Celebrating 20 years

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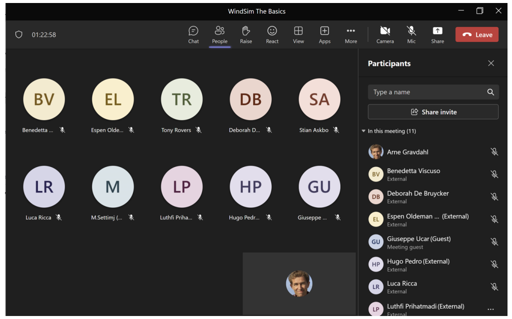
windsim

User Meetings – Getting together to learn and have fun

First UM in 2005 – "The 3F's for Funding - Family Friends and Fools"

UM in 2010 – Growing network

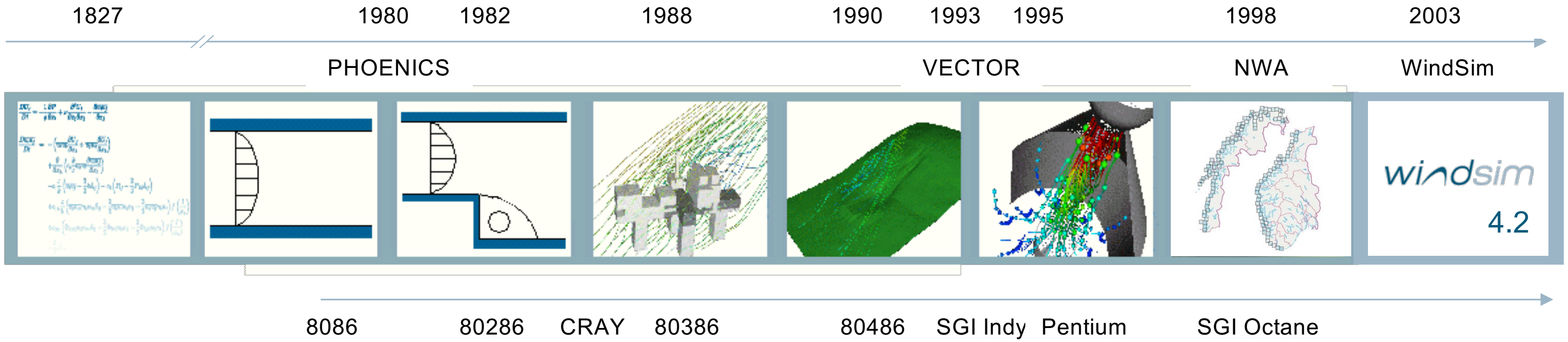
First UM in China – Xiamen 2016



We went online during COVID

UM was also great fun – we will get back here

CFD – We have the computing power

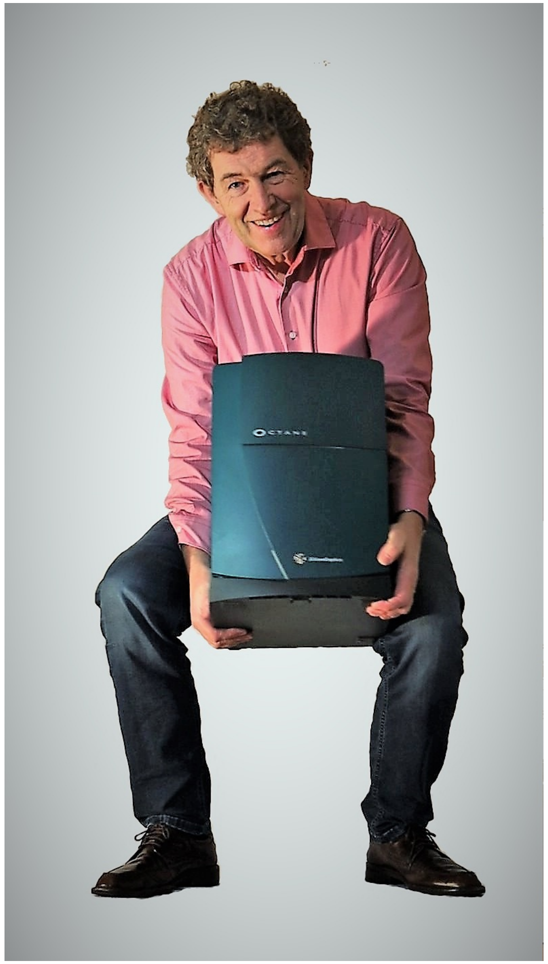


CFD development – A personal view

- 1980 - PHOENICS, first commercially available CFD software
- 1982 - Stanford, backward facing step, prediction of the size of the recirculation zone
- 1986 - CRAY X-MP 28, 28 MB RAM, Cost 10 Million EURO (First supercomputer in Norway)
- 1988 - Troll platform with 100 000 cells, presented as a “monster” model at the CRAY UM
- 1993 – VECTOR is established – SGI Indy “the pizza box”
- 1998 – Norwegian Wind Atlas (NWA) – WindSim is born
- 2003 – WindSim launched on Windows, 100 000 cells on ordinary 32-bit PC (Evaluation 5 000 cells)
