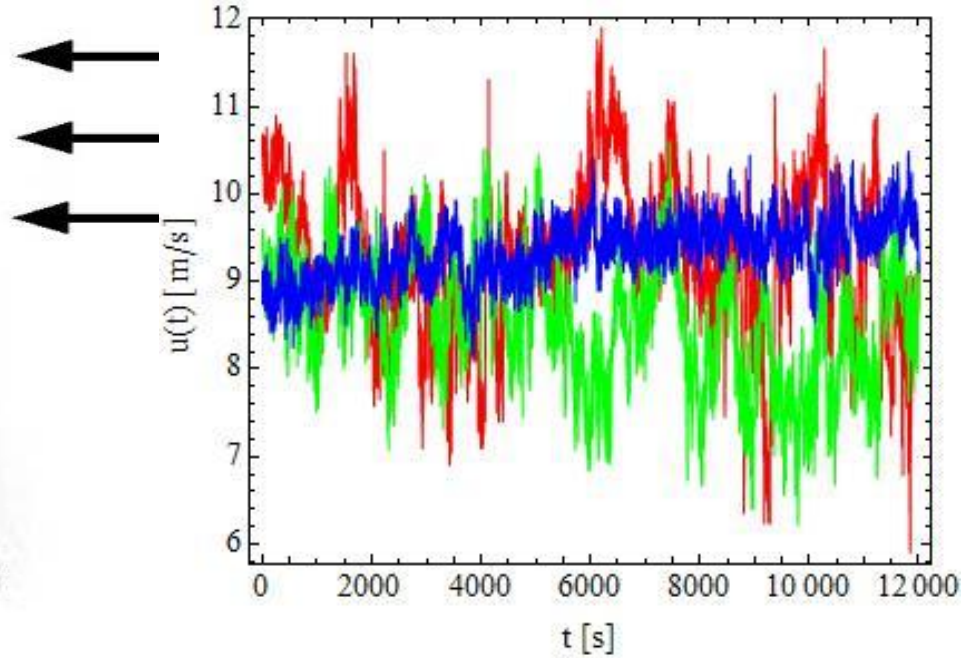
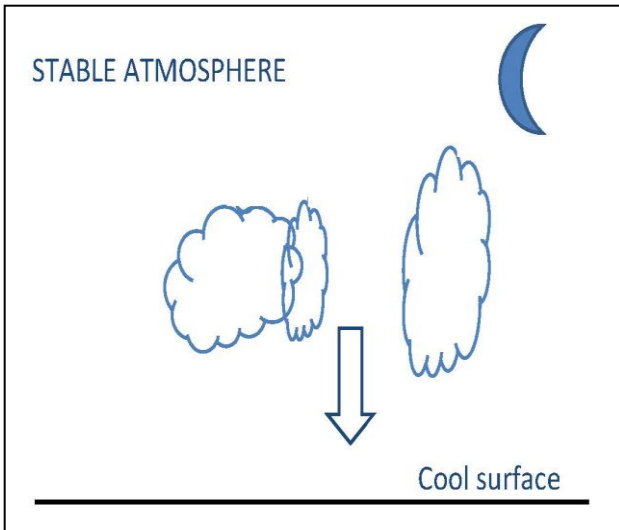
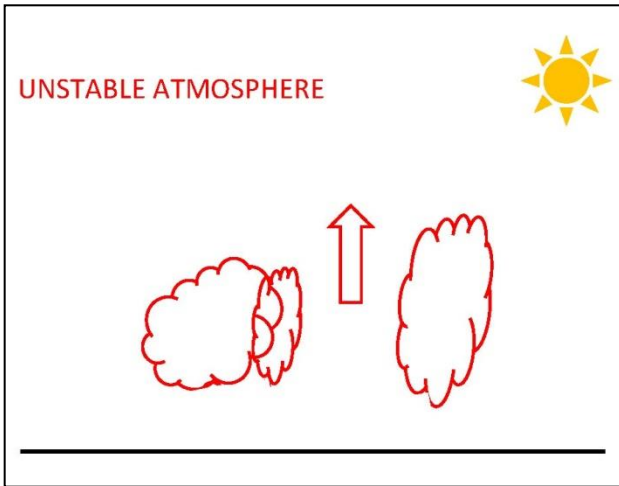
Outlook

- **Introduction**
- **Turbulence features**
- **Modeling**
- **Impact on fatigue**
- **Conclusions**

