Influence of sea structures on wind measurements: CFD analysis

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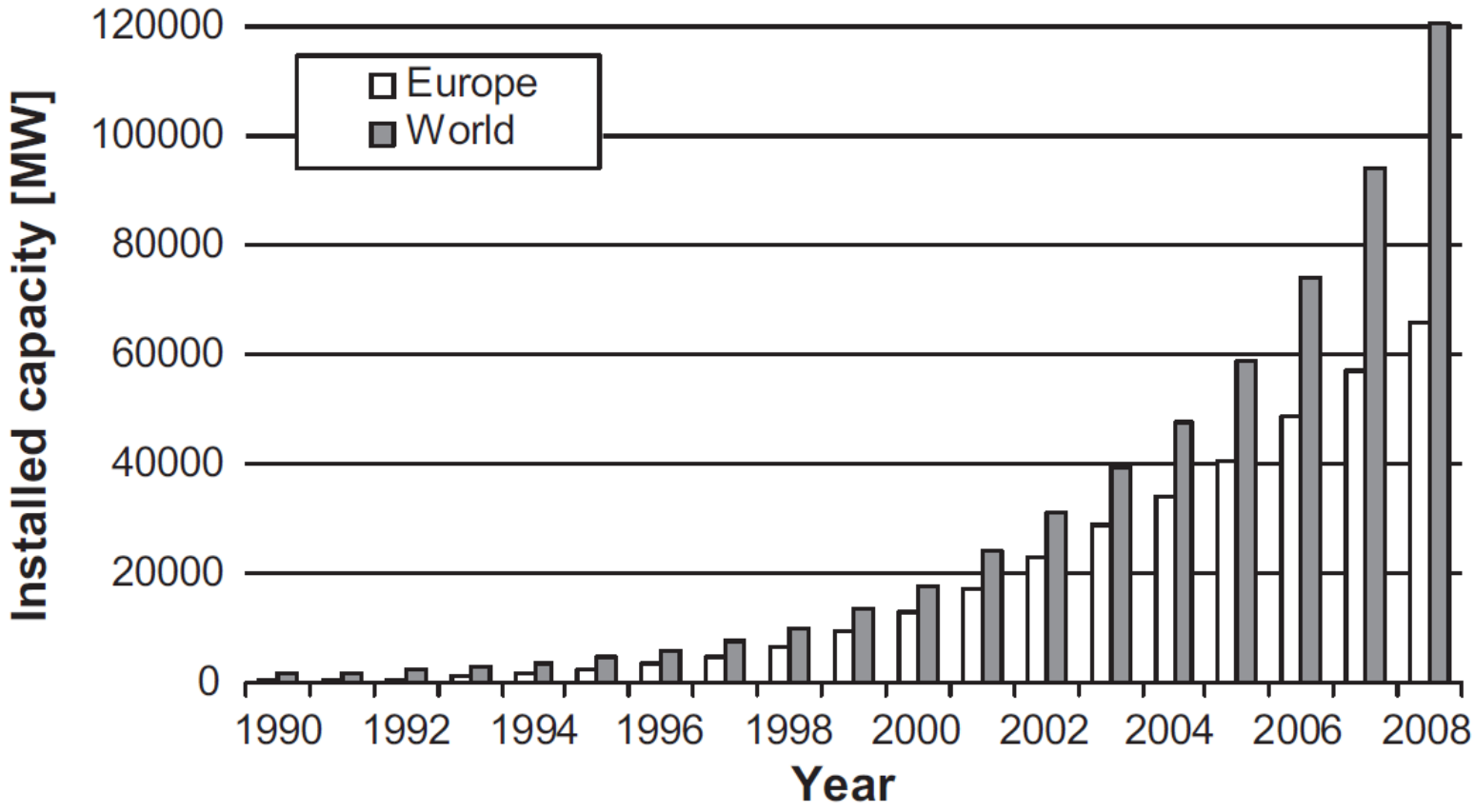
Motivation