- 2013 - WindSim 10 000 000 cells on ordinary 64-bit PC (Evaluation 50 000 cells)
- 2023 - WindSim Accelerator 100 000 000 cells in the Cloud

CRAY X-MP, height 190 cm, weight 3050 kg

Norwegian Wind Atlas – Heavy Computing



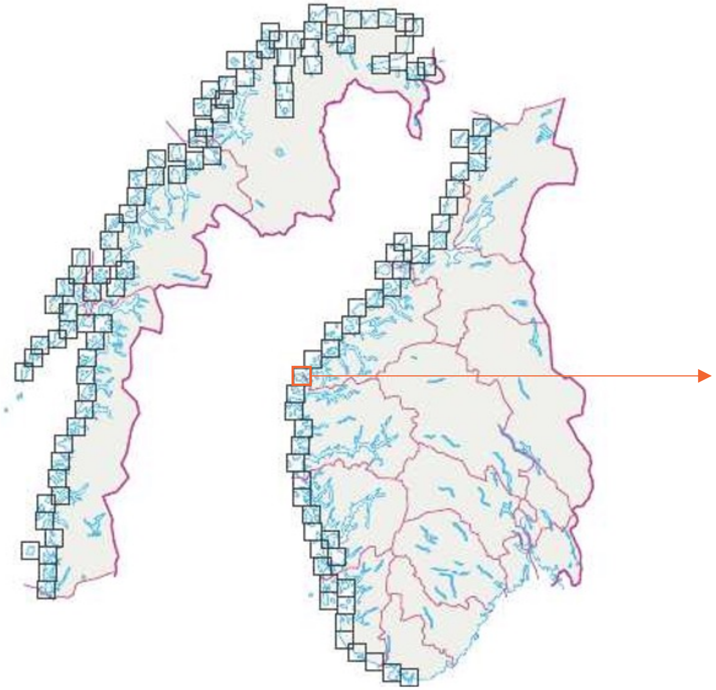
In the late 90s the Norwegian authorities decided to establish a Norwegian Wind Atlas. This is the project where WindSim was born.

We invested in a high-end workstation from Silicon Graphics to do the CFD simulations. I will not give you the technical specifications of the beautiful blue Octane workstation, you would be laughing, it is totally outdated. But I will reveal the weight, it was 25 kg, clearly we were in the category – "heavy computing".

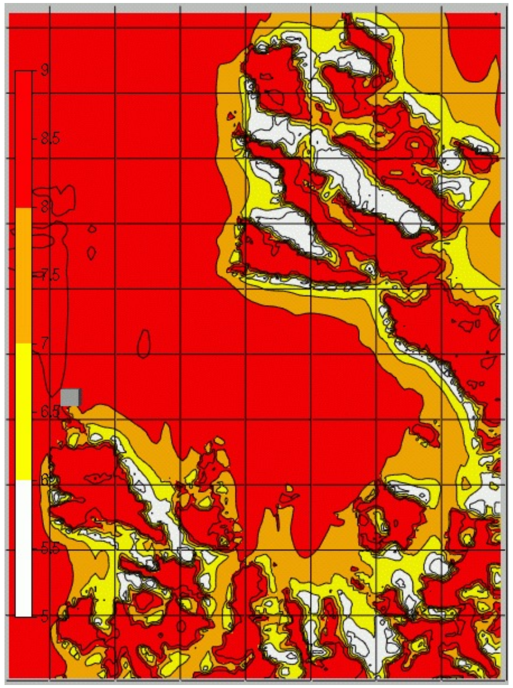
Manufacturer:	*Silicon Graphics, Inc.*
Release date:	*1997*
Discontinued:	*2004*
Operating system:	*IRIX*
CPU:	*MIPS architecture*
Memory:	*64 MB – 8 GB*

Norwegian Wind Atlas 1998 – 2003

- Micro scale modelling with WindSim (Computational Fluid Dynamics)
- http://windsim.com/wind_energy/wind_atlas/index.html



Models of approximately 30x30 km covering the Norwegian coastline (106 models)

