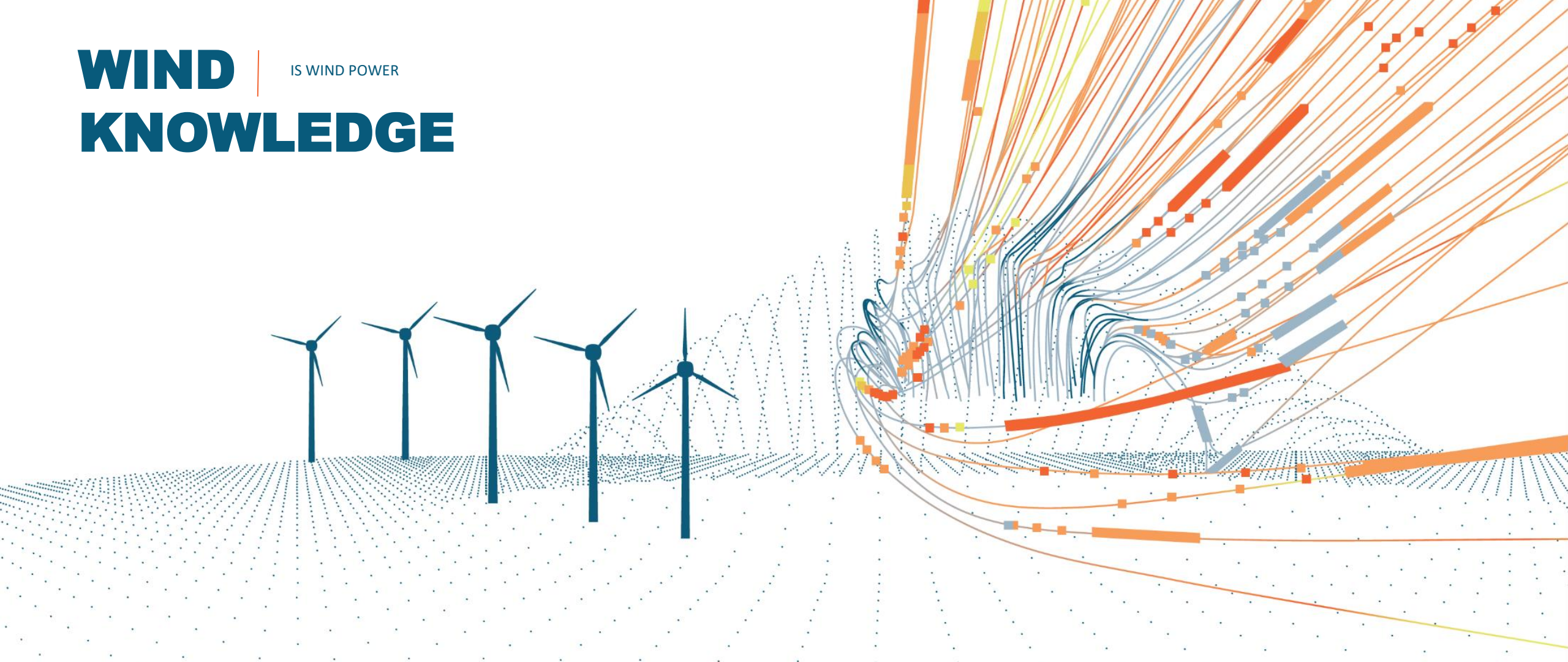


WIND KNOWLEDGE

IS WIND POWER



Usage of WindSim – Accuracy & Performance

WindSim 15th User Meeting, Online, 23 June 2021

PRESENTED BY: Arne R. Gravidahl

windsim

Usage of WindSim – Accuracy & Performance

- Development priorities
 - Accuracy
 - Improved physical models, improved procedures
 - Larger models in terms of number of cells
 - Performance, simulation time and memory usage
 - Modular split of the core in WindSim 11, allows for better memory optimization
 - Convergence – What is the right number of iterations?
 - User-friendliness
 - Cloud – WindSim X and Services