Cumulative installed wind power capacity

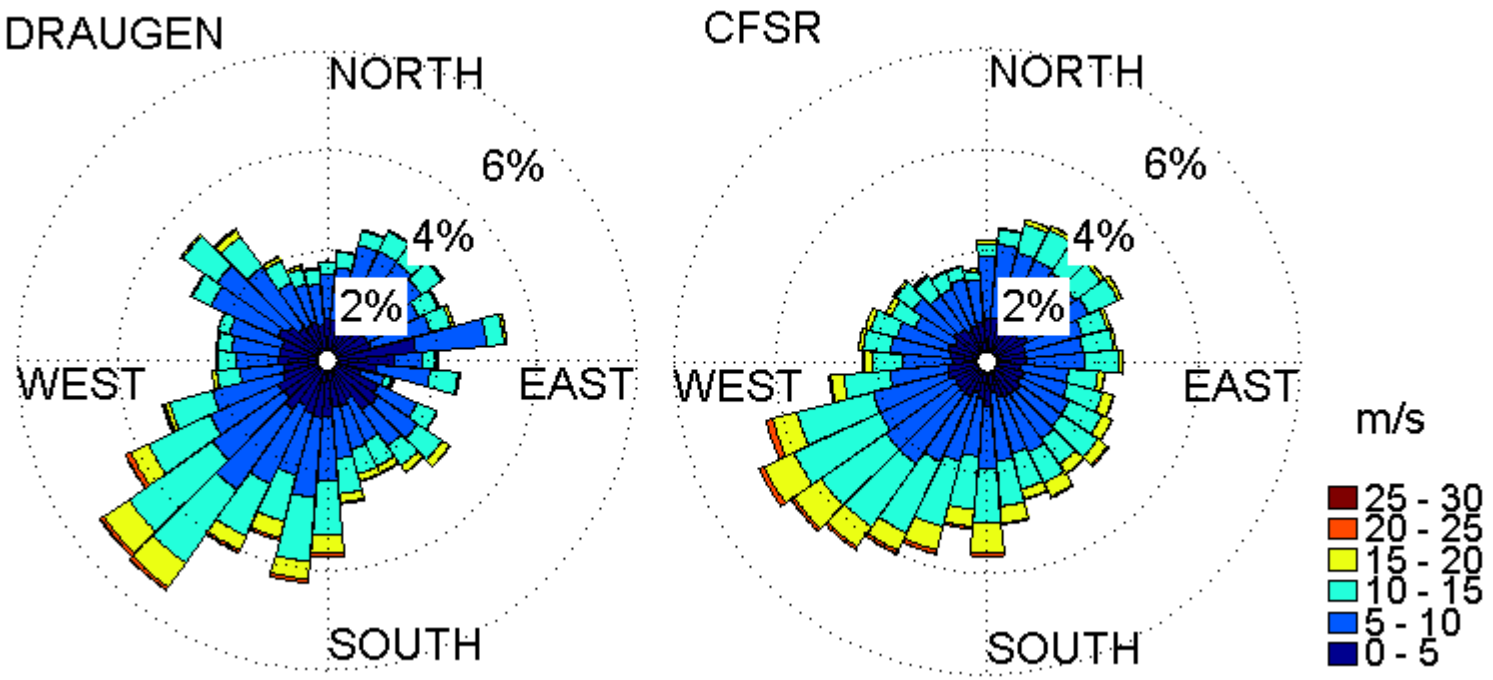
Picture from *Bilgili M, Yasar A, Simsek E. Offshore wind power development in Europe and its comparison with onshore counterpart. Renewable and Sustainable Energy Reviews, 15(2); 2011, p. 905–915.*

Motivation

- The number of offshore wind power installations is growing rapidly.
- Knowledge of metocean conditions in the Marine Atmospheric Boundary Layer conditions is important.
- Offshore wind measurements are essentially relevant for characterization of MABL and development of numerical models.
- Offshore wind measurements suffer from low quality and poor availability due to the influence of big structures.
- Such influence data cannot be used and must be discarded.

What if we could predict inconsistencies in influenced wind data and fix them?

Example



Wind roses plotted for the data obtained at Draugen oil platform and Climate Forecast System Reanalysis data (CFSR)

Draugen platform

How to treat influenced data?

