Wake effects above rated wind speed. - An overlooked contributor to high loads in wind farms

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Wake effects above rated wind speed.
-An overlooked contributor to high loads in wind farms

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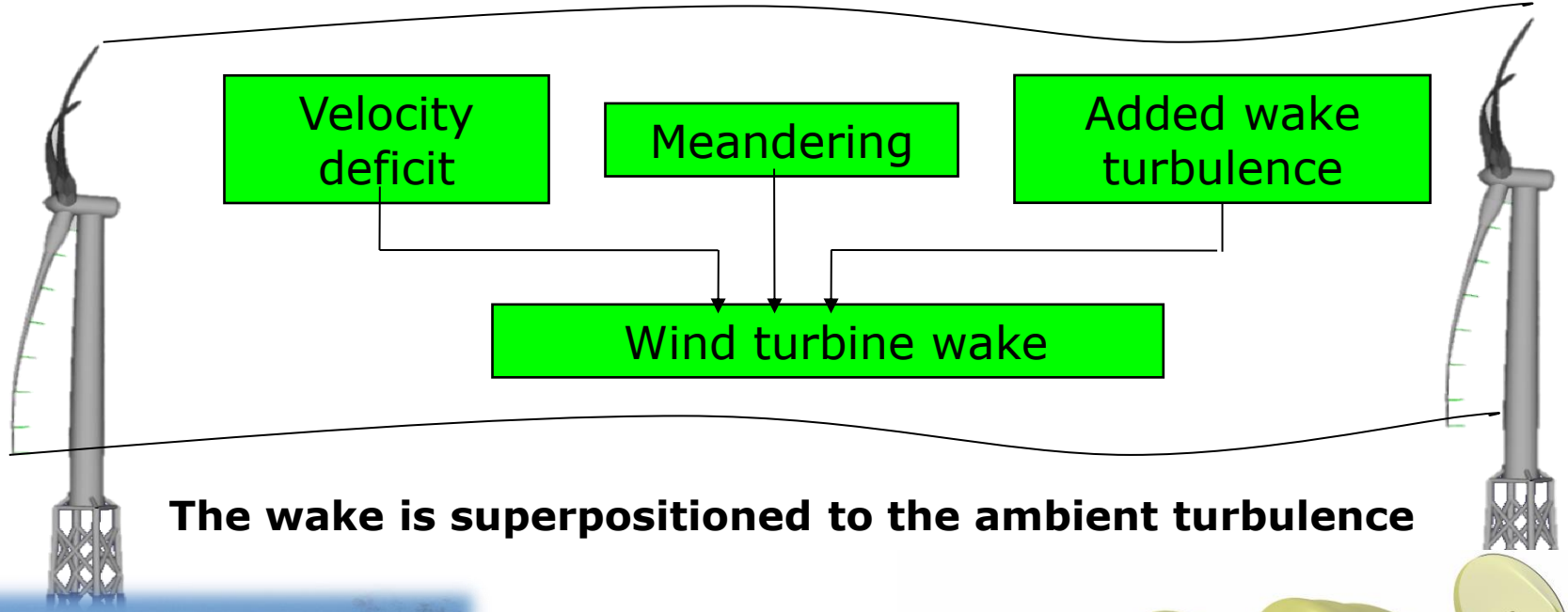
EWEA 2015

Paris, 17-20. Nov 2015

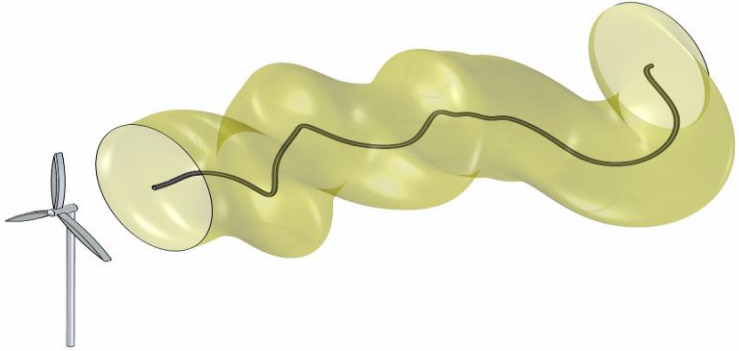
DTU Wind Energy
Department of Wind Energy