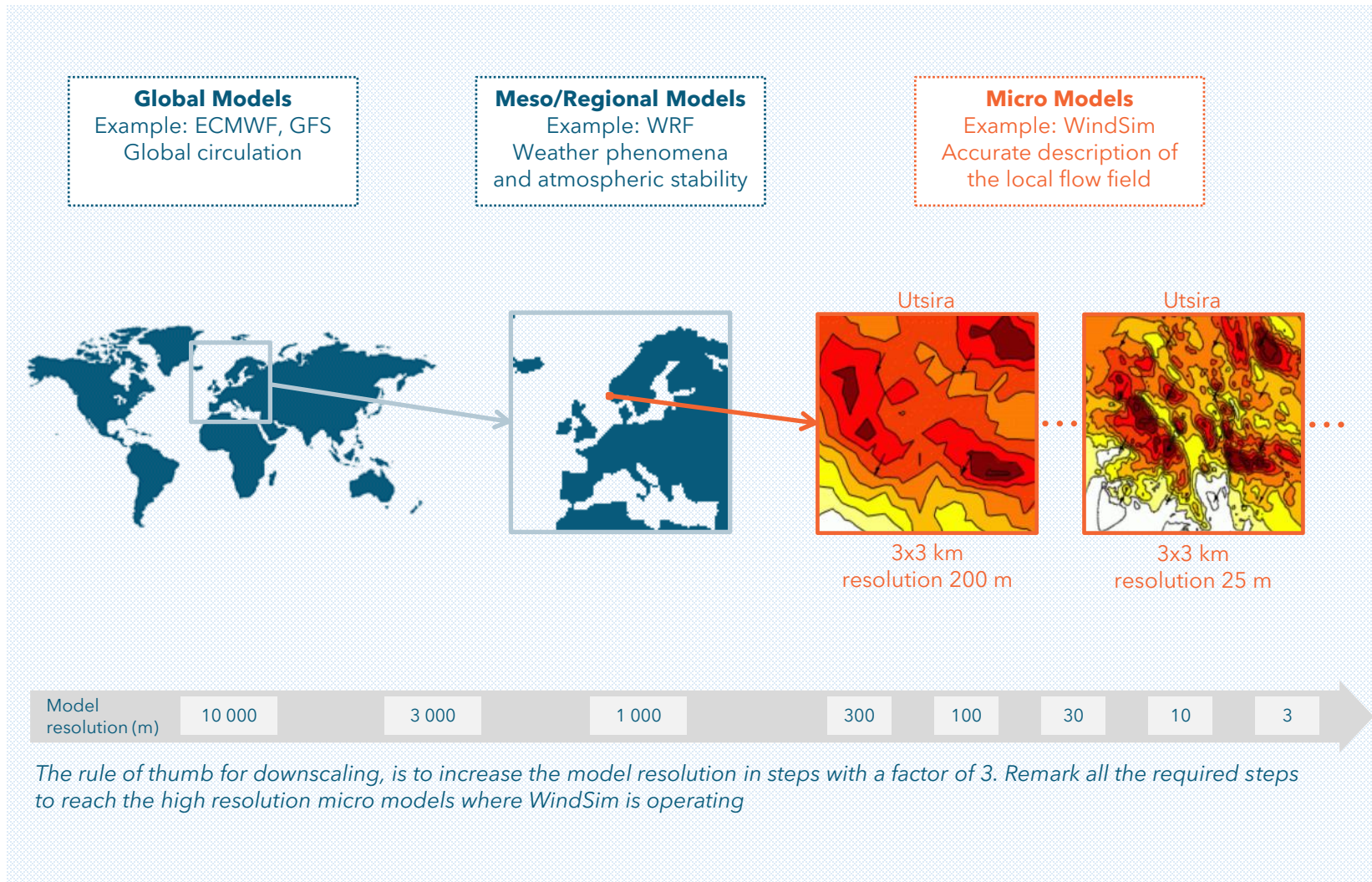
Model size in terms of number of cells

- Lower limit
 - WindSim Evaluation, maximum 50 000 cells (70 x 70 x 10)
- Upper limit
 - WindSim 11, maximum 240 million cells (2000 x 2000 x 60)
- According to our experience the typical user run models in the range 1-20 million cells
- How is the model size set?
 - Wanted accuracy (stage of development from early screening to matured projects)
 - Accessible hardware resources, # CPUs and memory
 - Practical constraints – Tailored model size for running outside regular office hours (16:00 – 08:00)
 - Time available before simulation results have to be ready according to project schedule

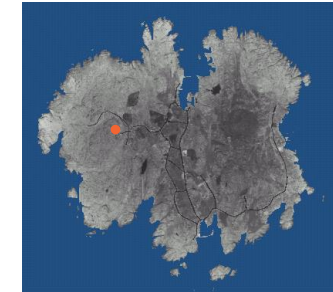
Empirical laws – Memory and simulation time

- Empirical law on memory usage: Model of N million cells requires $N * 1.3$ GB RAM
- Empirical law on simulation time: Simulation time (hours) = $N * \text{\#iterations} / 200$
- Example: Simulation time for running 50 iterations for a 10 million cell model is: $10 * 50 / 200 = 2.5$ hours
- Back to my two questions:
 - What is the right model size in terms of number of cells?
 - How many iterations are required?