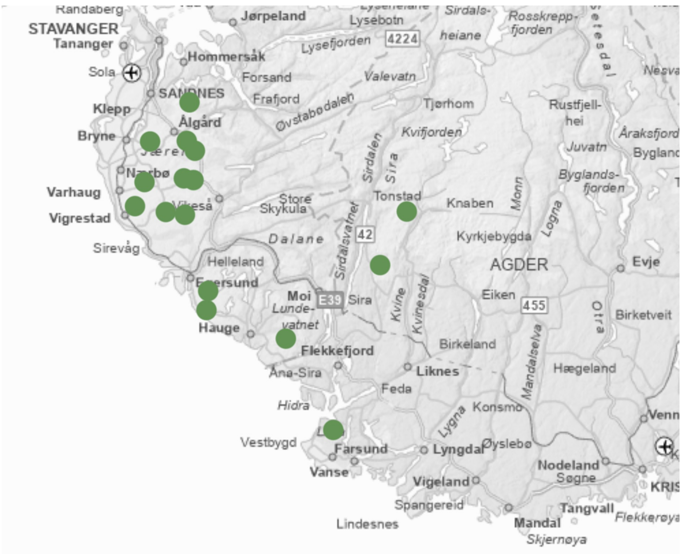


Model resolution 200x200 meters, model size in the order of 300 000 – 400 000 cells (Elevation data 100x100 meters)

The blue Octane workstation was running more or less continoulsy for one year to complete the simulations

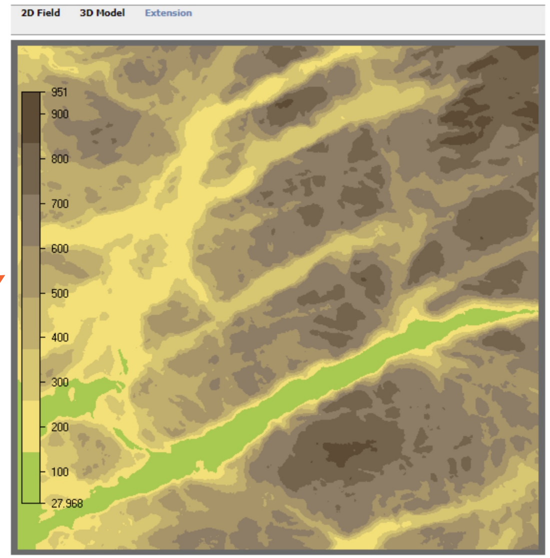
Rerunning an NWA model in 2023

- 16 wind farms has been built in Southern Norway
- Build a WindSim model in the area with a 20x20 km extension
- Extract data with WindSim Express, roughness CORINE (90x90 meters), elevation SRTM (38x38 meters)



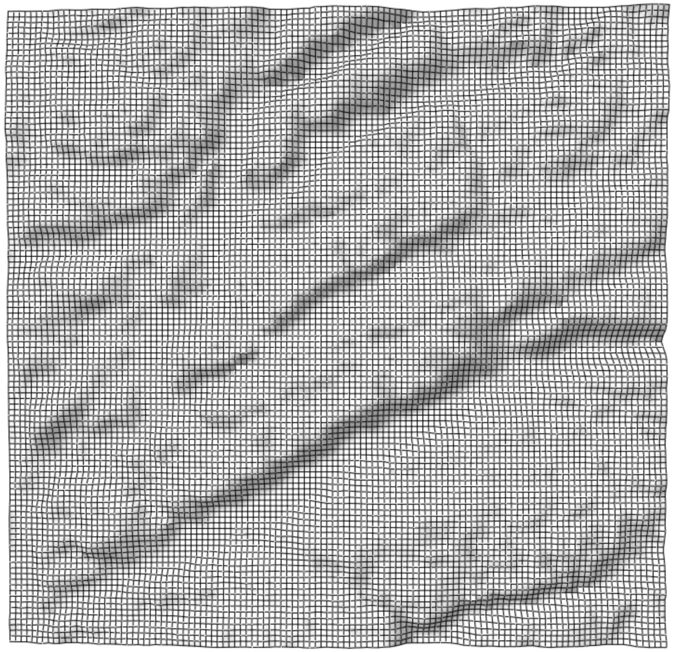
16 wind farms has been built in the Southern Norway (2023)