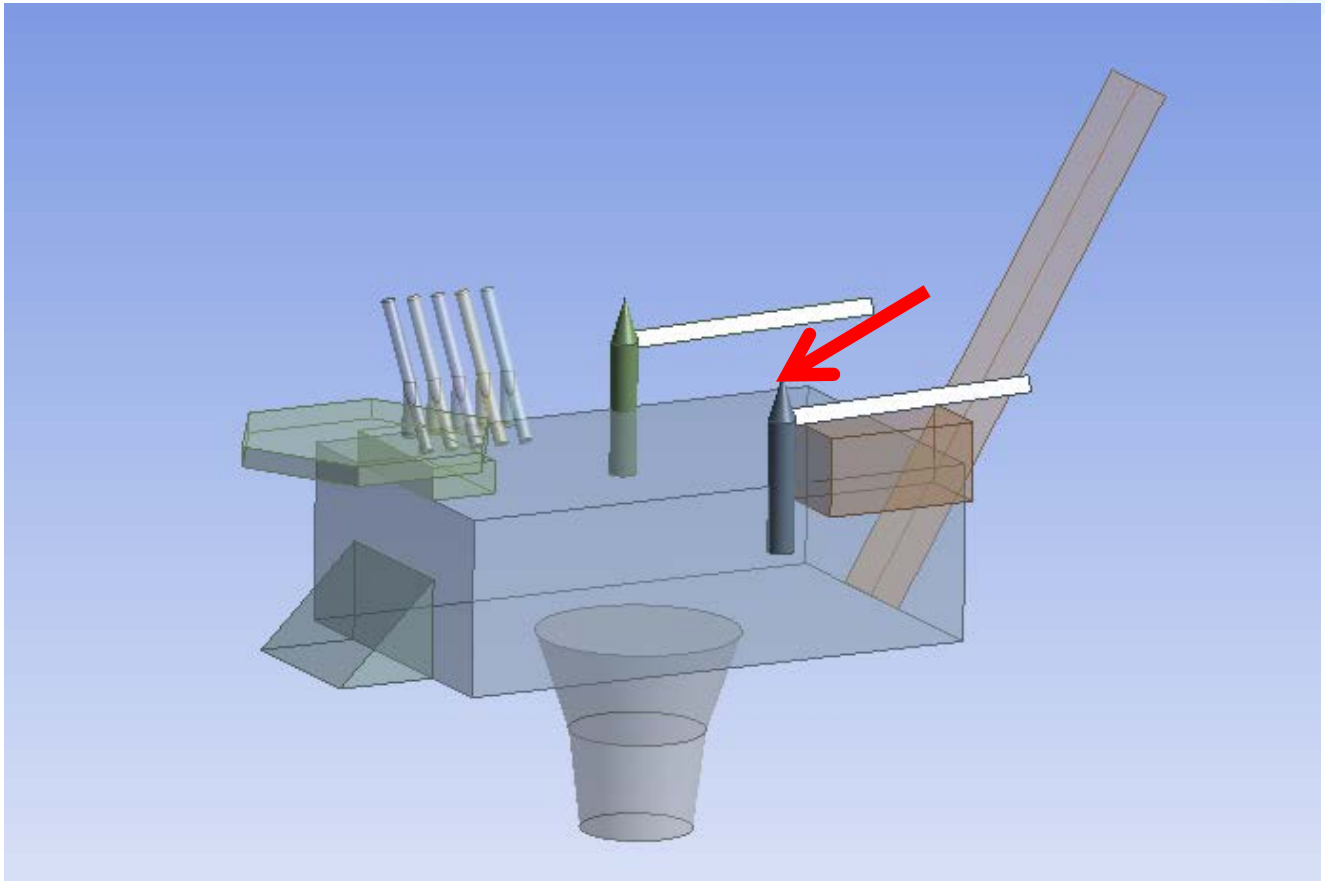
- Resolve MABL on microscale. HOW?
- Use Computational Fluid Dynamics (CFD). WHY?