What is the right model size? It is the grid independent model



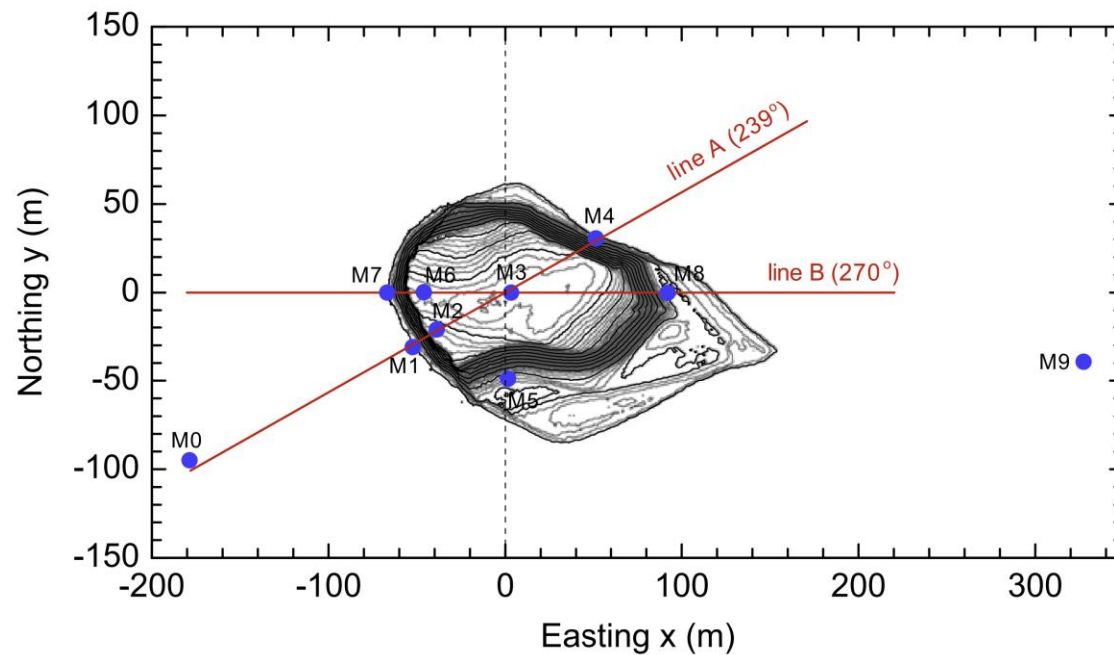
- Utsira is an island outside the west coast of Norway



- A model with the extension of 3x3 km cover the island Utsira
- What is the required resolution before grid independency is reached? That is, what is the resolution required when a further refinement doesn't change the "results" anymore
- The "results" for us is the wind conditions over the swept area of a wind turbine

Grid independency – Bolund experiment

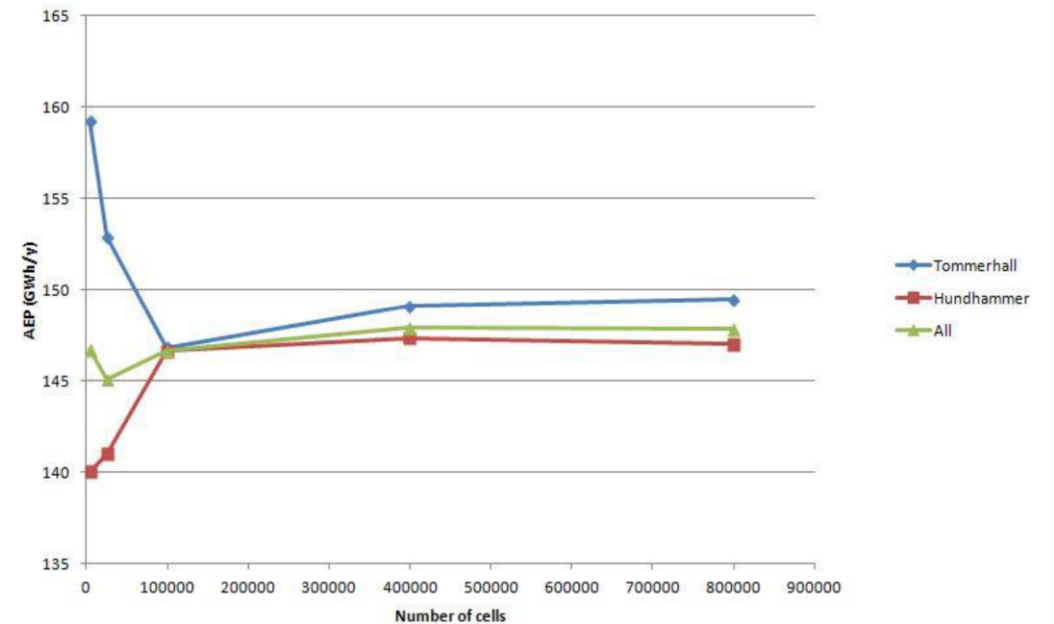
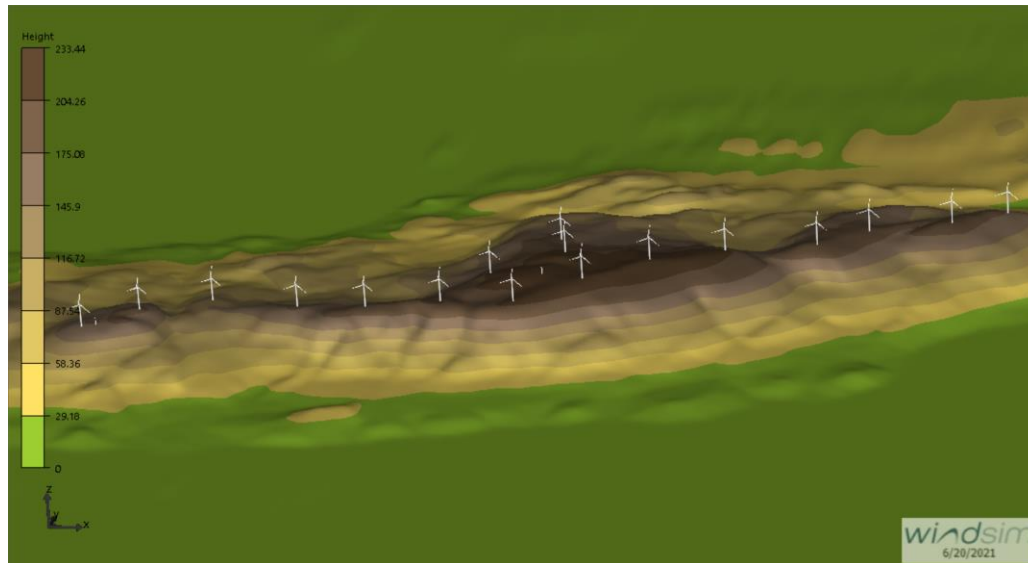
- Validation against two lines of measurements with masts of 10 meters height (1/10 of the scale of a commercial project)
- Grid independent at 700 000 cells (with respect to mean wind speed at measurement masts)