Models of the Norwegian Wind Atlas

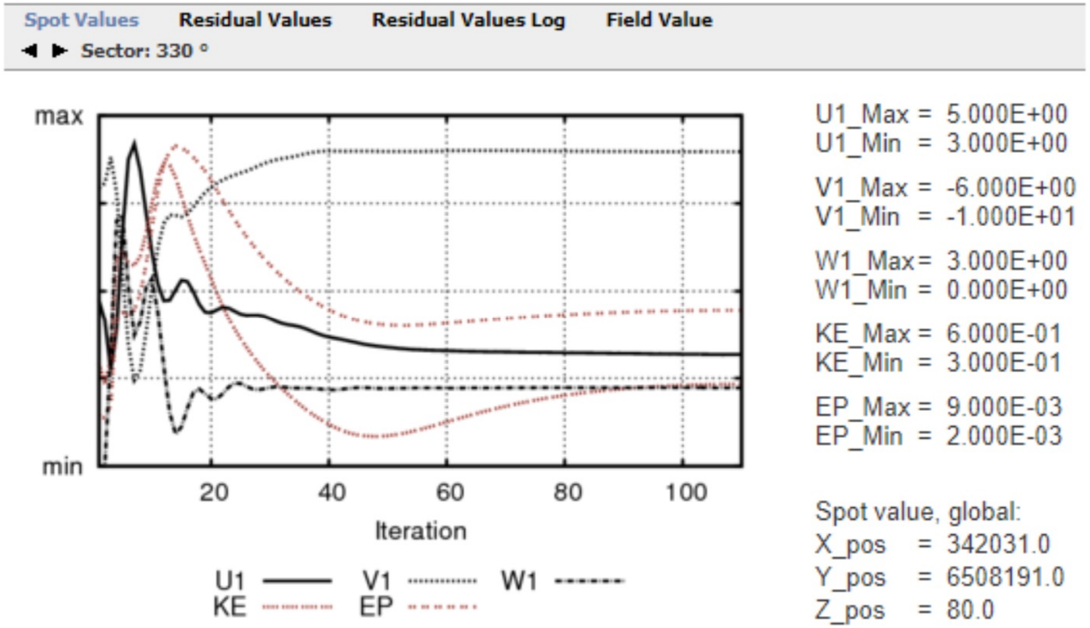


WindSim model 20x20 km extension. It is not overlapping with a NWA model, it is further inland, as extraction of models with areas over open sea proved to have no elevation coverage

Simulation time for the "old" NWA setup is today 6 minutes



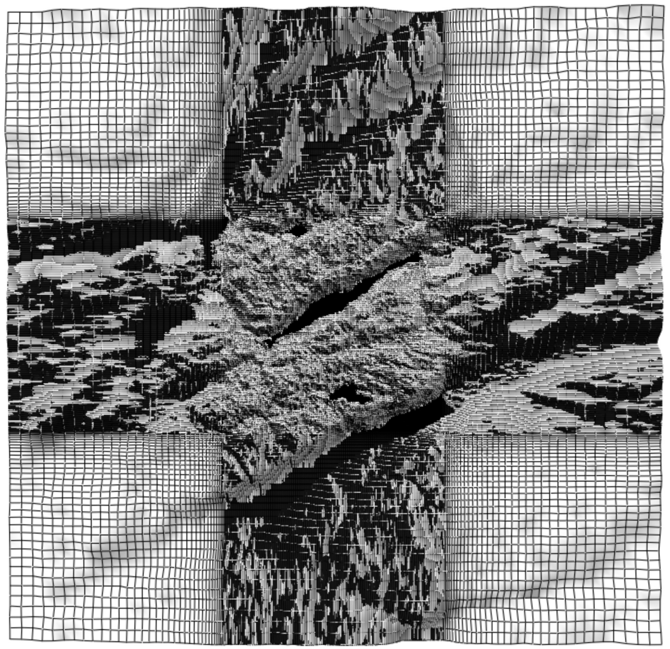
Model extension 20x20 km, resolution 200x200 meters, model size 0.25 M cells (20 vertical cells)