- CFD is usually used for modeling fluid flow on microscale.
- CFD is very accurate comparing to mesoscale and large scale models.
- Full control over accuracy, including numerical validation.
- Information about physical quantities (such as fluid velocity magnitude and direction, turbulence, pressure, temperature, etc.) is available at any space point within the model boundaries.

Therefore CFD is a powerful tool for such applications.

- The goal is to mimic the real data inconsistency which occurs on the platform with the CFD model…
- …so in the future we could predict this inconsistency and correct the data.

CFD model

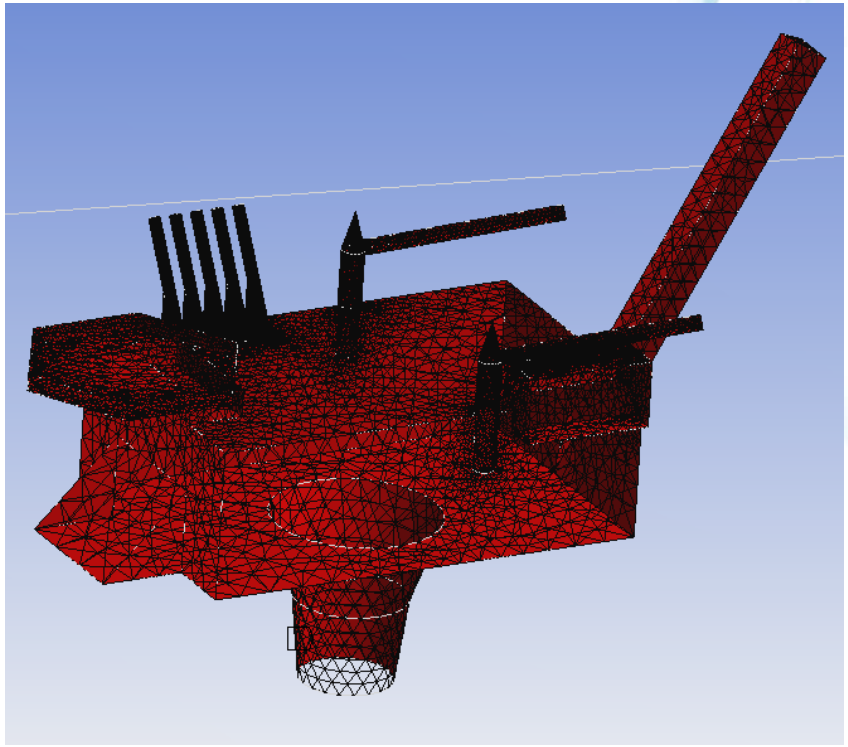


Simplified CAD model of Draugen platform

CFD model

Model mesh:

- Flat sea surface (neglected sea state)
- Tetrahedral grid
- Grid adaption for small components
- 1.3 mil. cells
- Control of aspect ration
- Control of skewness