EWEA 2015 PARIS
EUROPE'S PREMIER WIND ENERGY EVENT
17-20 NOVEMBER

Principle of Dynamic Wake Meandering



The wake is superpositioned to the ambient turbulence

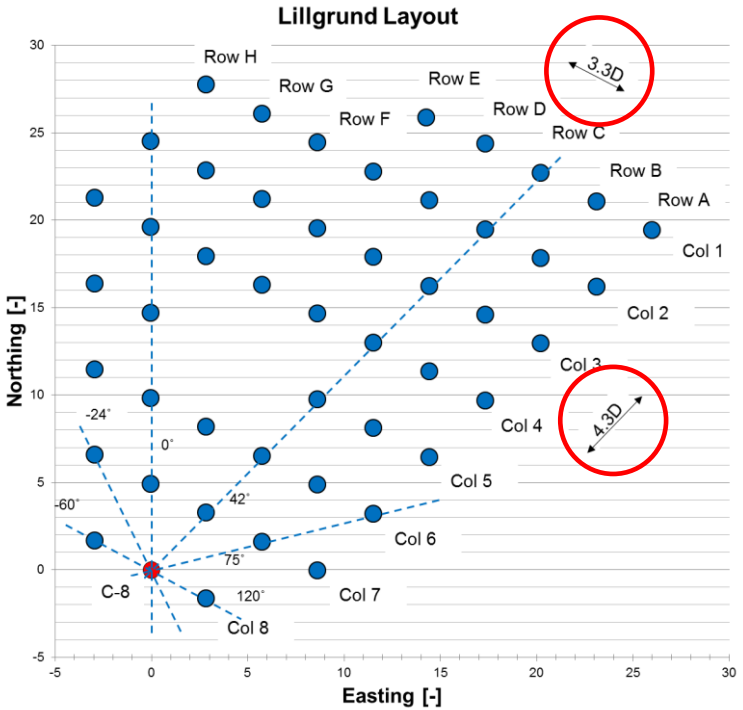


Multiple wake handling today

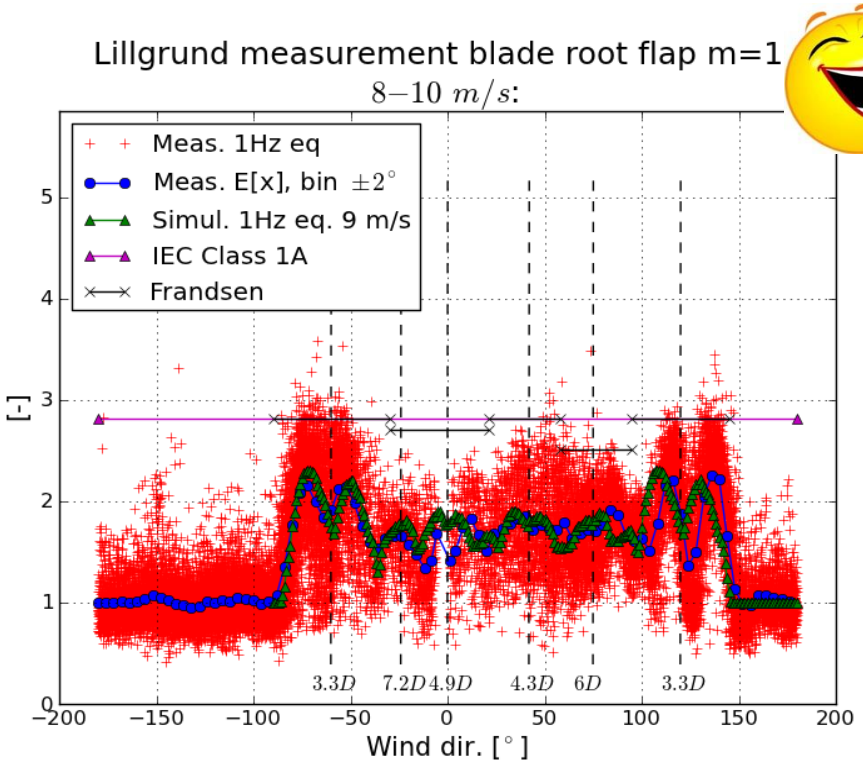
- Previous studies (Larsen, et. 2013, Madsen et al ???) indicated that a flow equilibrium seem to occur so the extracted energy equals the restoring flow from turbulent mixing)
- The power production of turbine n in a row is almost the same as for turbine 2.
- A MAX operator was recommended – well knowing that it is not a perfect approach.