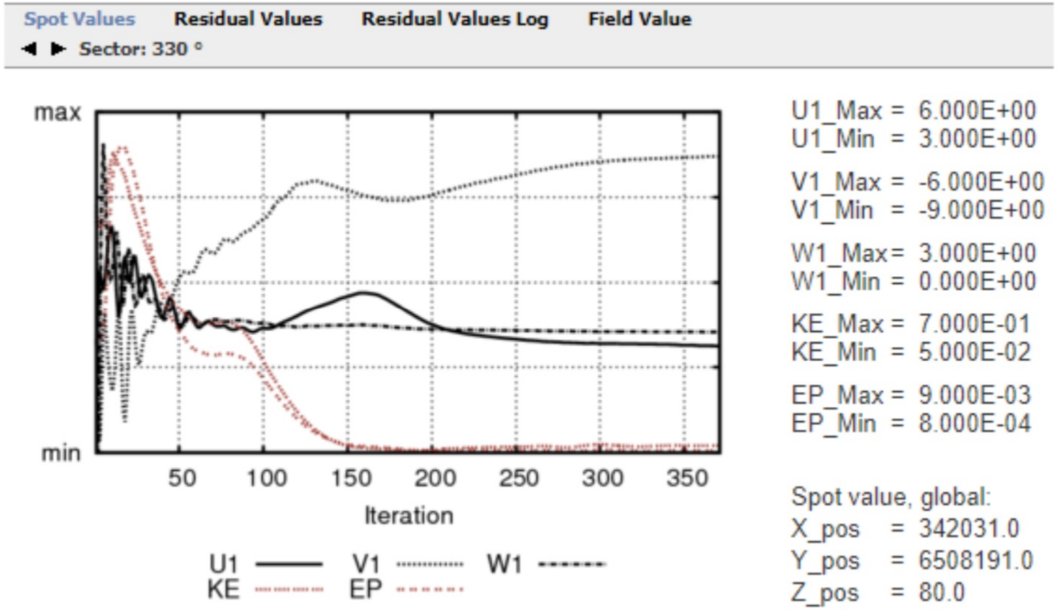
*Convergence monitoring with spot values, convergence reached after 110 iterations taking **6 minutes** (convergence criteria = 0.005)*

- Rerunning NWA today on WindSim Accelerator would not impose any challenge with respect to simulation time
- Launching large amounts of projects would be easily managed by the new Accelerator API, it should take 6 minutes

From 0.25 to 5.0 million cells



Model extension 20x20 km, resolution in refinement area 20x20 meters, model size 5.0 M cells (30 vertical cells)

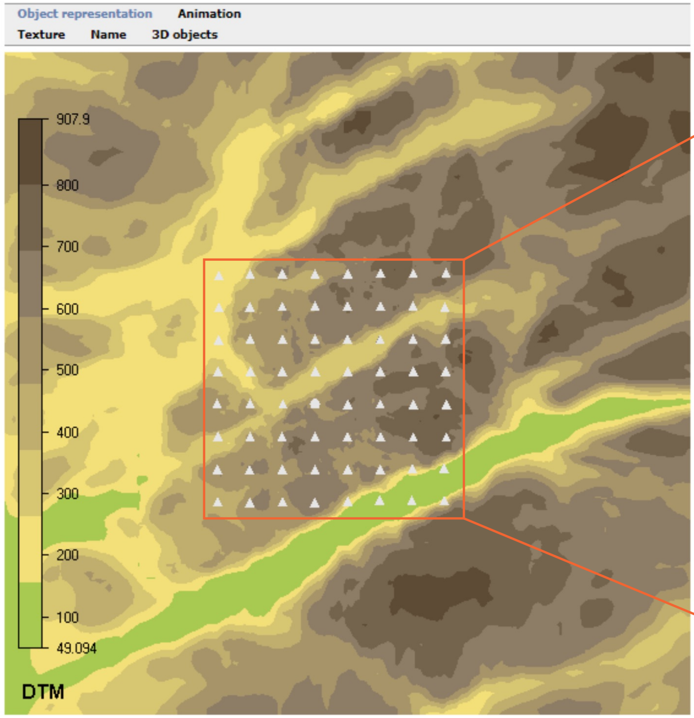


Convergence monitoring with spot values, convergence reached after 366 iterations taking 6:33 hours (convergence criteria = 0.005)

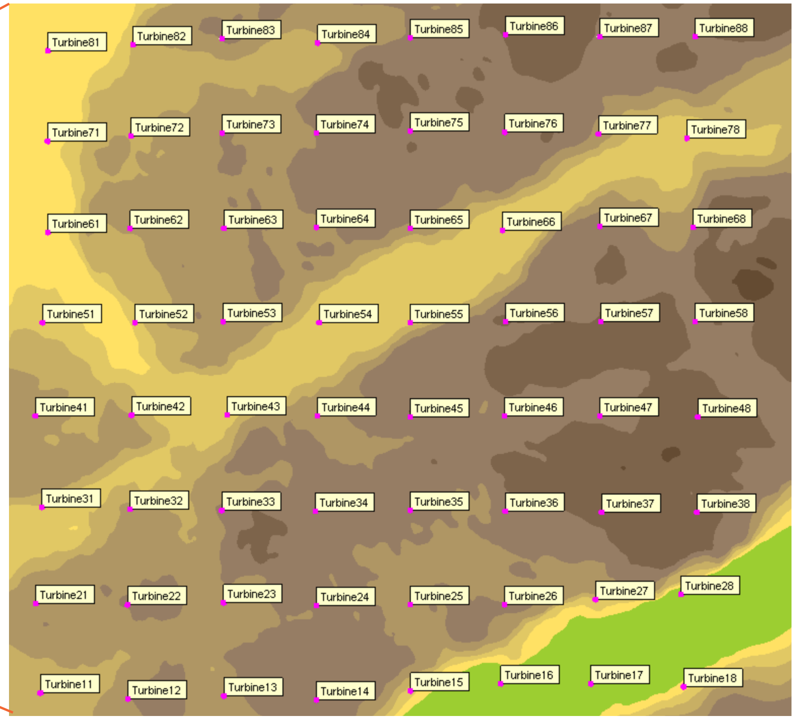
- Simulations done with GCV solver takes 6.33 hours (not parallel GCV)