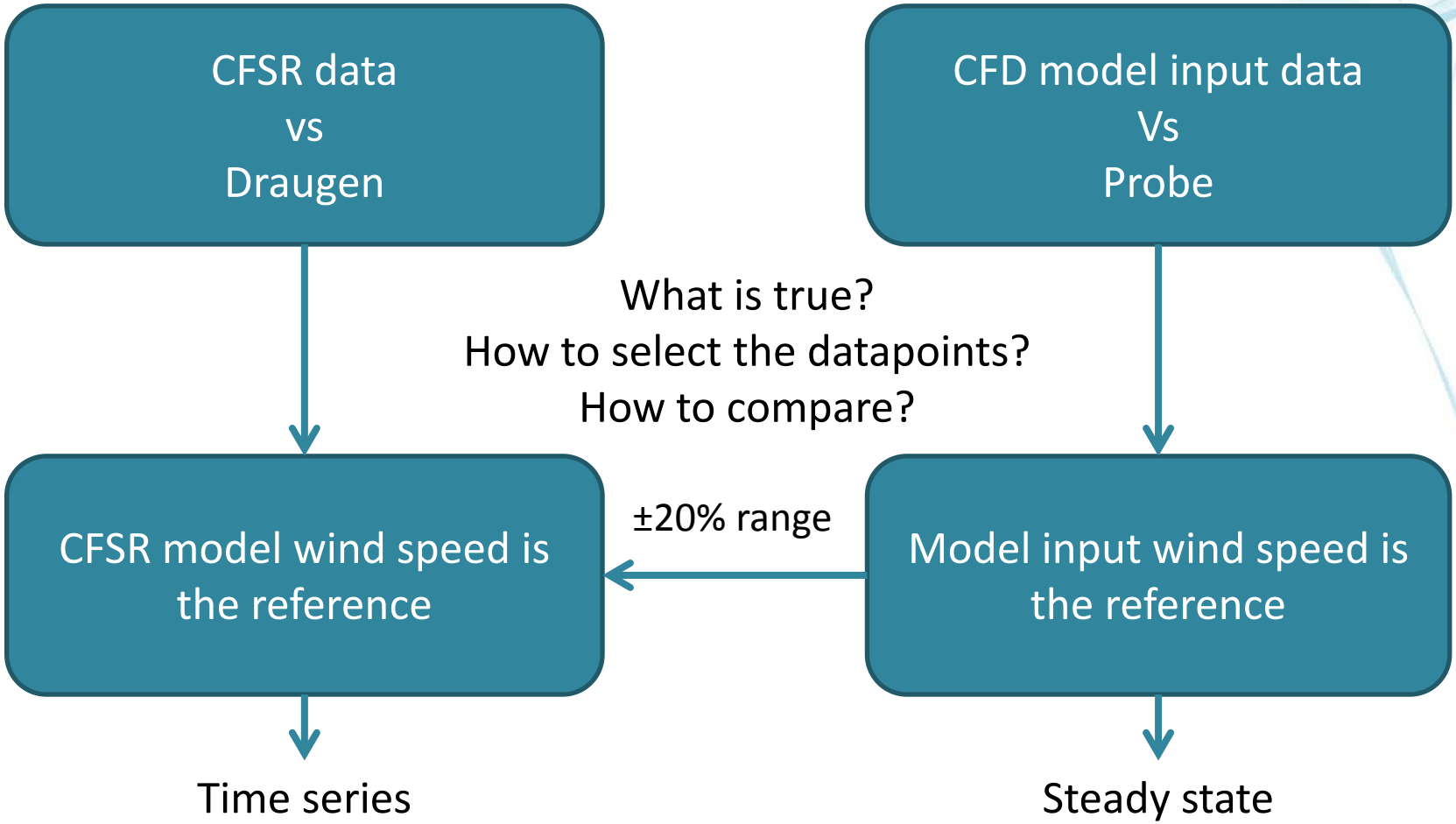
CFD model

Set up of physics

- Single phase flow (air)
- Uniform boundary velocity (wind speed and direction)
- Shear Stress Transport (SST) *k-ω* turbulence model (turbulent kinetic energy and dissipation rate)
- Steady state analysis

- Model set up, meshing and solution was performed using ANSYS Fluent.
- Ask me for more solving details.