Outlook => Introduction

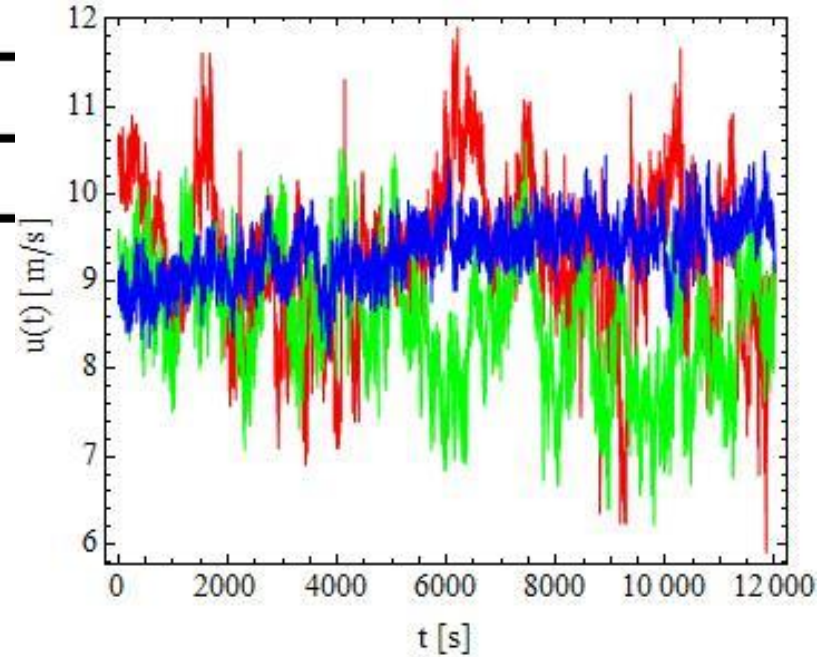


Outlook => Introduction

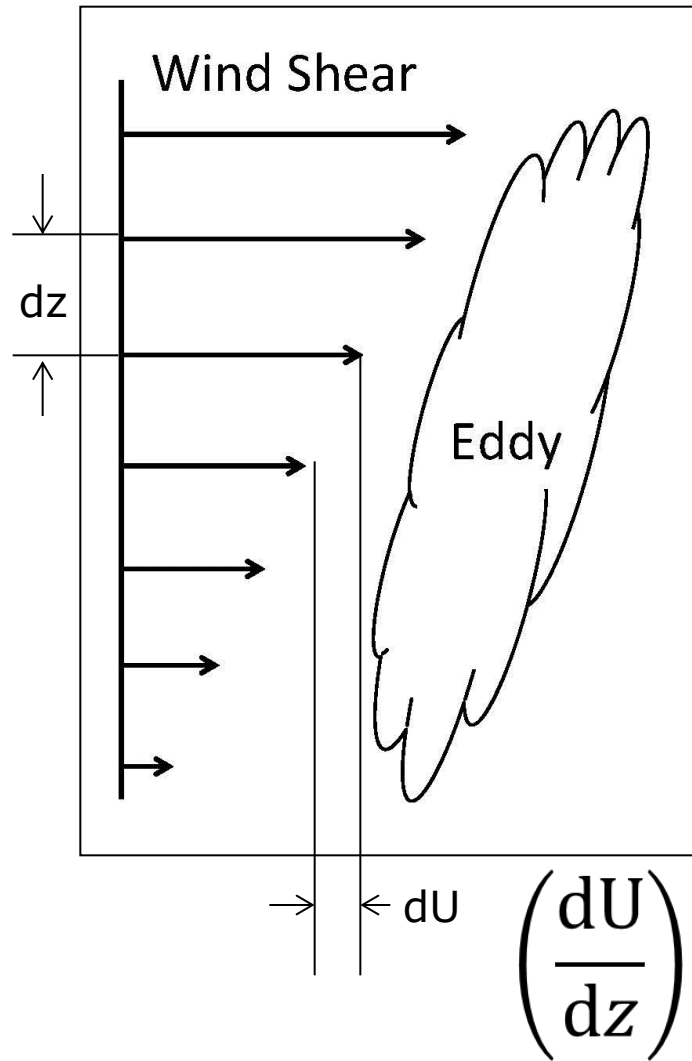


Outlook => Trubulence features

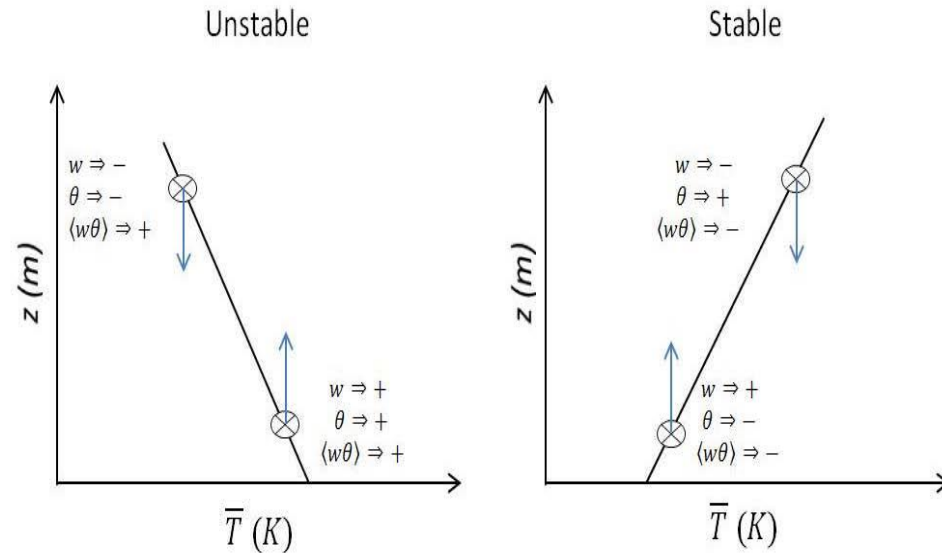
- **Spectra**
- **Cross-spectra**
 - **Coherence**
 - **Phases**