Parametric study – improvements of elevation and roughness

- Determine the AEP variability within an array of 8x8 turbines when changing elevation and roughness data



Turbine type "NREL_Reference_4MW", hub height 120 meters, horizontal spacing 1 km both directions



Name syntax

Parametric study – Simple climatology

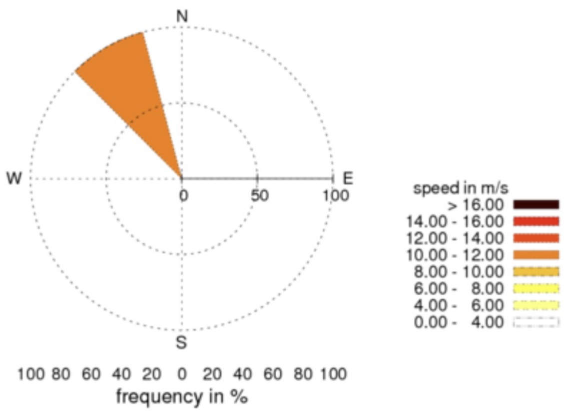
- Specify the wind climate at 3000 meters height, since there is no influence from the ground at this height, the AEP is only determined by the set boundary conditions, which is almost equal for all cases (except possibly for the case with a forest)

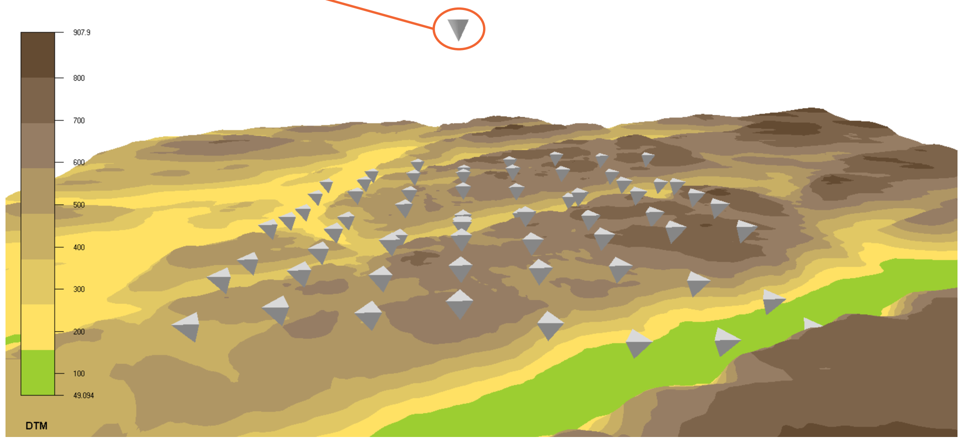
site name	Dummy_330deg_3000m_95ms		
filename	330deg_3000m_105ms		
measurement period	00.00.00 - 00.00.00		# records = -
position	x = 341036.8	y = 6507557.5	z (agl) = 3000.0
Weibull param., average speed	k = 10.33	A = 10.88	average = 10.50

Table 1. Climatology characteristics, including Weibull (k,A) and average wind speed (m/s) of all sectors.