Source: Prospathopoulos J. M, Politis E. S, Chaviaropoulos P.K., “Application of a 3D RANS solver on the complex hill of Bolund and assessment of the wind flow predictions”, August 2012 Journal of Wind Engineering and Industrial Aerodynamics s 107–108:149–159

Grid independency – WindSim demo, Hundhammerfjellet

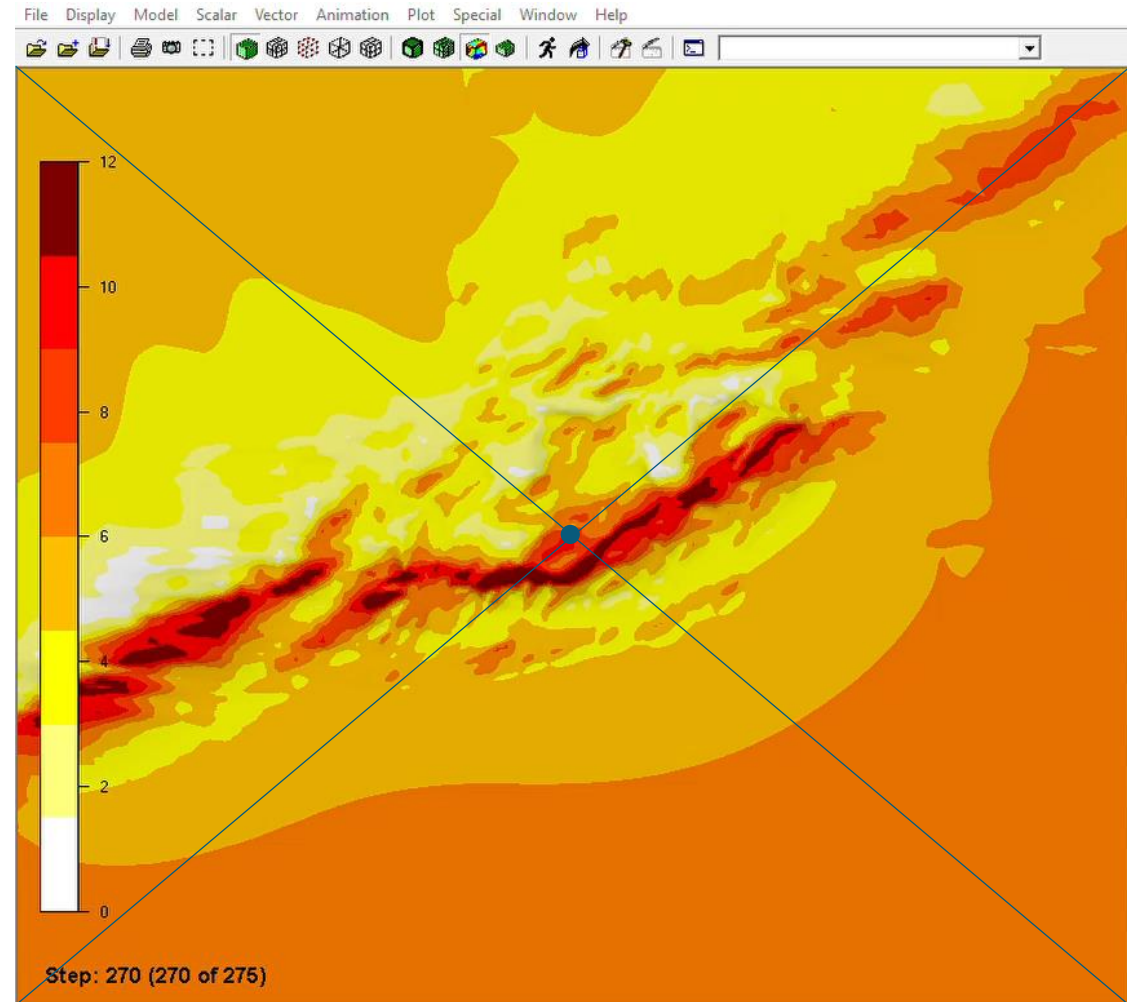
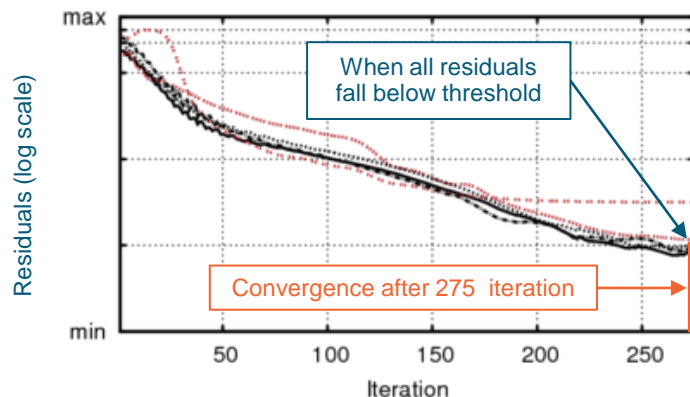
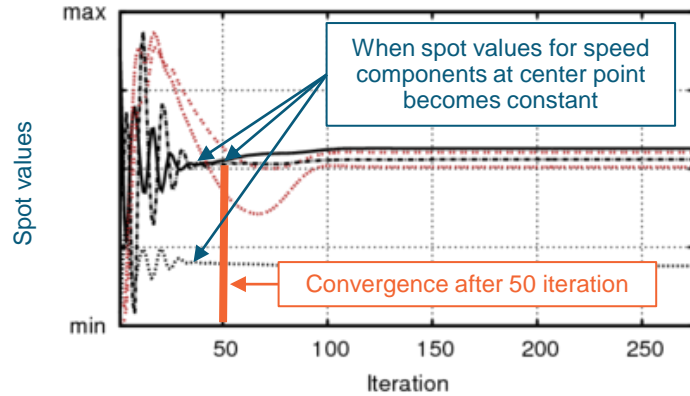
- Resolution of .gws is 25 meters
- Model extension is 9x8 km
- Grid independent at 400 000 cells (with respect to turbine production along ridge)
- Models of 400 000 and 800 000 cells yields 26 and 18 meters resolution in the center of the model