Data comparison and validation



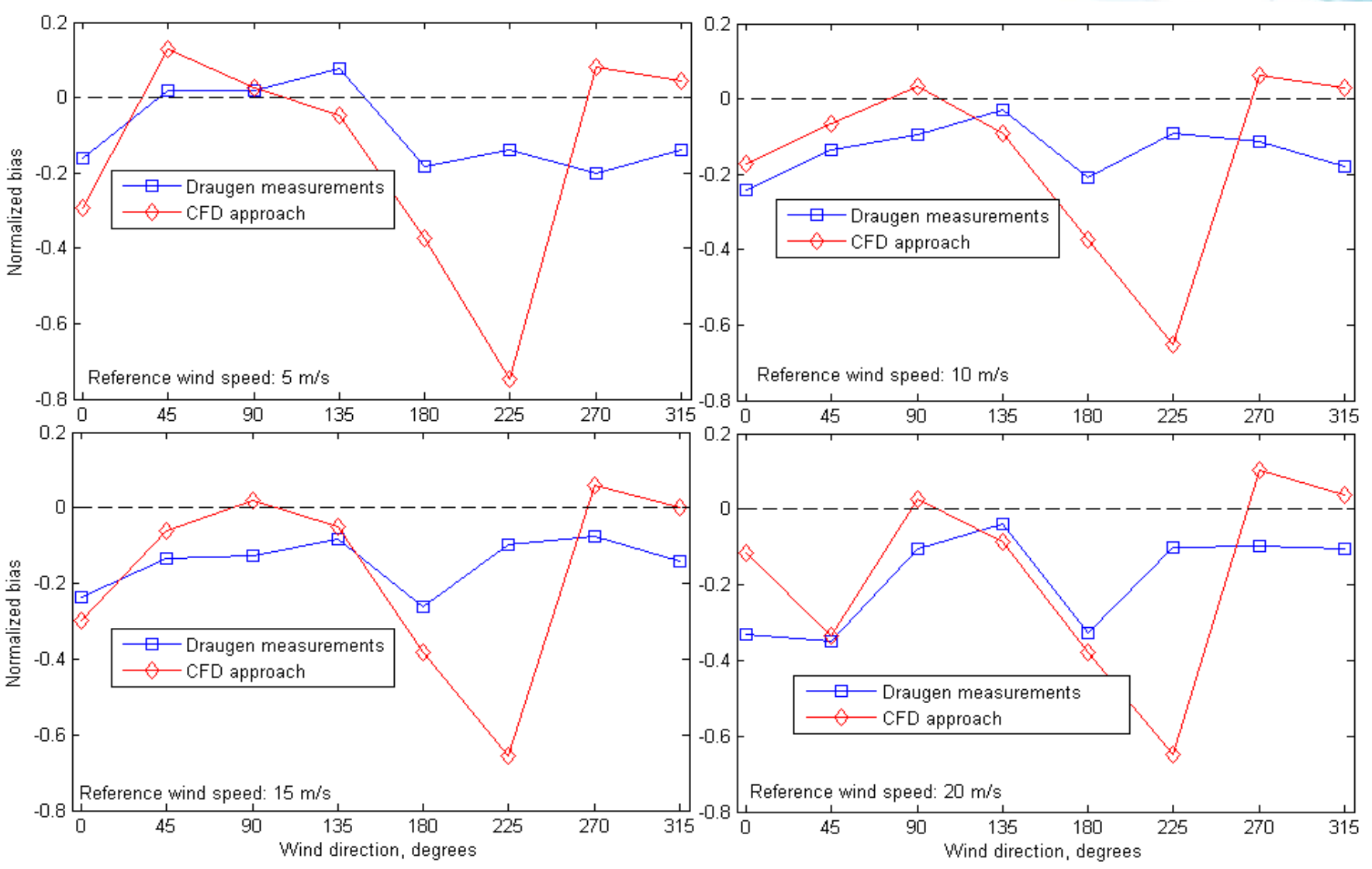
Data comparison and validation

Data to be compared via the wind speed bias.

$$Platform\ w.s.bias = \frac{\langle Platform\ meas. - CFSR\ data \rangle_{selected\ points}}{ref.wind\ speed}$$