Frequency distribution

◄ ► **Sector: all Sectors**





Simplified wind climate with average wind speed of 10.5 m/s at 3000 meters height in the center of the model

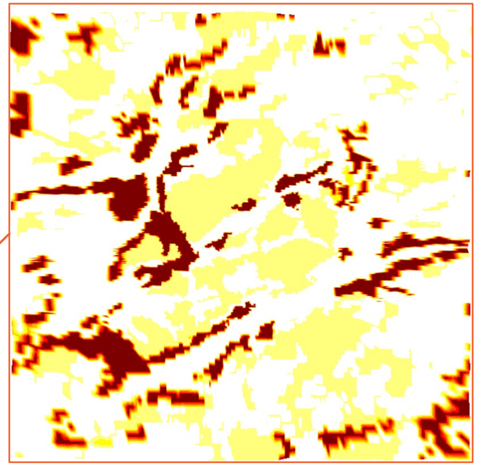
Parametric study – 4 cases

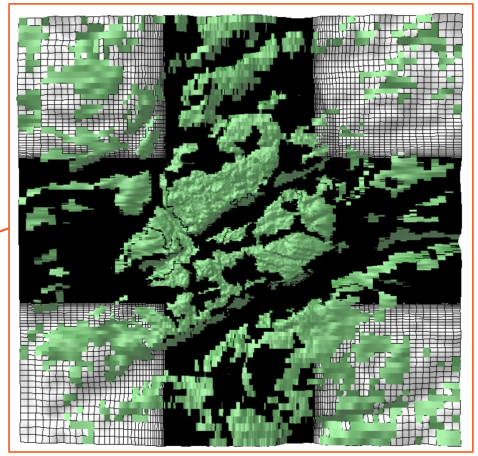
Case: 0.25M – var z0
Model size: 0.25 Million cells
Model resolution: 200x200 meters
Roughness z0: Variable (CORINE)

Case: 5.0M – const z0
Model size: 5.0 Million cells
Model resolution: 20x20 meters in refinement area
Roughness z0: Const = 0.03

Case: 5.0M – var z0
Model size: 5.0 Million cells
Model resolution: 20x20 meters in refinement area
Roughness z0: Variable (CORINE)

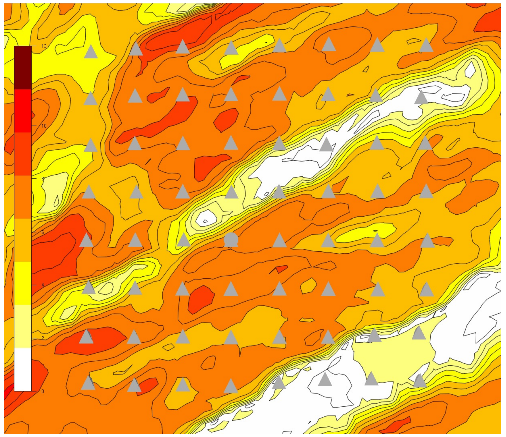
Case: 5.0M – forest
Model size: 5.0 Million cells
Model resolution: 20x20 meters in refinement area
Roughness z0: Forest (2 types 15 and 30 meters heigh)



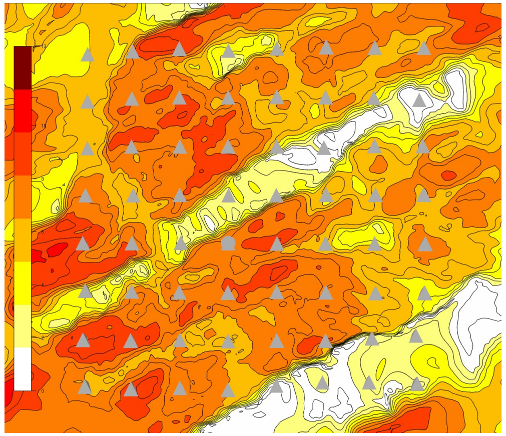


Parametric study – Wind resources

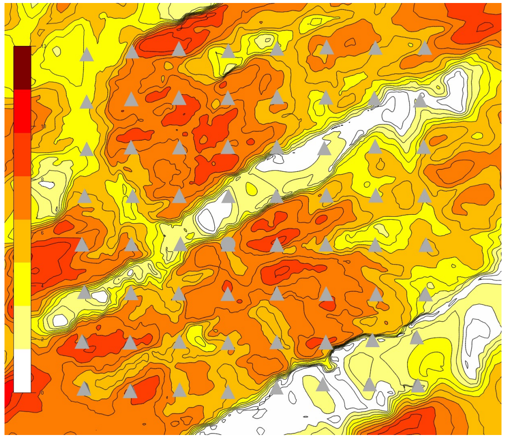
- Wind resources within the refinement area at hub height, 120 meters
- All plots scaled with same legend <0,13> (m/s)