Source: "Getting started" part of the documentation included in the WindSim software

How many iterations are required – Convergence monitoring

- When is convergence reached?



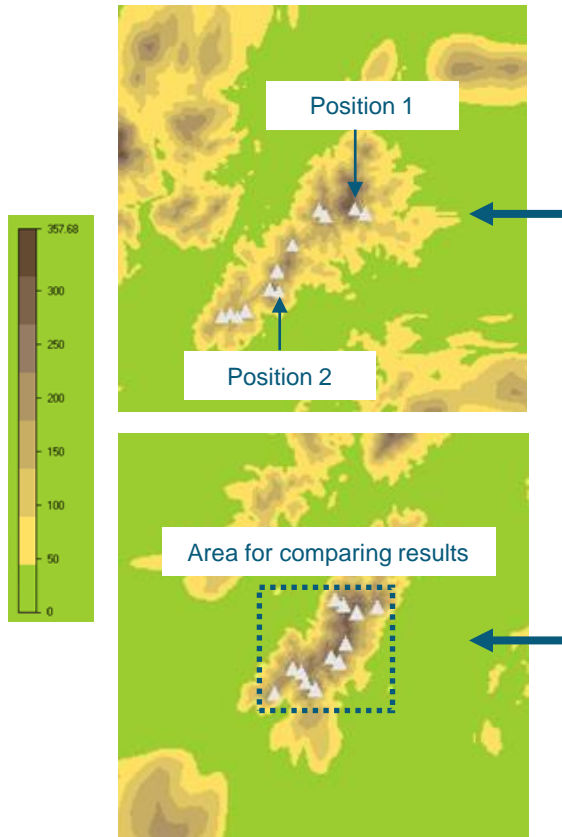
Exposed areas where turbines are located have a fully developed flow field after less than 50 iterations (model size 800 000 cells, wind direction 150 degrees)