Outlook => Modeling



+

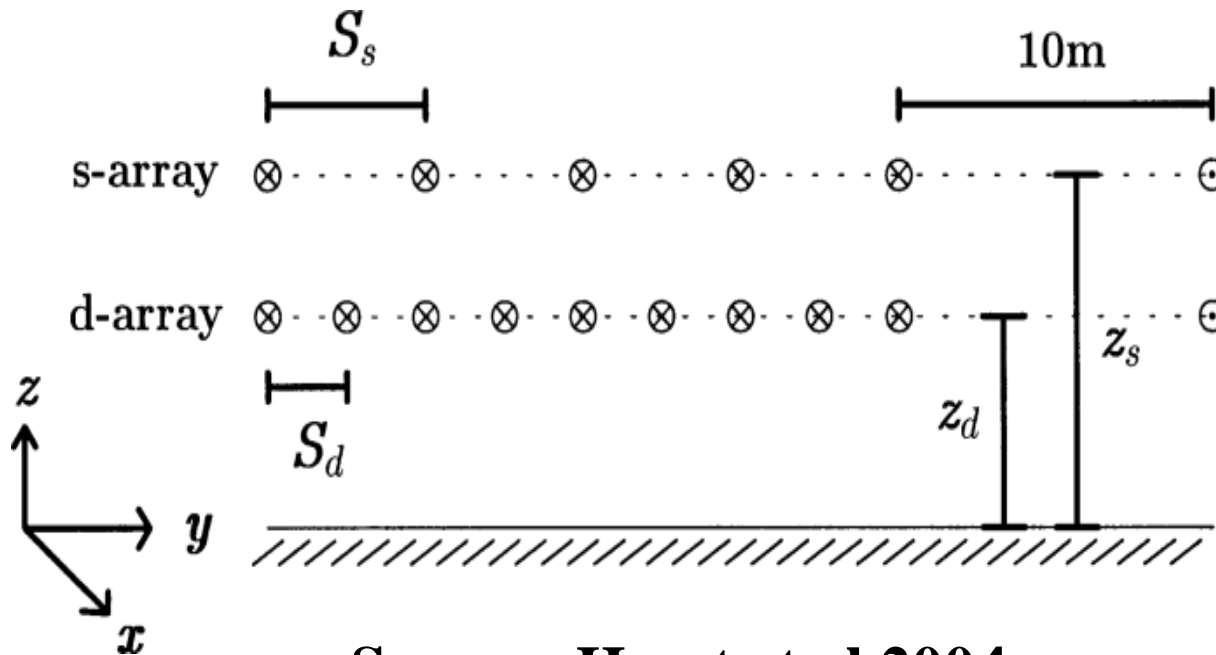


Richardson number

$$Ri = \frac{\left(\frac{g}{\bar{\theta}}\right) \left(\frac{d\bar{\theta}}{dz}\right)}{\left(\frac{dU}{dz}\right)^2}$$

Outlook => Modeling

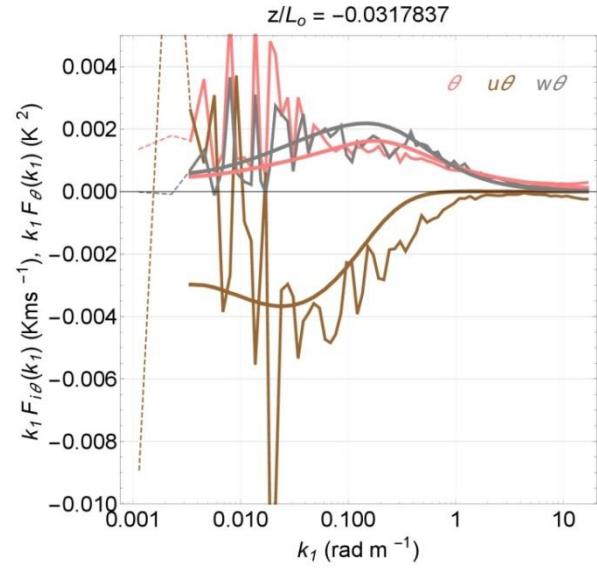
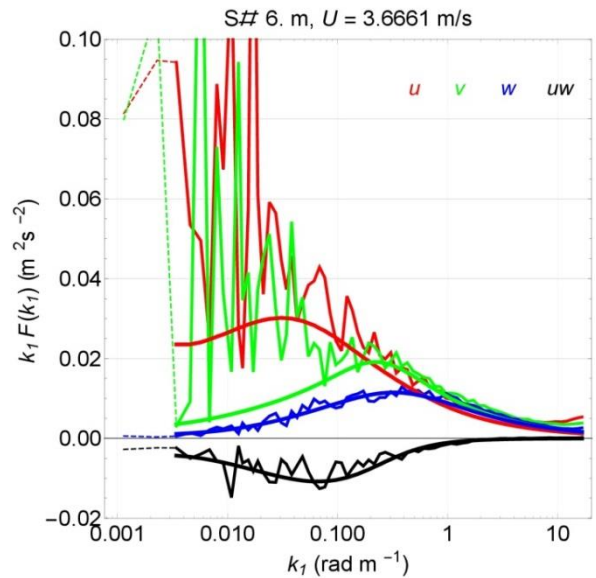
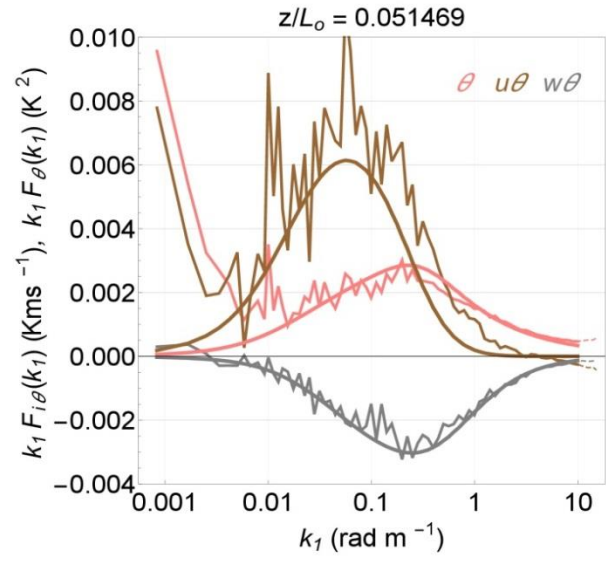
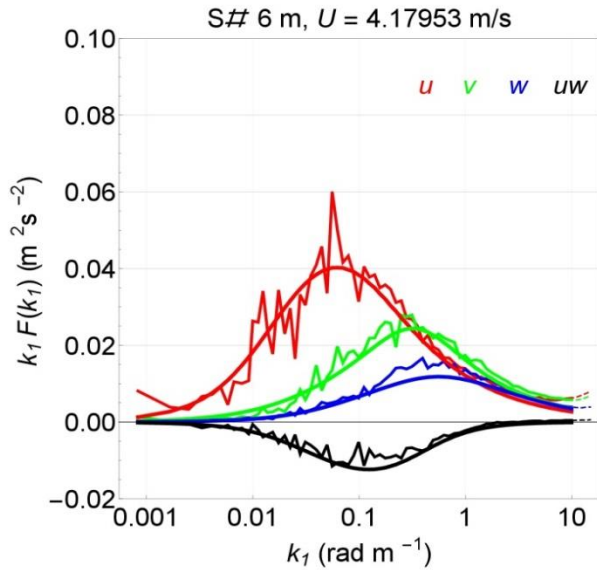
- **HATS data (Horizontal Array Turbulence Study)**



