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Aeroelastic code validation - A mixed collection of examples

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Aeroelastic code validation
- A mixed collection of examples

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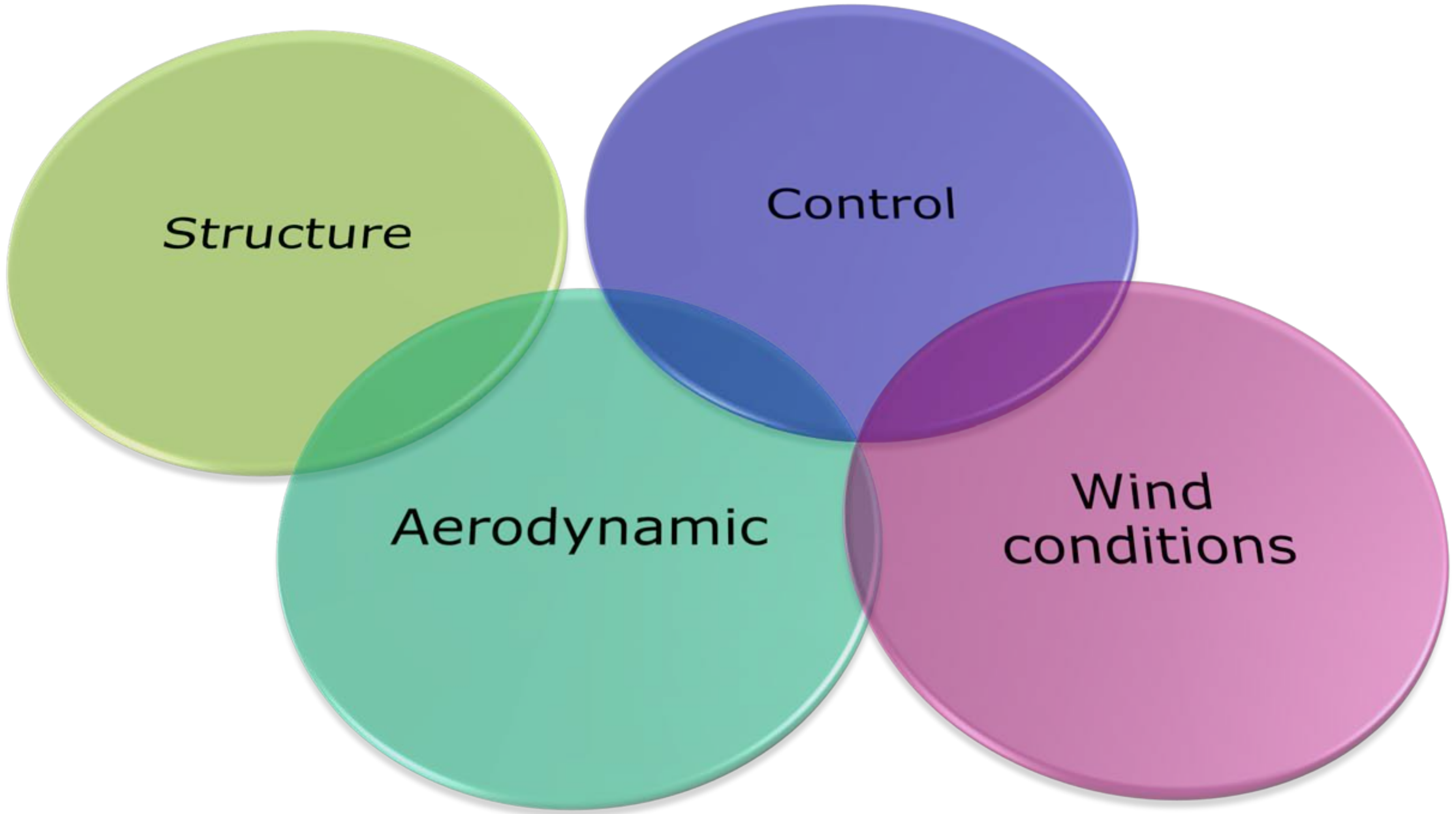
IEA Wind Task 11