Convergence monitoring

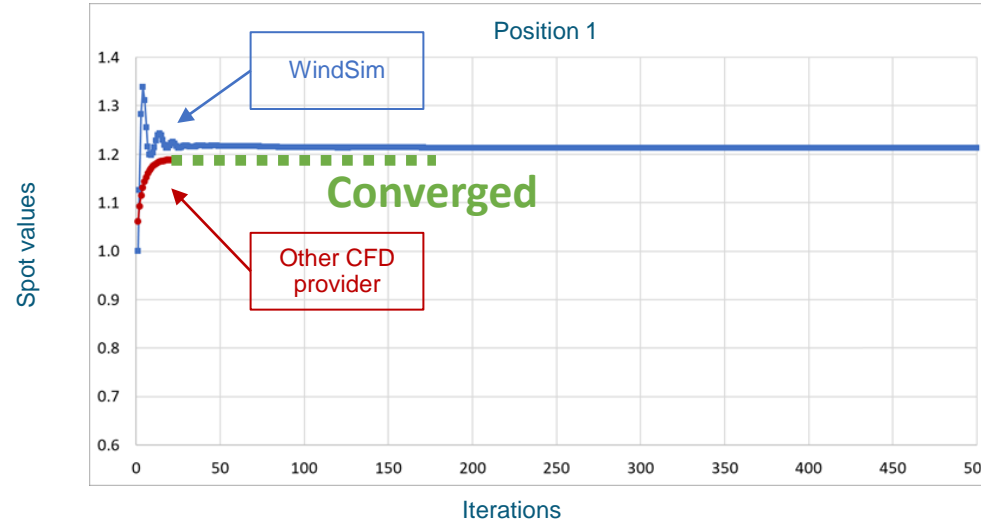
- Convergence is measured differently in various CFD software
- WindSim has a default convergence criteria, which is rather strict, based on residuals
 - It could lead to the usage of too many iterations
- Another CFD provider has a default convergence criteria, which seems rather loose
 - It could lead to the usage of too few iterations and that convergence is not reached

Convergence monitoring – Comparison

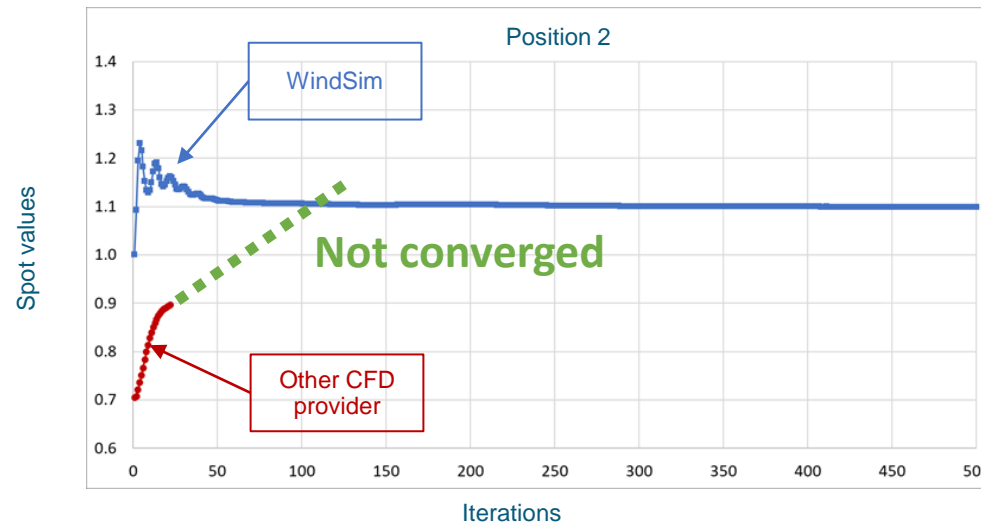
- Sample model with 10 million cells
- Convergence monitored at two different positions, 1 and 2, both well exposed



Subsections of model, first turbine group (upper) second turbine group (lower)