Source: Horst et al 2004

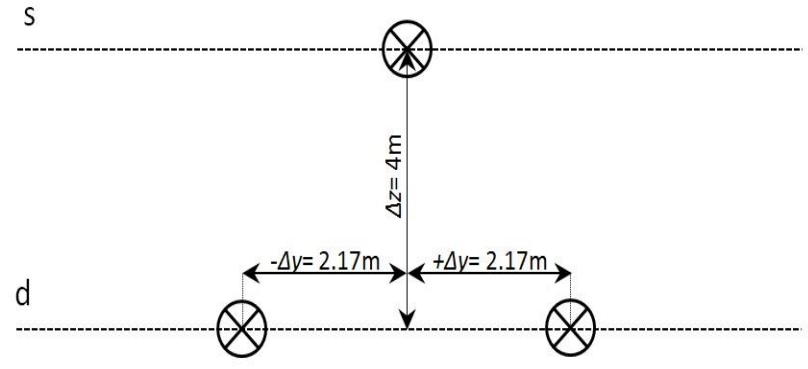
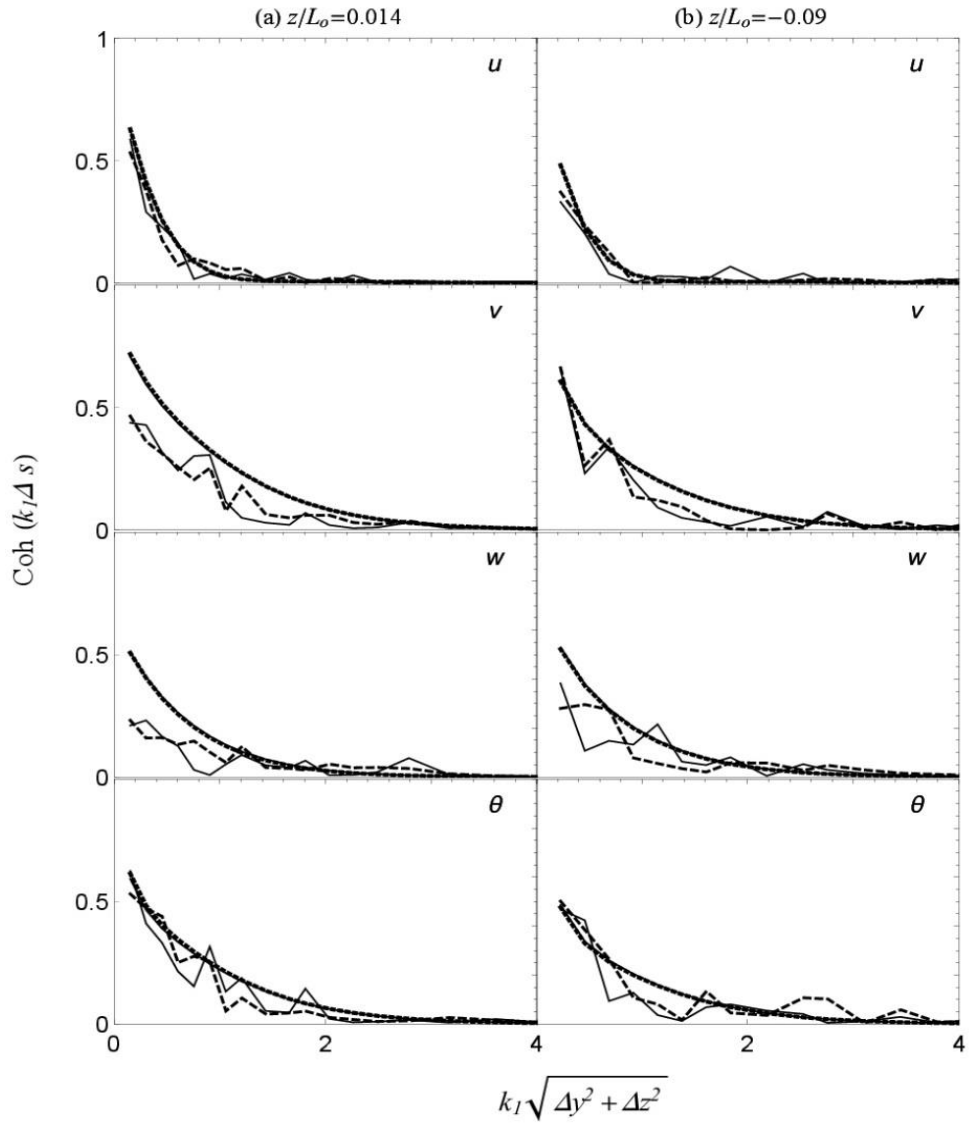
Outlook => Modeling