Scotland 06.09.2017

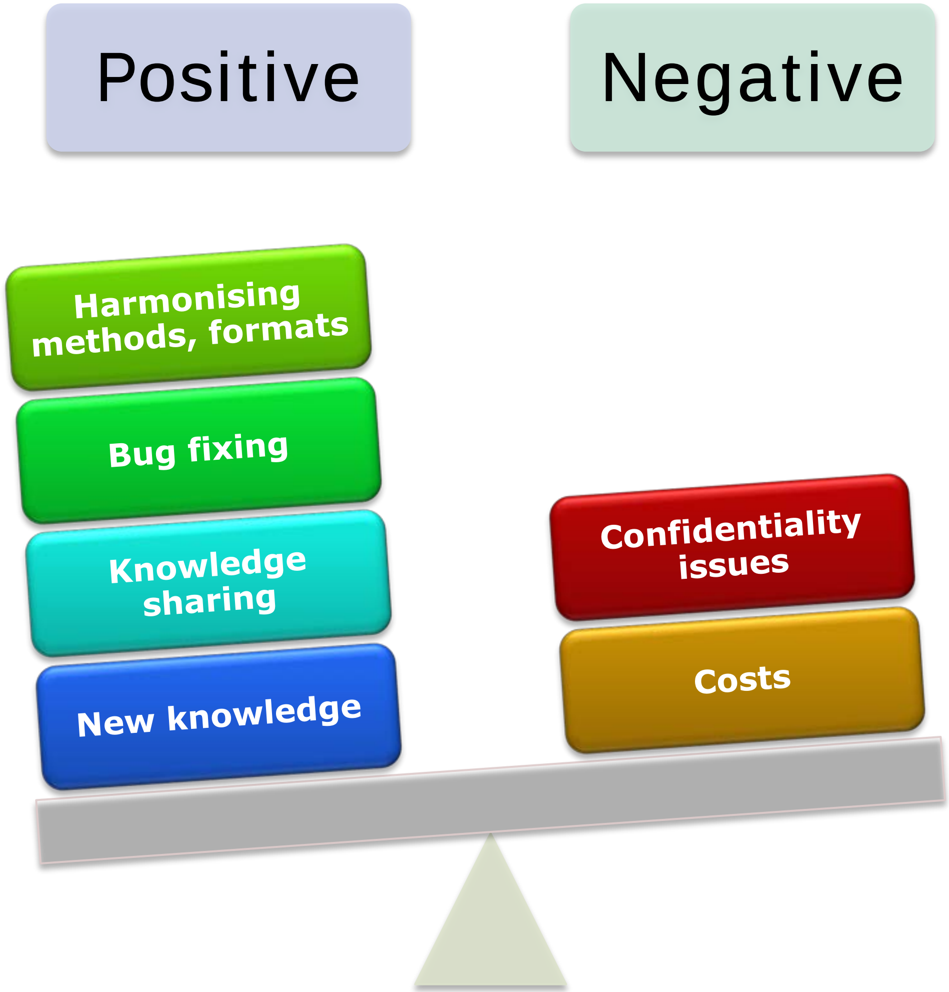
DTU Wind Energy
Department of Wind Energy

The four load drivers



We can choose to focus on individual areas, but all has to be OK for the loads to be correct

What do we want to achieve?



- Code-2-code comparison
  - Codes of same complexity level
  - Codes of varying complexity
- Code-2-controlled experiments
  - Eg wind tunnel experiments
  - Floating wind turbine tests
- Code-2-fullscale experiments
  - Wind turbine level
  - Wind farm level

OC3, OC4, (OC5) Code-2-code

- Public fictive reference turbine generated
- Comparing in steps. Start simple – advance gradually
- Comparison possible also for new types of concepts
- Great for knowledge sharing, interesting discussions
- Enabled a much bigger community within (relevant) wind turbine load simulations