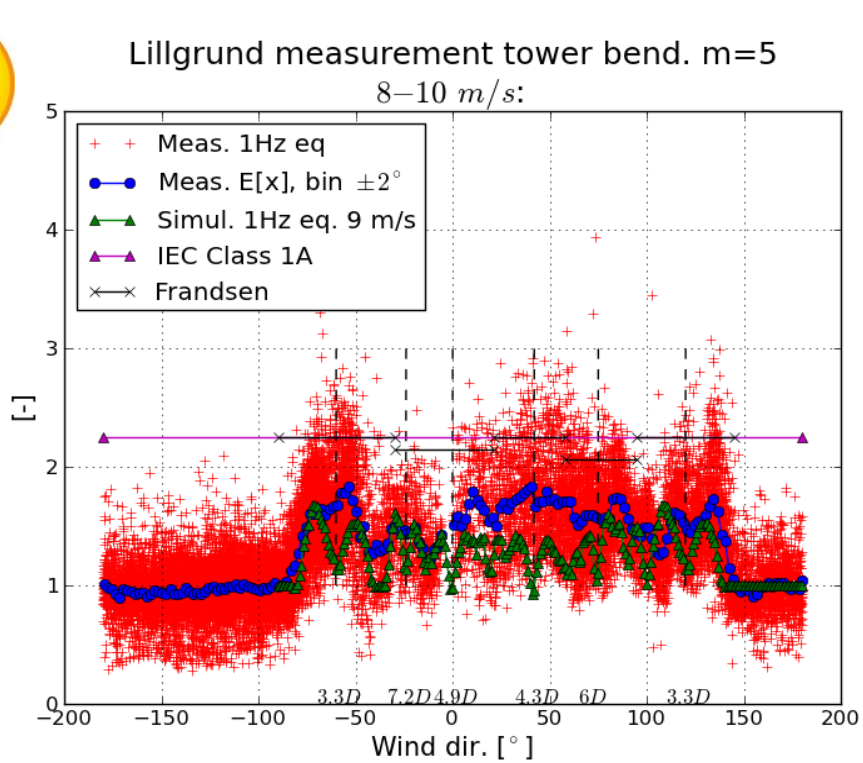
Lillgrund Wind farm

- 48 SWT 2.3 MW prvs turbine
- Lowest spacing is 3.3D
- Turbine C-8 is fully instrumented with strain gauges. We have access to results for the blade bending moment and tower bottom bending moment
- The met mast data cannot be used