- Spectra**



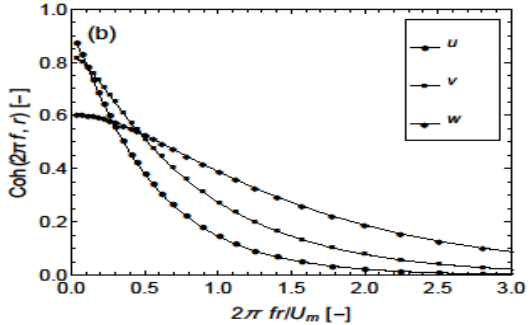
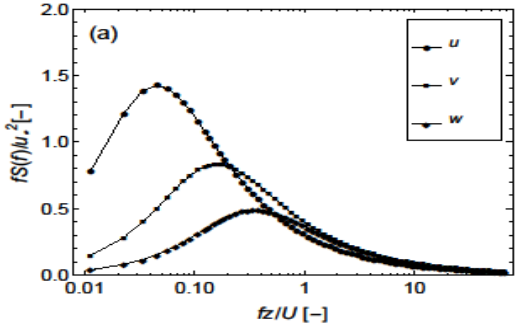
Outlook => Modeling

- Coherence**



- Smooth lines: model
- Ragged lines: data
- Solid lines: +dy
- Dashed lines: -dy

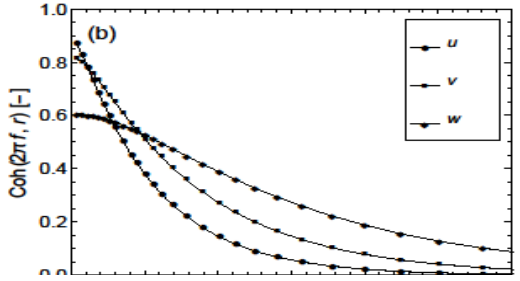
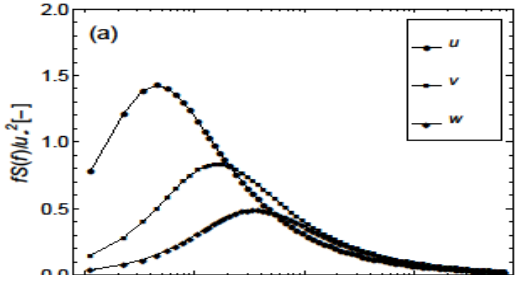
Risø SMOOTH
model + Exp. coh



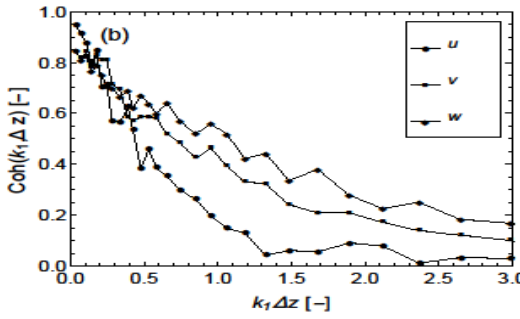
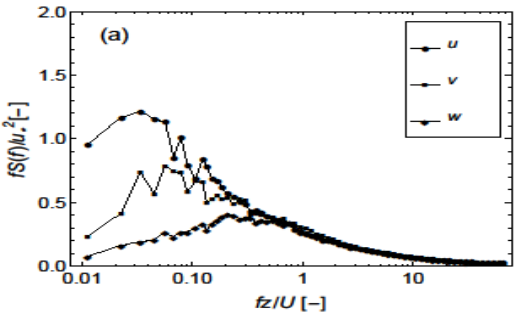
1. Model