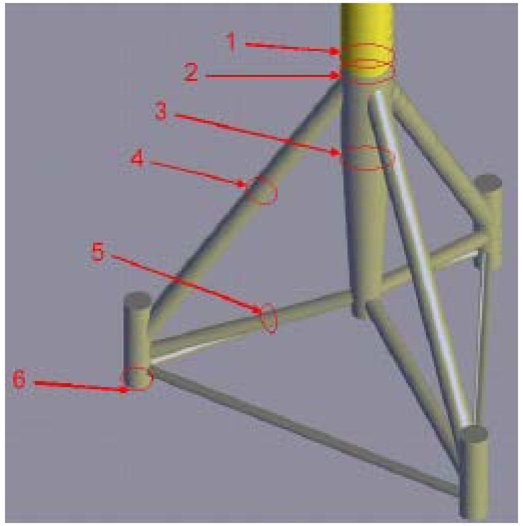


Figure 2. *Tripod load output positions*

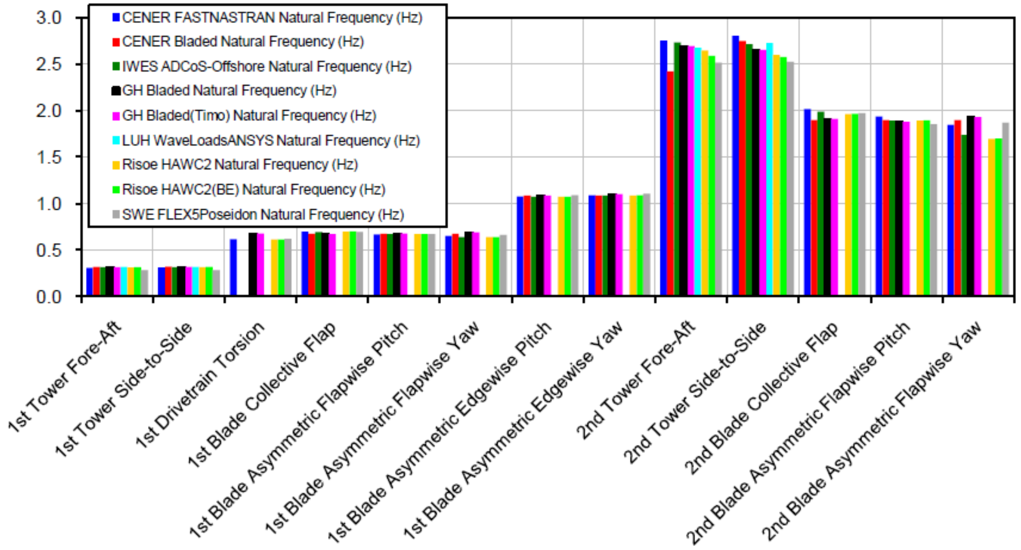


Figure 20. *Full-system natural frequencies from load case 1.2*

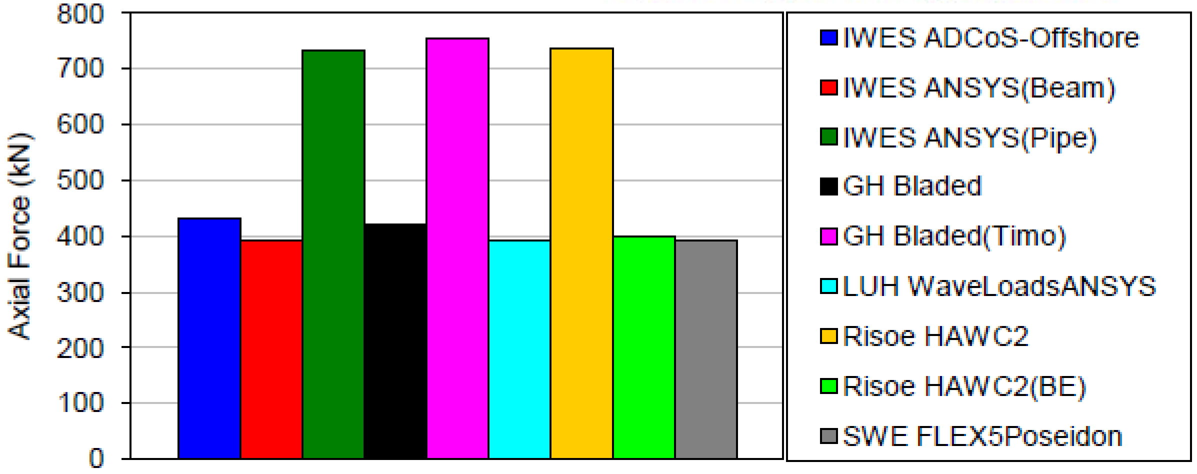
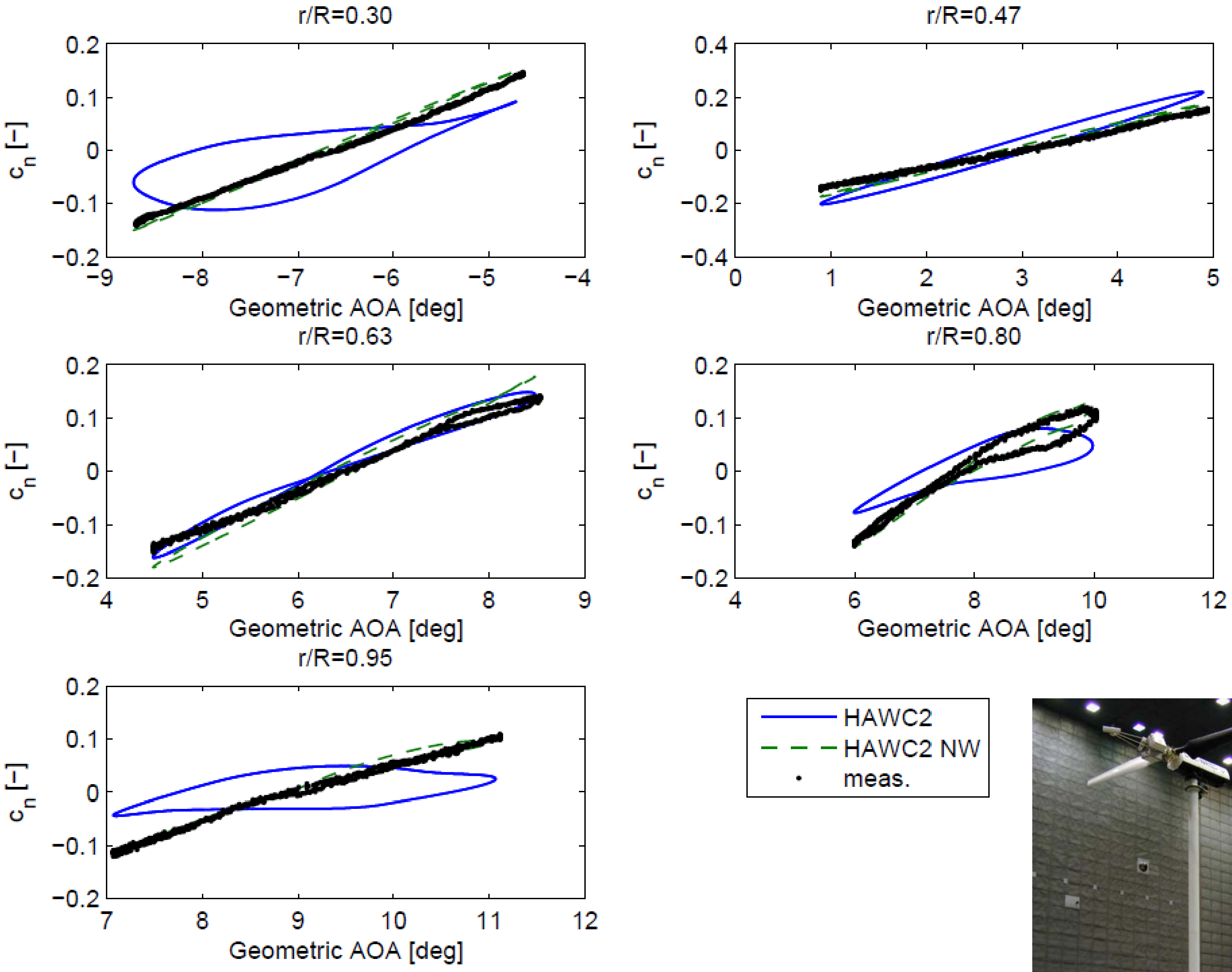