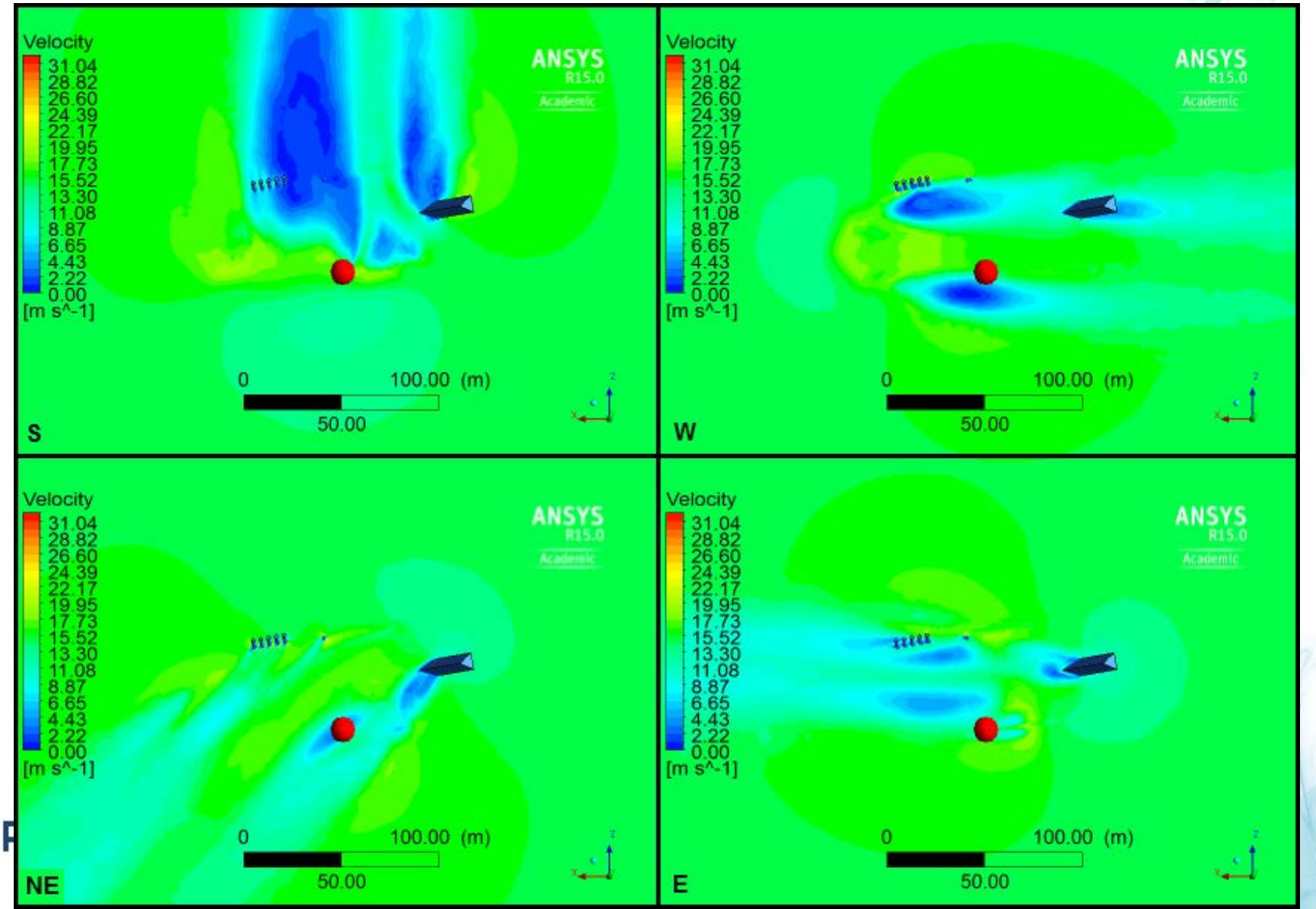
$$CFD\ model\ w.s.bias = \frac{CFD\ probe\ meas. - BC\ wind\ speed}{ref.wind\ speed}$$