Risø SMOOTH
model + Exp. coh

NREL met-mast
data, 100 and
50 m



1. Model

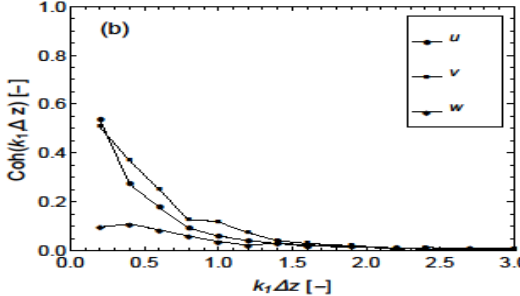
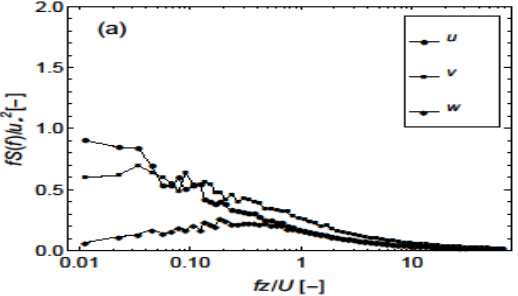
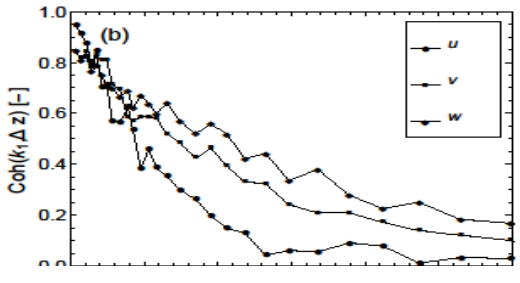
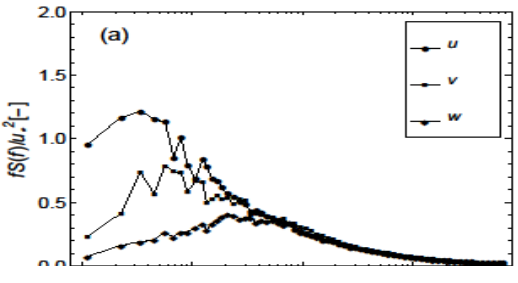
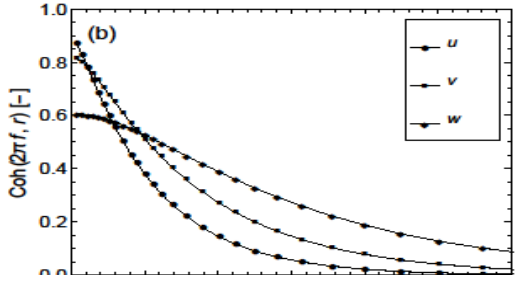
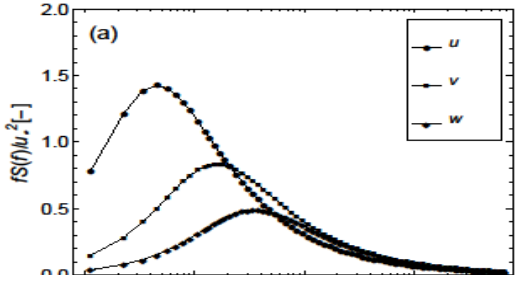


2. Data

Risø SMOOTH
model + Exp. coh

NREL met-mast
data, 100 and
50 m

TurbSim+no coh.



1. Model

2. Data

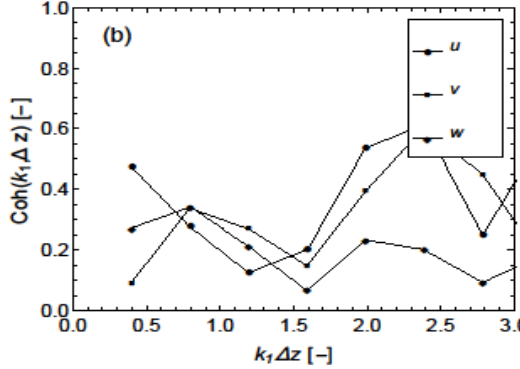
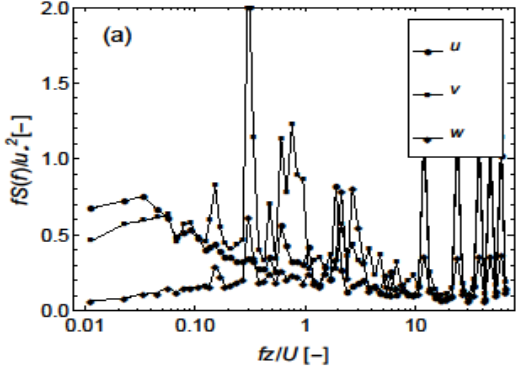
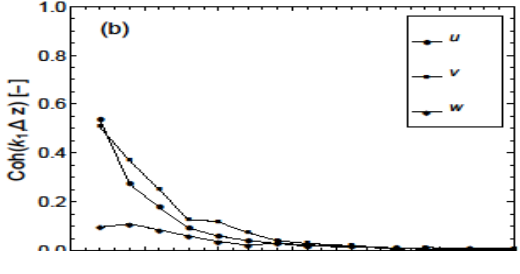
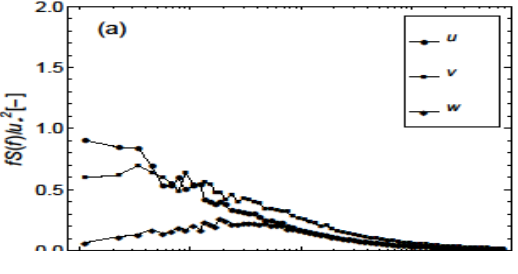
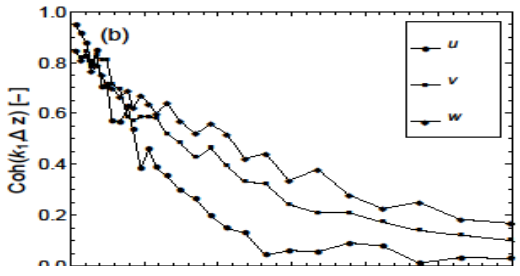
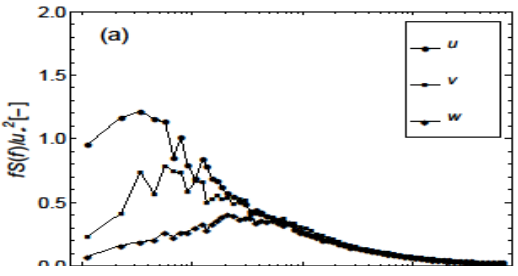
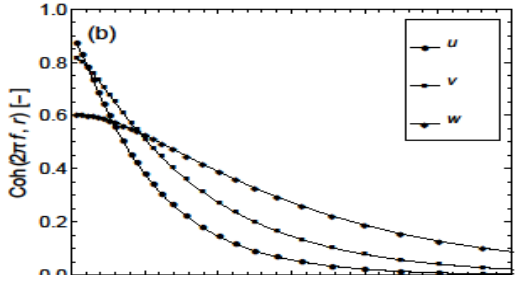
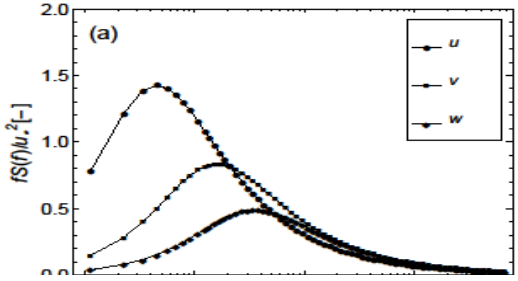
3. Synthetic
data
WITHOUT
coh. events
added