Figure 18. *Axial force 10 m under MSL in the central column of the tripod (location 3 as described in Figure 2)*

Dedicated experiments

- NREL/NASA phase VI experiment
- Example of Stand still situation with pitching blades
- Pitch amplitude 2deg
- Wind speed 23.3m/s

- Comparison with HAWC2 results and HAWC2 with a nearwake model



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Manuscript under review for journal Wind Energ. Sci.
Discussion started: 6 March 2017

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Open Access WIND ENERGY SCIENCE DISCUSSIONS

Trailed vorticity modeling for aeroelastic wind turbine simulations in stand still

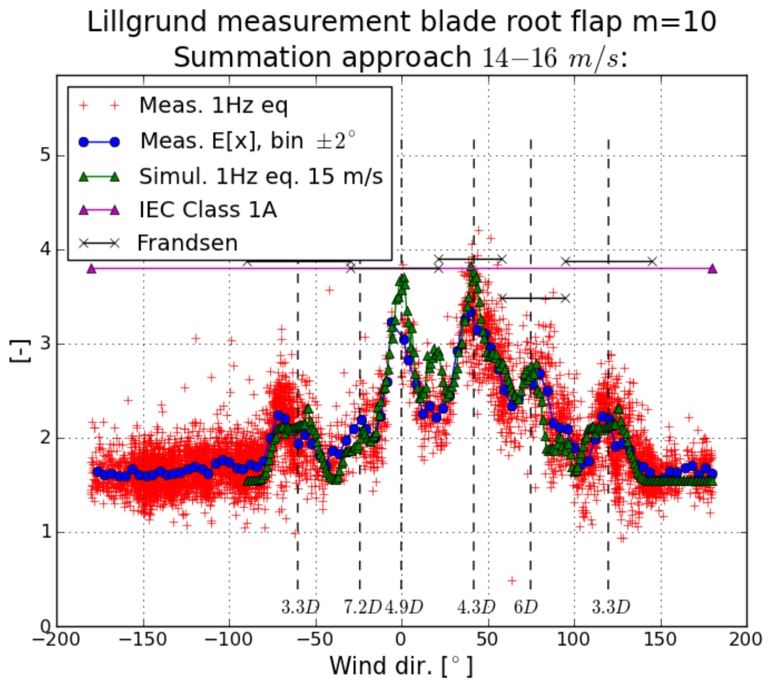
Georg R. Pirrung[1], Helge Aa. Madsen[1], and Scott Schreck[2]
[1]Wind Energy Department, Technical University of Denmark, Frederiksborgvej 399, DK-4000 Roskilde, Denmark
[2]National Renewable Energy Laboratory, 15013 Denver West Parkway, Golden, CO 80401, USA
Correspondence to: Georg R. Pirrung (gepir@dtu.dk)