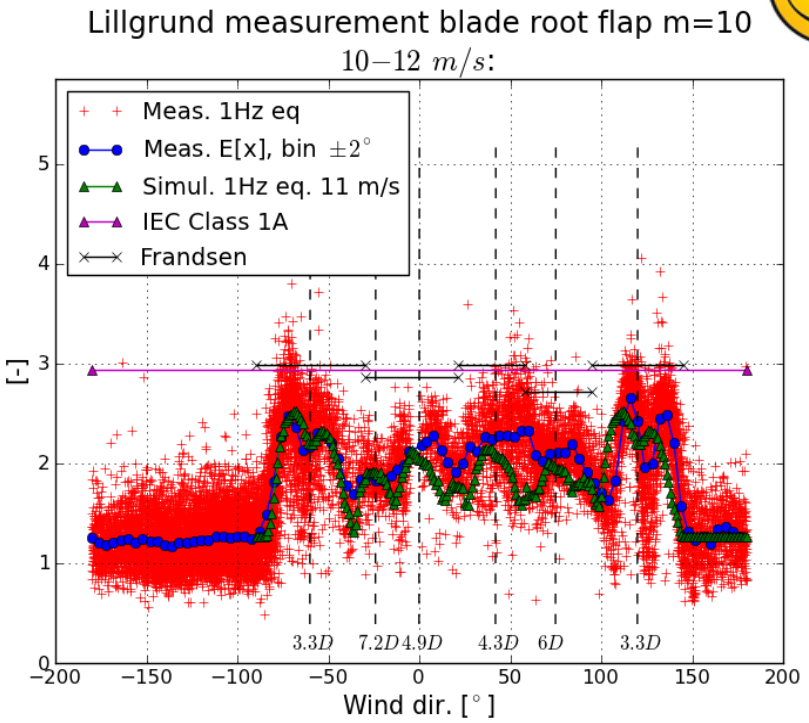
Lillgrund 8-10 m/s

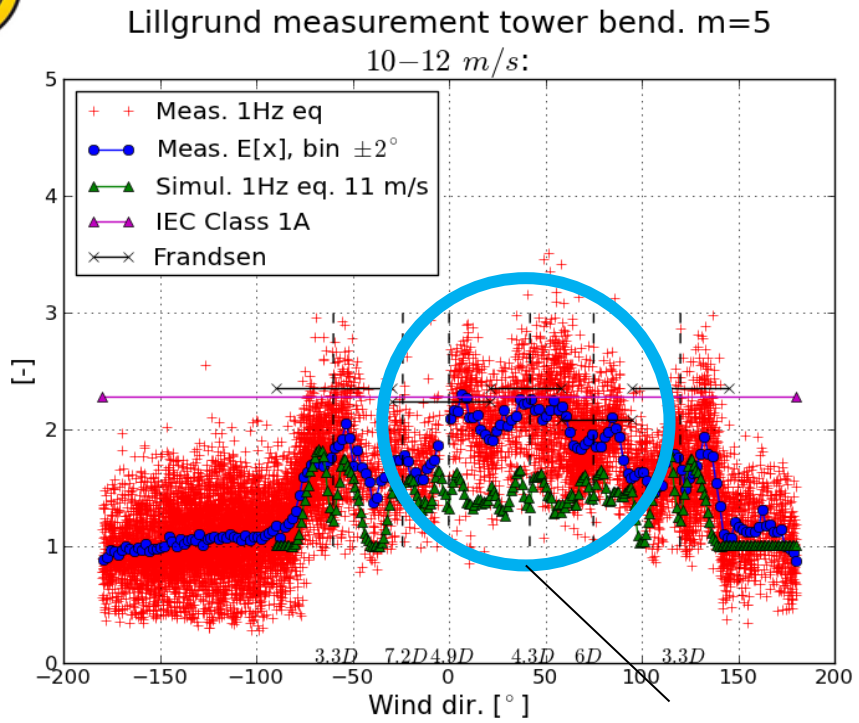




Results using MAX deficit operator

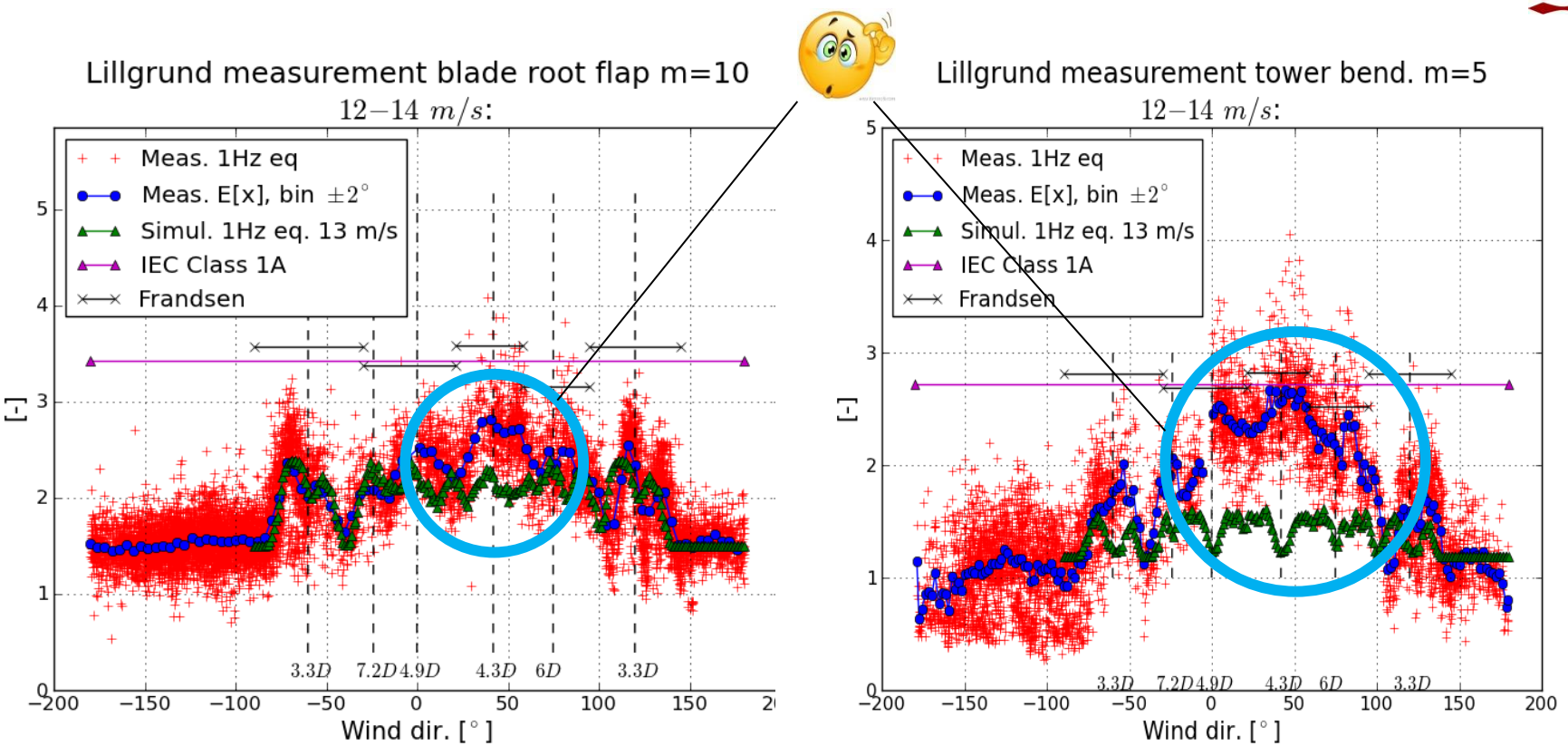
Lillgrund 10-12 m/s





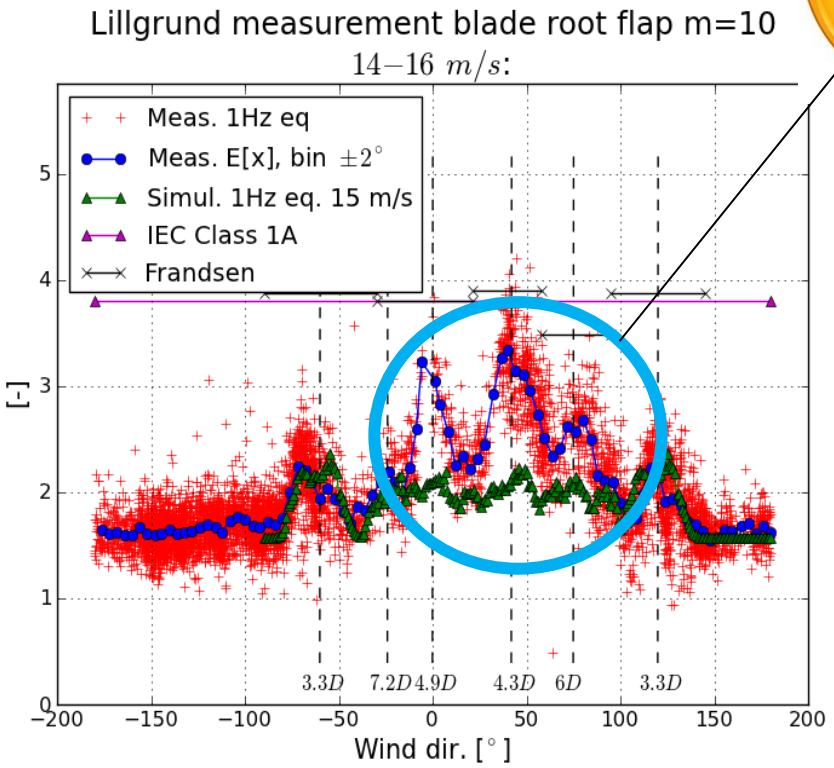