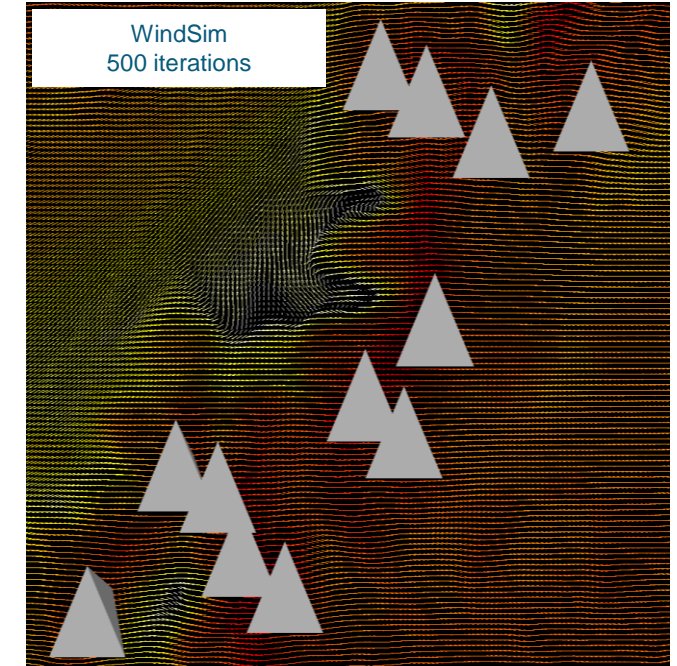
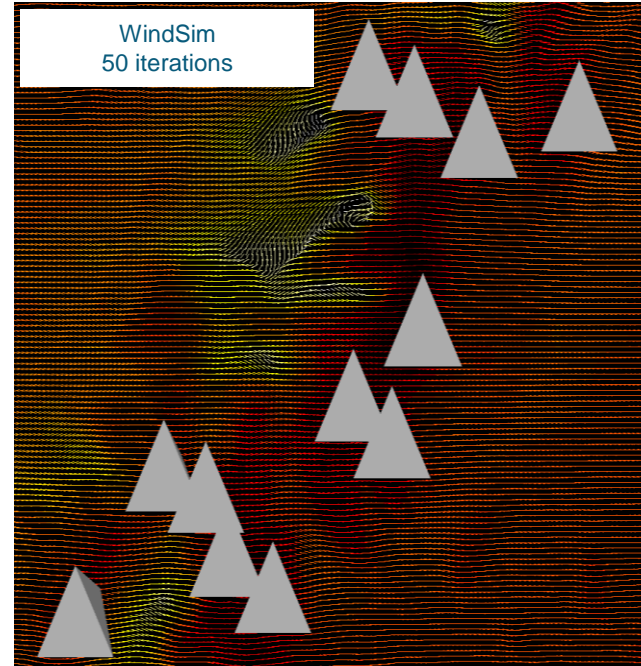
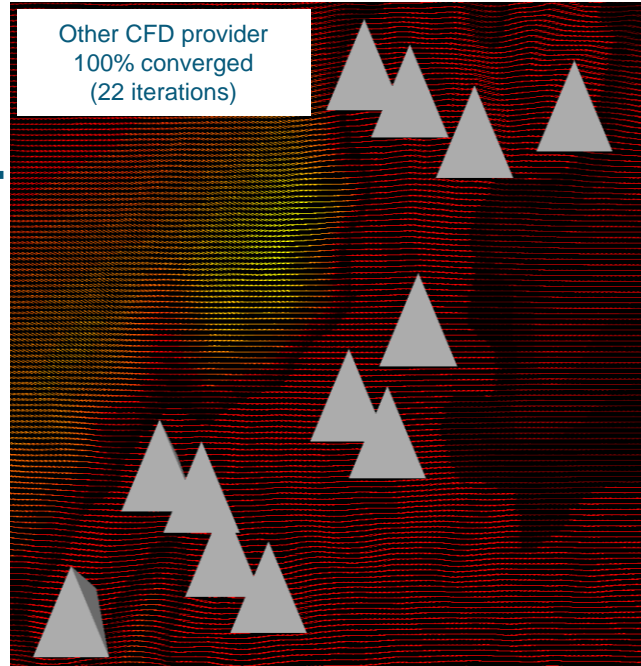


- WindSim minor changes after 25 iterations
- Other CFD provider claims 100% convergence after 22 iterations – seems OK at position 1

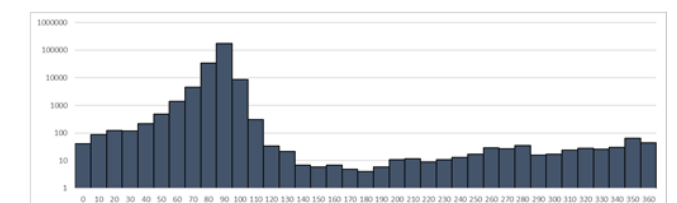
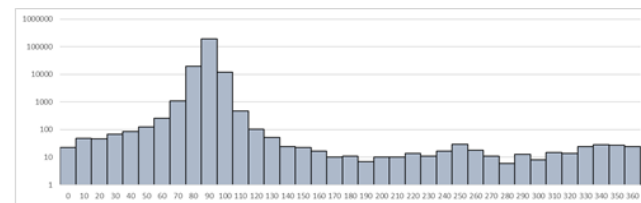
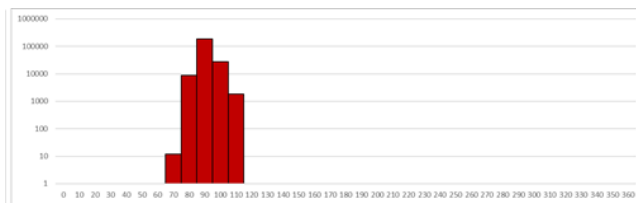


- WindSim minor changes after 50 iterations
- Other CFD provider claims 100% convergence after 22 iterations – seems NOT OK at position 2

Vector field comparison at 90 meters height, Wind direction 90 degree



- Differences in mean wind speed on the east side (upstream side)