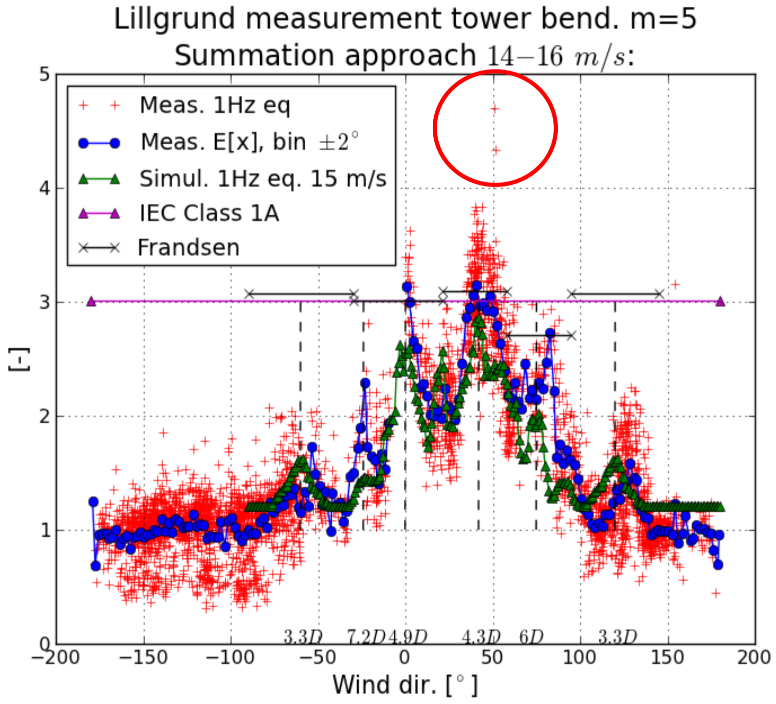
Previous results
Lillgrund - 2015

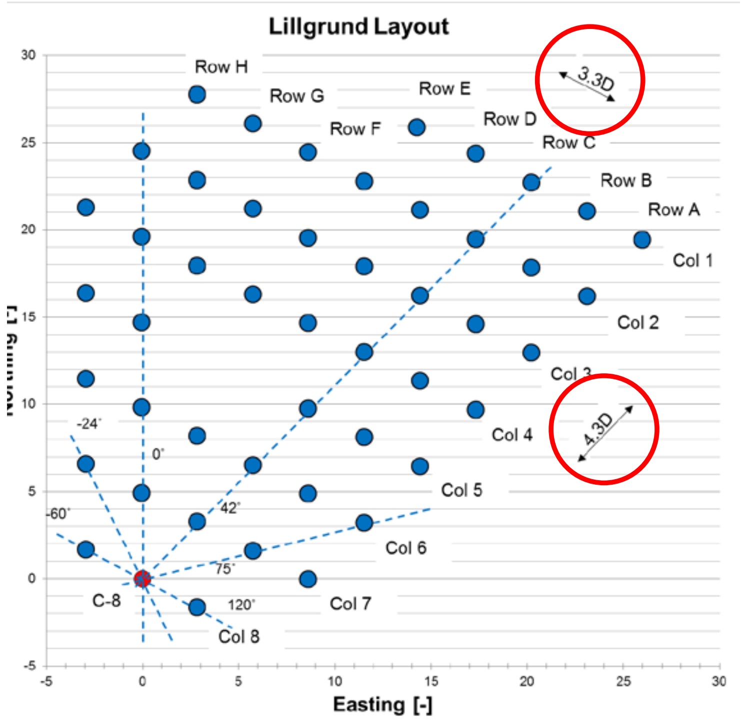
17 - 20 November 2015 | Porte de Versailles Pavillon 1, Paris, France