Results using MAX deficit operator

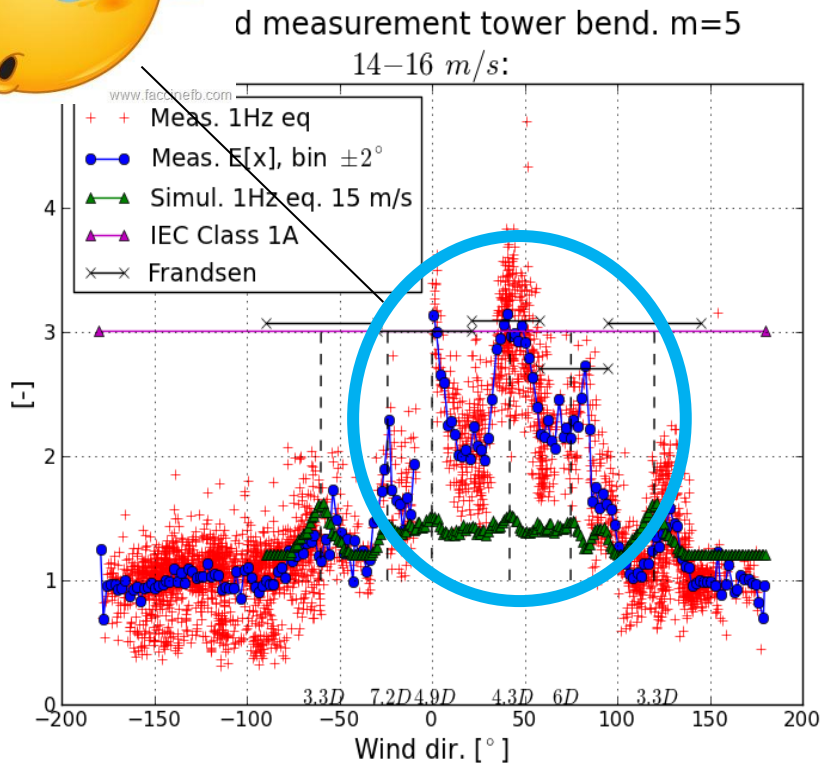
Lillgrund 12-14 m/s



Results using MAX deficit operator

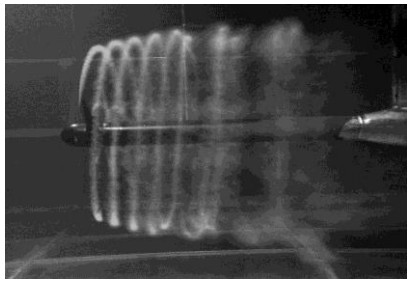
Lillgrund 14-16 m/s



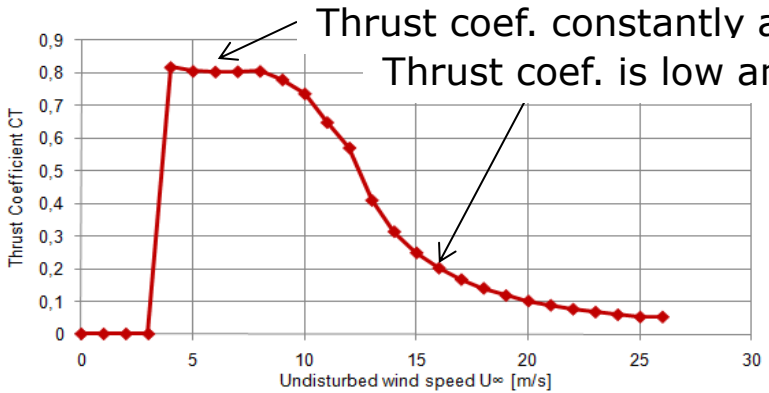


What happens at high wind speeds?

- The wind turbine thrust is significantly lower than at high wsp
- The turbulent mixing is reduced – as the vortex strenght and deficit depth is not as high as at low wsp
- The wake vortex system is in general more stable in low thrust situation.