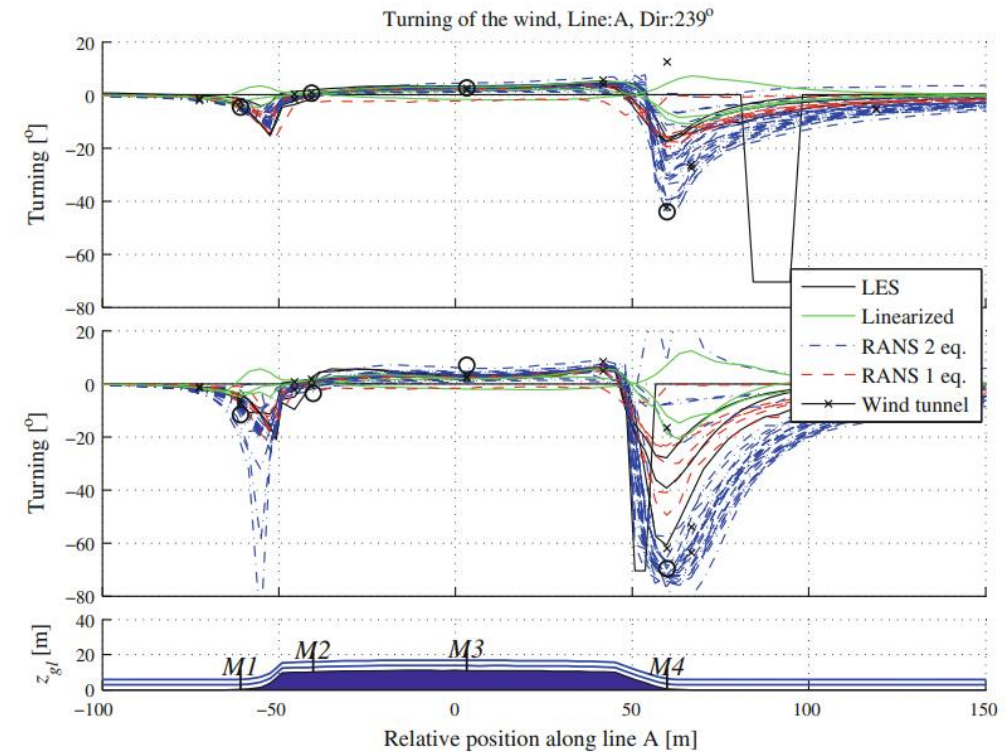
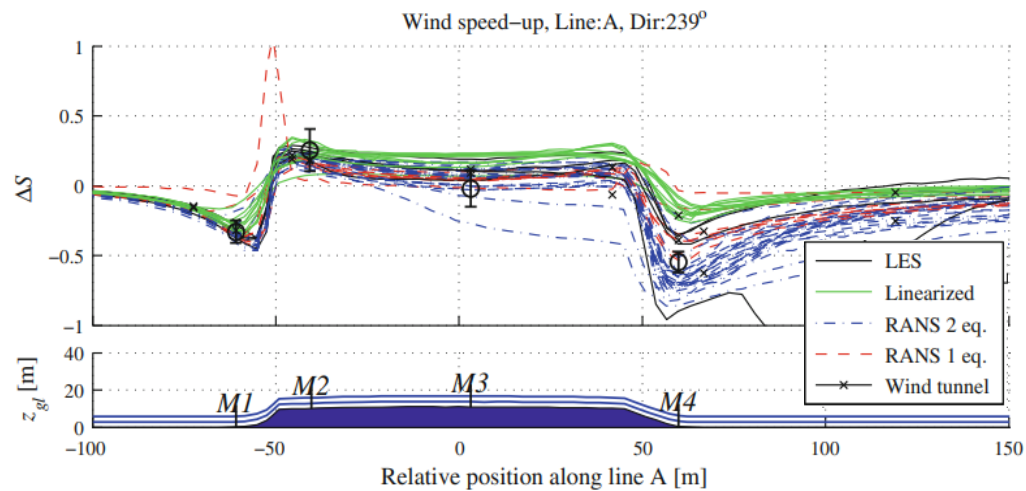
- Differences in the veering of the wind on the west side (lee side)

Vector field comparison

- What is the reason for the large differences?
 - Convergence has not been reached for the other CFD provider
 - Differences in the physical models
 - WindSim, 2 equation turbulence closure
 - Other CFD provider, 1 equation turbulence closure
 - There is a significant difference in the veering
 - Less veering could indicate a high level of turbulent viscosity
 - Let's check with literature

Differences between 1 equation and 2 equation models

- The Bolund experiment displays a less pronounced speed and veer variability, hence a more viscous solution, for the 1 eq. models than the 2 eq. models



- Difference in the vector fields could partly be due to incomplete convergence, but it is also due to differences in the physical modelling of the turbulent viscosity

Source: Bechmann et al. (2010). The Bolund Experiment, Part II: Blind Comparison of Microscale Flow Models, 2010

Summary

- Check for grid independency – you might run too large models
- Check convergence monitoring – you might have too long simulation time
 - Relax on the convergence criteria for screening and initial simulations
 - Restart with tighter convergence criteria for final simulations
- Finally, we would like to hear from you – the successful development of WindSim relies on your feedback
 - Sharing of experiences
 - Sharing of data (validations, cross checking)
 - Common development – Joint Industry Projects (JIPs)

Thank you



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