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

T.J. Larsen, G. Larsen, H.A. Madsen and S.M. Petersen





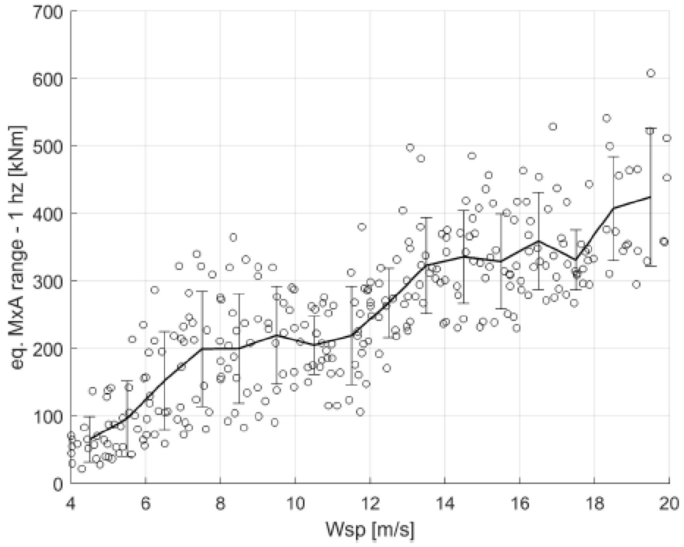


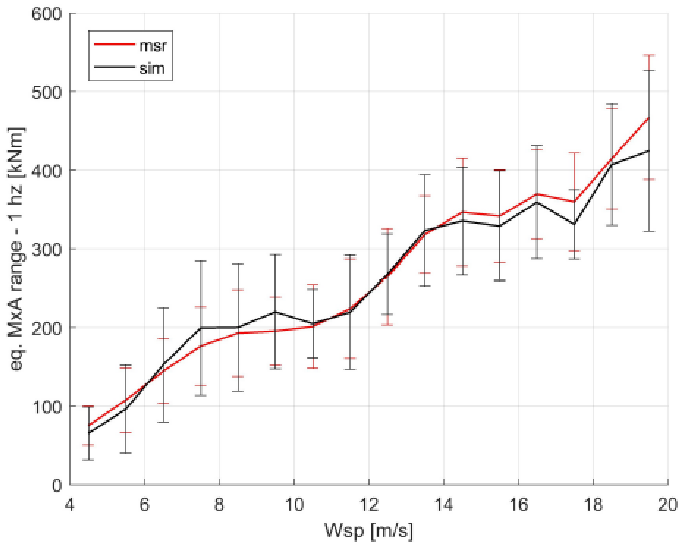
14-16m/s

- **Generally a very good to excellent agreement is seen**
- **High wind speed situations are highly important**
- **What happens in the “outlier” situations?**

The V52 DTU test facility

- Fully instrumented V52 turbine (pitch, speed, power, strain gauges, accelerometers)
- Met mast in western sector
- LIDAR in nacelle in upwind configuration
- Inflow with 5-hole pitot tube
- Spinner anemometer
- Aeroelastic model
- Ongoing project for creating one-2-one sim / meas comparisons





West

North

East

South

Increasing the wind field information

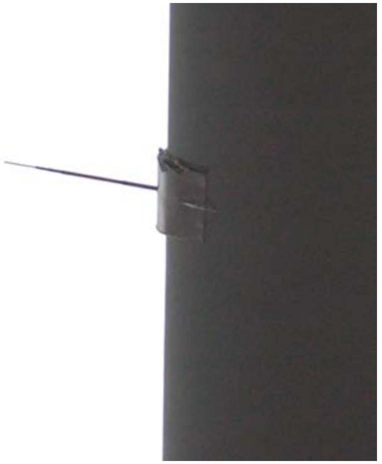
Siemens SWT 3.6MW Tjæreborg

Pitot tube installed on one blade

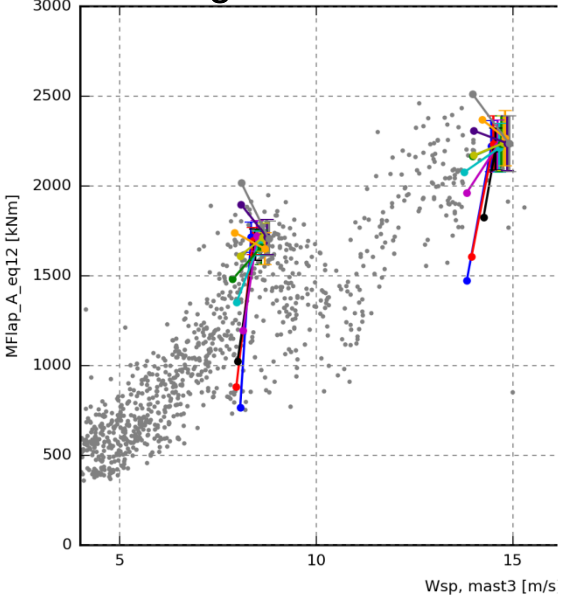
Free wind information derived based on pitot measurements and an inverse induction model