Data comparison and validation



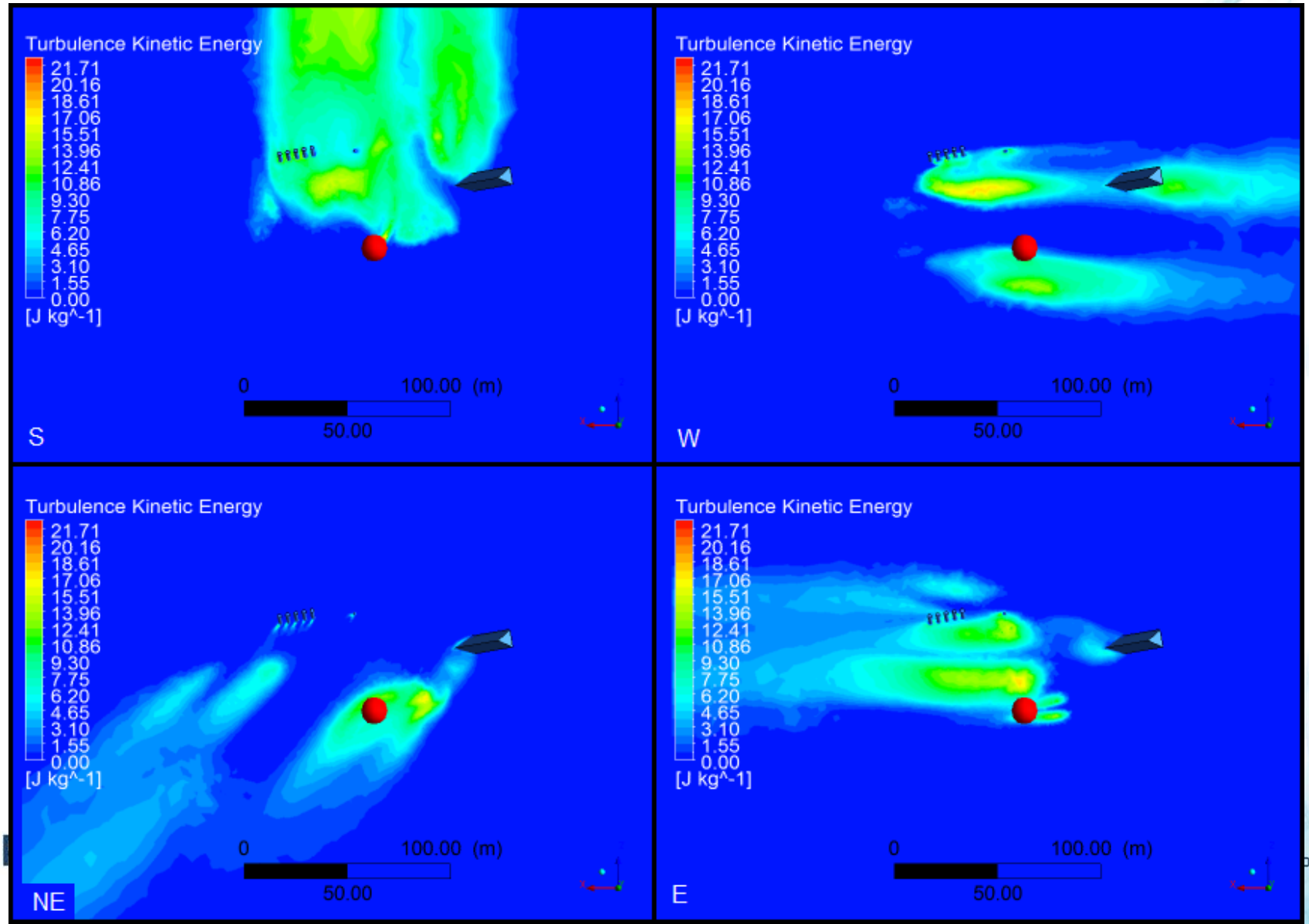
Discussions

Why some points (especially north east wind) did not line up so well?



Discussions

Indeed. Look at the turbulent kinetic energies.



Known problems

- Turbulence is by nature unsteady.
- Steady state analysis is not sufficient.

Solution:

- Perform a transient simulation (very very long).
- Perform a number of steady state simulations for a velocity distribution (stochastic approach, also computationally expensive).

Other known problems

CFSR data and platform records

- Data is not the real uninfluenced data – it is just a model
- Data spatial and temporal resolution
- Instruments and methods

CFD

- Mesh sensitivity test
- Sea roughness
- Velocity profile at the boundaries
- Geometry details
- Model physics and solvers
- Numerical error
- Other…

Conclusions

- CFD is able to mimic the influence of structures and landmarks on meteorological measurements.
- We hope that CFD modeling can serve for correction of the influenced meteorological measurements as well as improvement of the meteorological models.
- We hope that our case example on the use of CFD for treating influenced meteorological measurements will inspire a deeper investigation of the problem.

Thank you!