Risø SMOOTH
model + Exp. coh

NREL met-mast
data, 100 and
50 m

TurbSim+no coh.

CTWind+LES
events



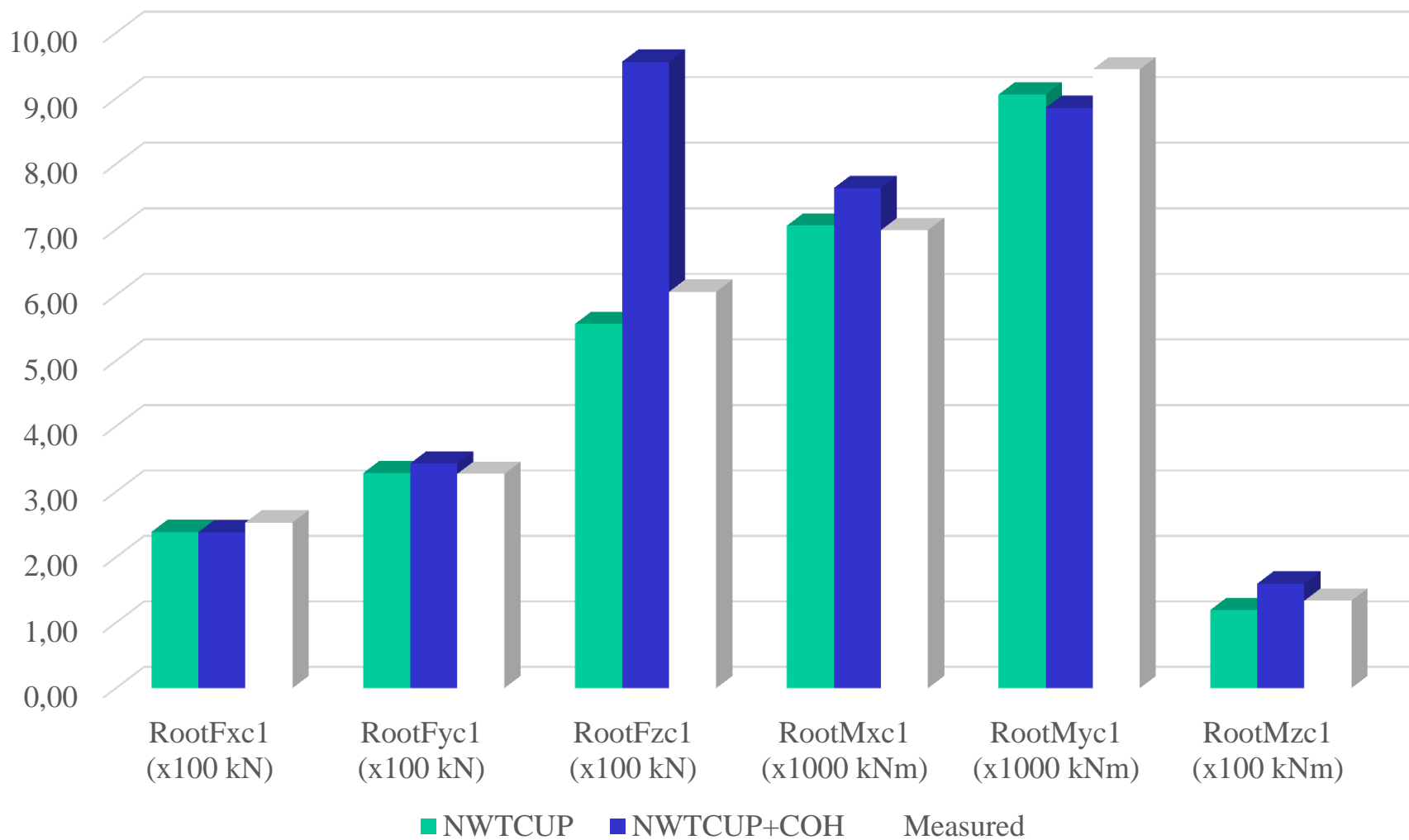
1. Model

2. Data

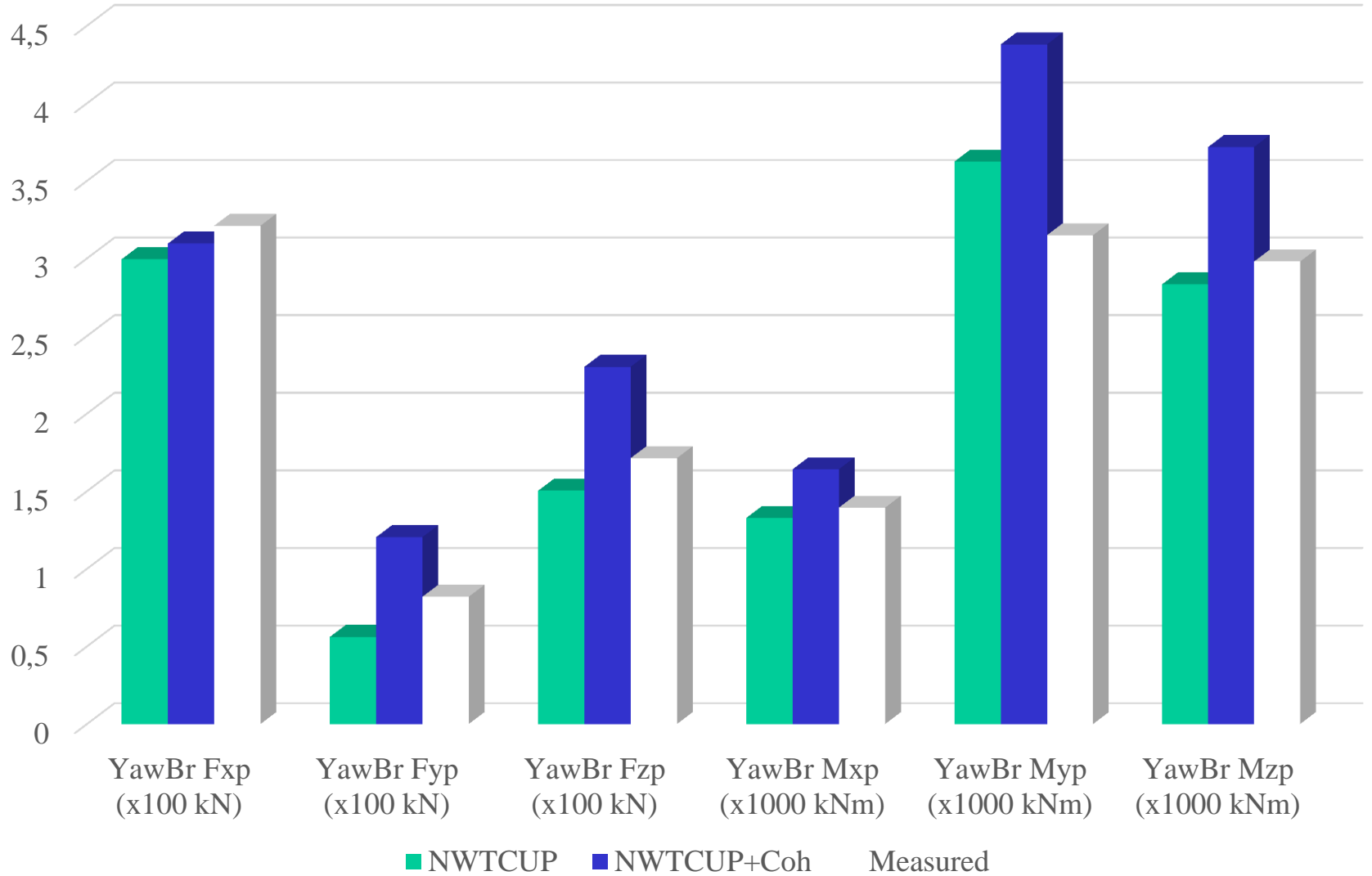
3. Synthetic
data
WITHOUT
coh. events
added

4. Synthetic
data WITH
coh. events
added

Comparison of Damage Equivalent Blade Root Loads



Comparison of Damage Equivalent Nacelle Bearing Loads



Outlook => Conclusions

- **Spectra and coherence modeling: atmospheric stability**
 - **stable spectra => promising results (tested upto 100 m height)**
 - **unstable spectra => scale on the order of 0.6 Km**
- **Steps further:**
 - **3D turbulence generator: synth. data in time domain**
 - **offshore winds: NORCOWE => OBLEX, FINO**
- **More work on impacting loads**
 - **scale dependent coherence events**
 - **tools: TurbSim => FAST**
- **Statistics beyond spectra and coherence**
 - **velocity increments**
 - **higher order statistics**