Courtesy: Siemens Wind Power

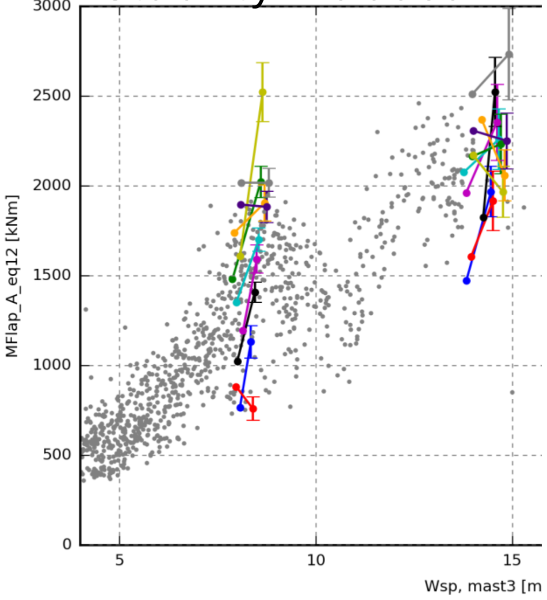
Mads M. Pedersen, DTU Wind Energy



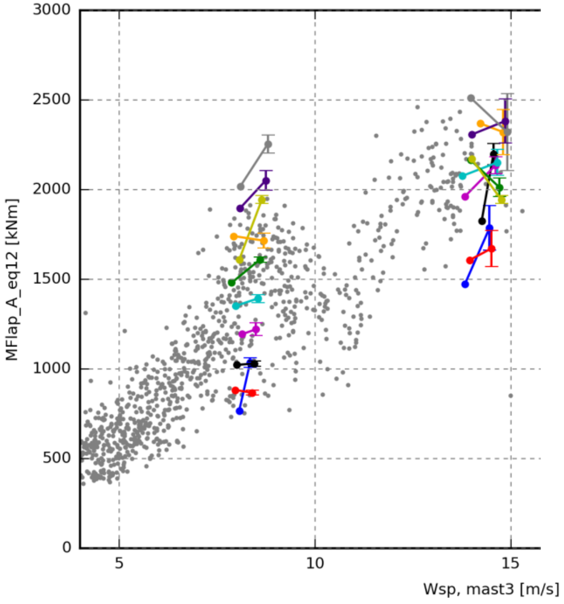
Average sector wind

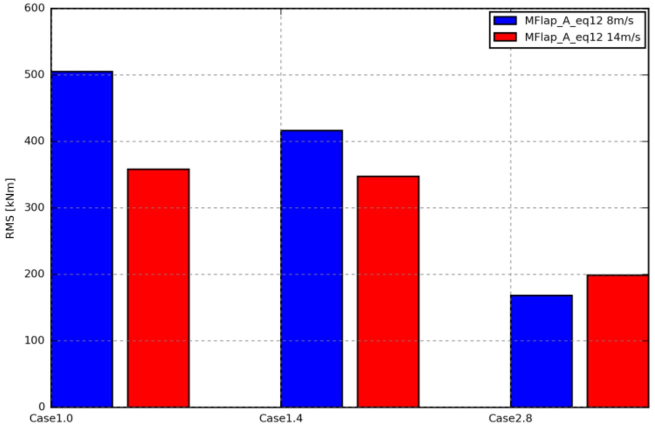


Stability included



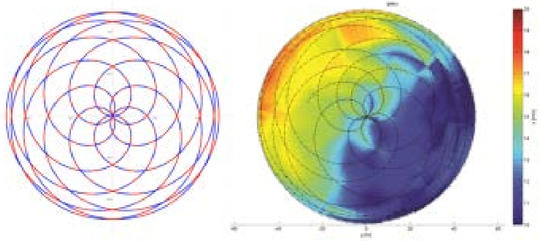
Constrained turb.