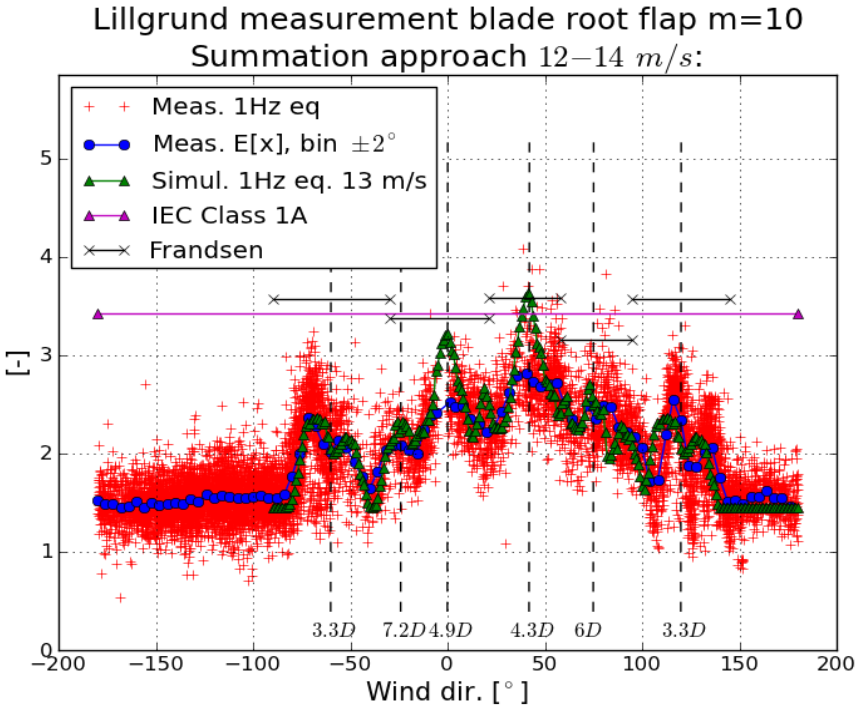
From R. Mikkelsen, TSR=8

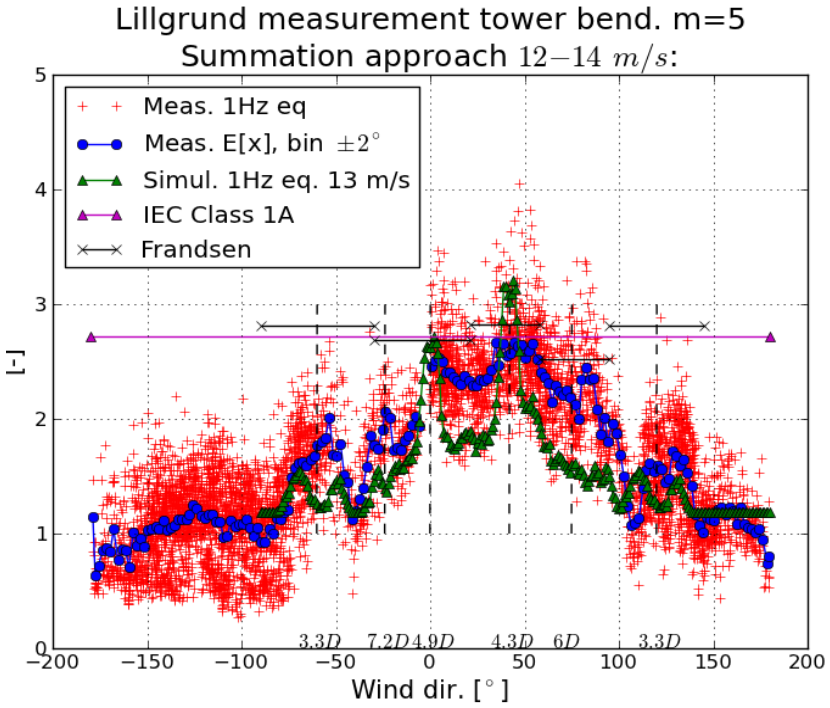


Nasa Ames experiment 2000, low thrust

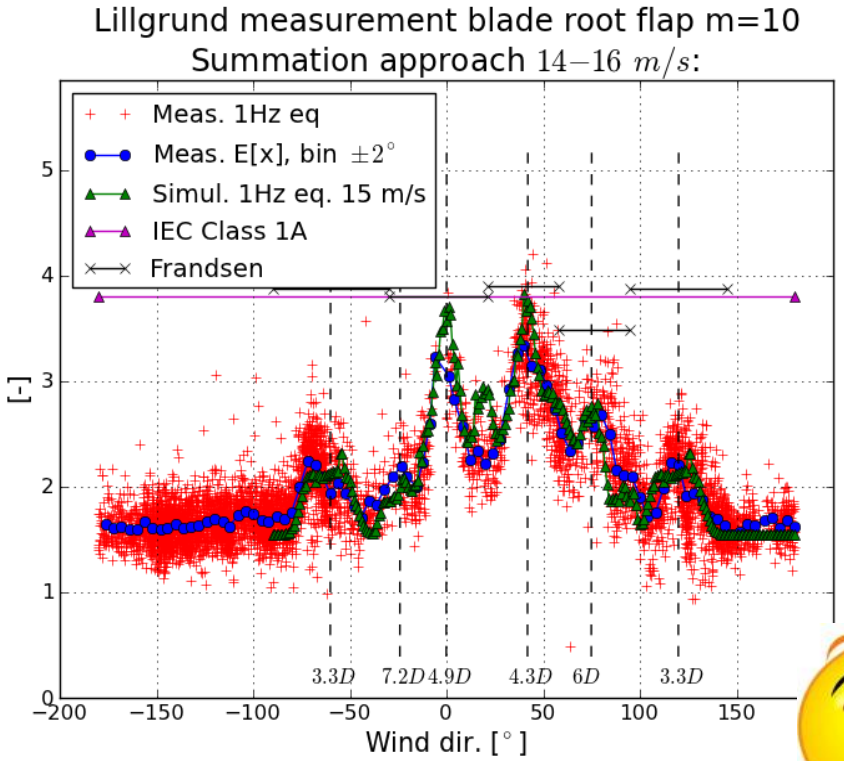
- So far no CFD simulations has been performed in multiple wake – high wsp situation as the main focus has been directed to power production

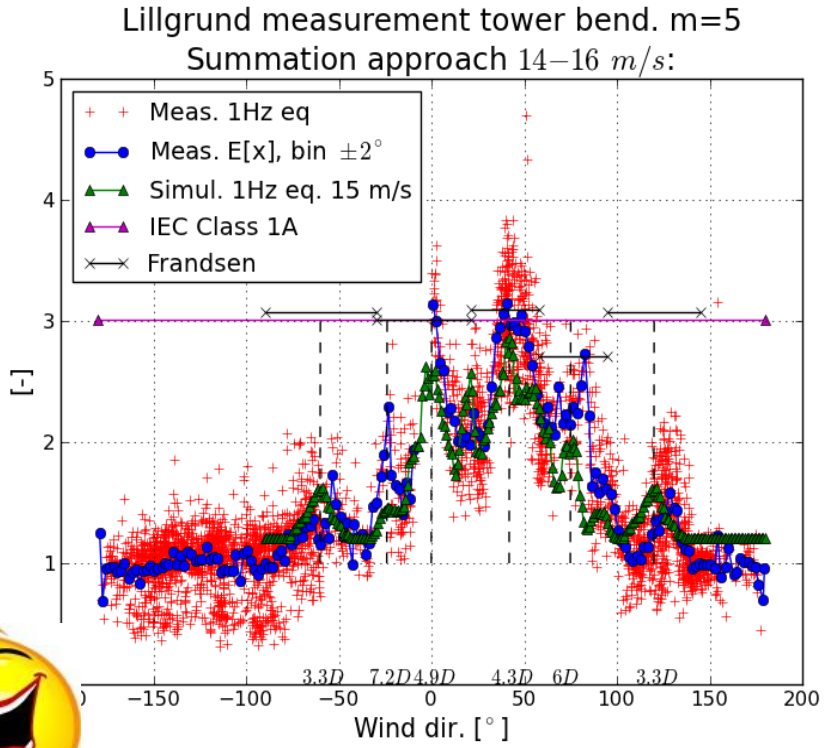
Results using linear superposition





Results using linear superposition





Conclusions

- In multiple wake situations
  - **Wake effects may cause significantly increased loads at high wind speeds, even though a wind turbine here is "aerodynamic transparent"**
  - DWM: A maximum deficit operator works well below rated power
  - DWM: A linear superposition works well above rated power

With this in mind:

The load levels in wind farms can be simulated highly accurate using the DWM approach!

  - The Frandsen method is still conservative in most situations
    - And highly conservative in single wake with short spacings!
  - The IEC class 1A is also still conservative in most situations

  - The highest normal operation loads occurs at high wind speed situations. Even with DWM in complex wake conditions: *Increased ambient turbulence cause increased loads*.