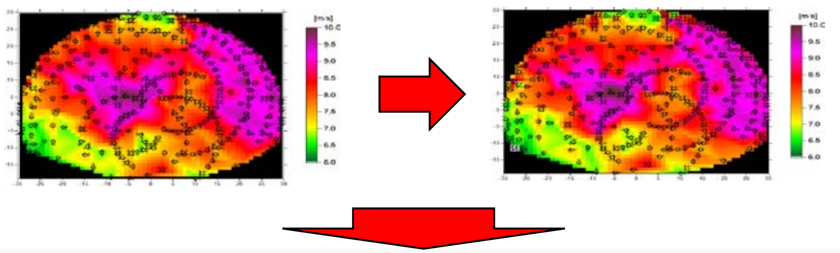


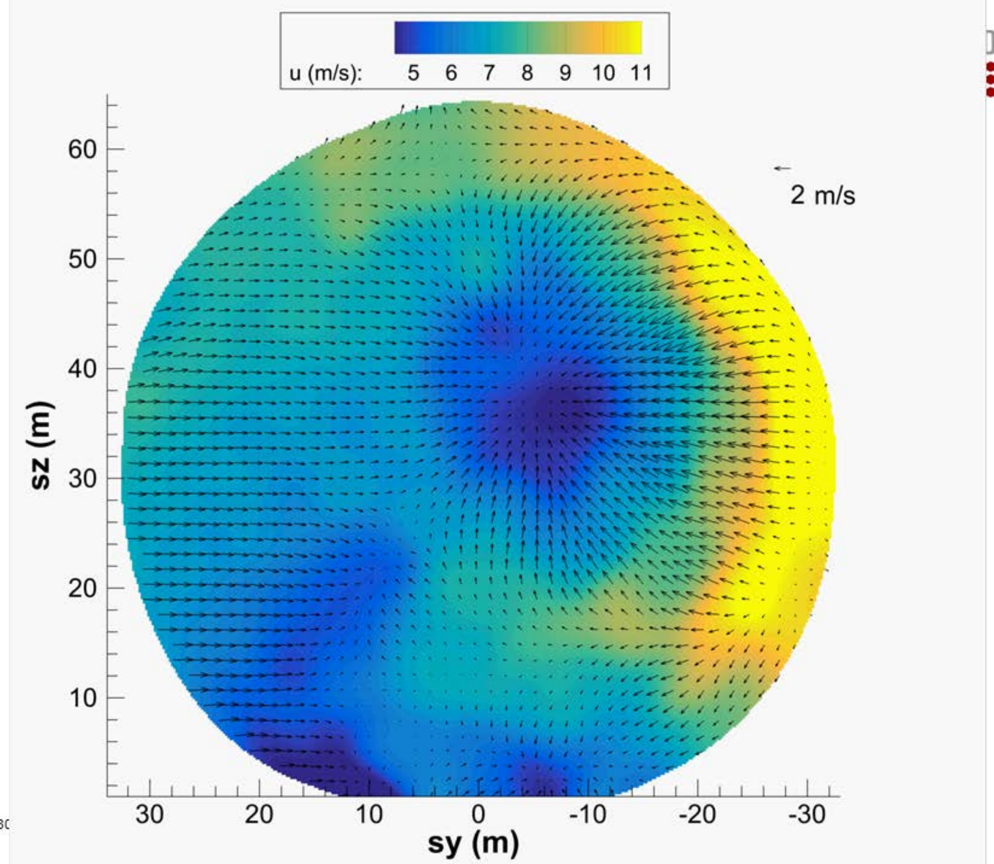


Spinner LIDARS provide unique options

- Lidars technigues evolves very quickly
- DTU Spinner LIDAR scans a full disc in 2 sec (LOS)
- Using a linearized flow solver a good estimate of u,v,w components can be found
- This could remove most of the uncertainty related to the windfield







$$U\frac{\partial u}{\partial x}+V\frac{\partial u}{\partial y}+W\frac{\partial u}{\partial z}=-\frac{\partial}{\partial x}\frac{p}{\rho}+K_{xy}\left[\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right]+K_z\frac{\partial^2 u}{\partial z^2}$$

$$U\frac{\partial v}{\partial x}+V\frac{\partial v}{\partial y}+W\frac{\partial v}{\partial z}=-\frac{\partial}{\partial y}\frac{p}{\rho}+K_{xy}\left[\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right]+K_z\frac{\partial^2 v}{\partial z^2}$$

$$U\frac{\partial w}{\partial x}+V\frac{\partial w}{\partial y}+W\frac{\partial w}{\partial z}=-\frac{\partial}{\partial z}\frac{p}{\rho}+K_{xy}\left[\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}\right]+K_z\frac{\partial^2 w}{\partial z^2}$$

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0$$

Courtesy: Mikkel Sjøholm,
Torben Mikkelsen
DTU Wind Energy

Summary

- Code 2 code validation
  - Very good for knowledge sharing
  - Great for bug fixing
  - Testing of details that may be difficult to test in experiments
  - Cost are low
  - Reference is missing

- Code 2 controlled experiments
  - Often new knowledge
  - Mexico, New Mexico
  - Test of floating wind turbines

- Code 2 controlled experiments
  - New knowledge and understanding
  - Focus on details
  - The big picture is missing
  - Issues with scaling, Re numbers, boundary effects etc.

- Full scale experiments
  - Excellent for new knowledge
  - All aspects included
  - Costly, confusing, confidentiality issuess
  - New flow measurement options may bring it closer to a controlled experiment!