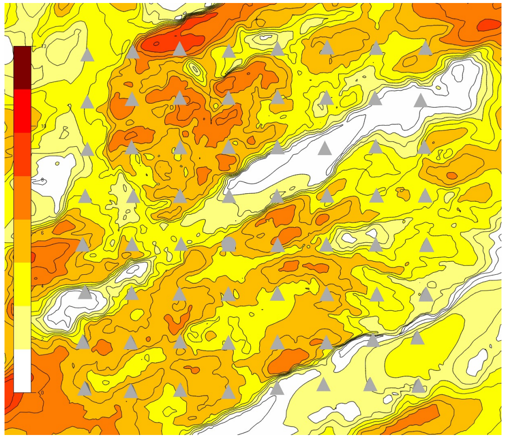
0.25M – var z0



5.0M – const z0



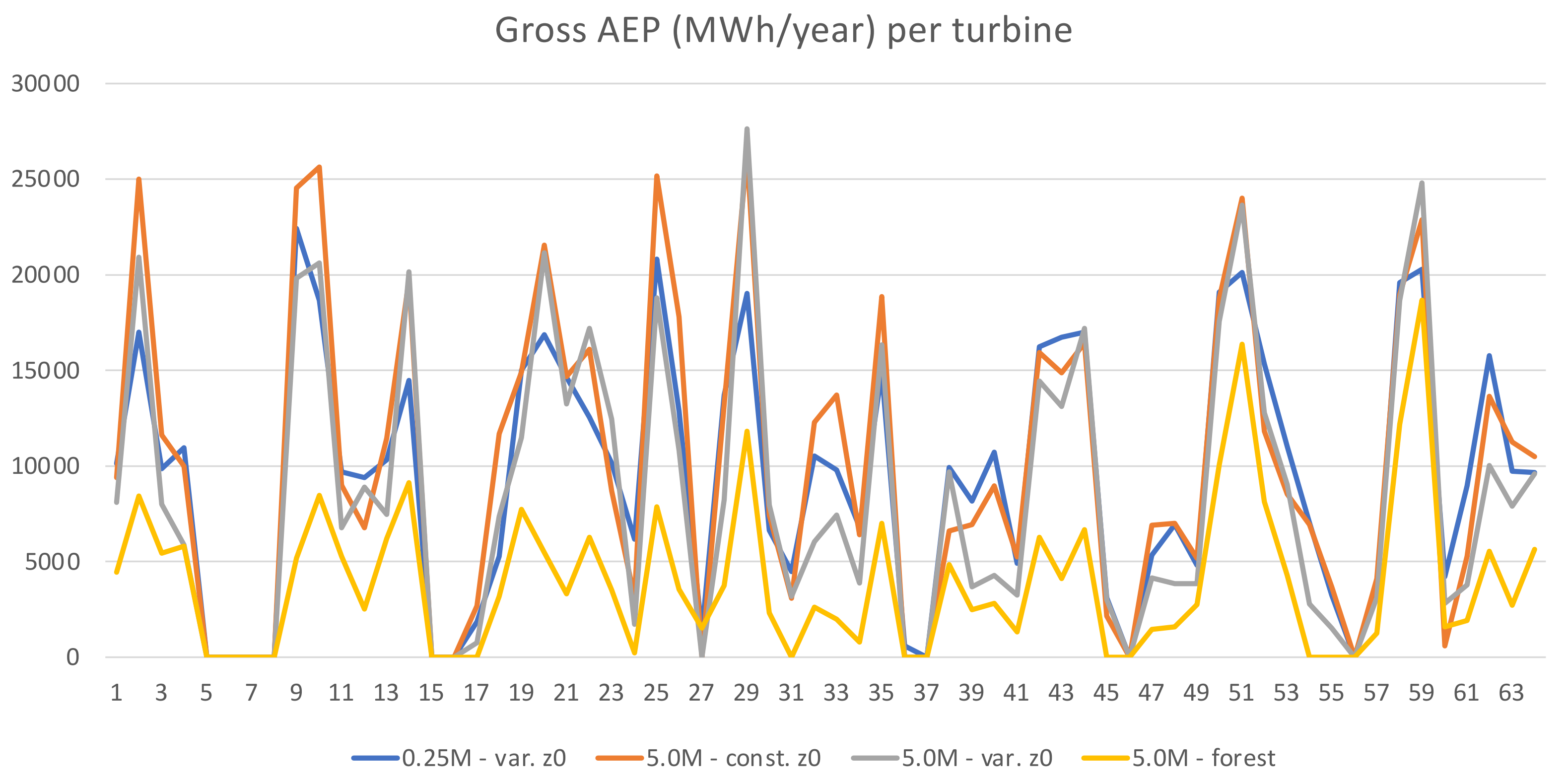
5.0M – var z0



5.0M – forest

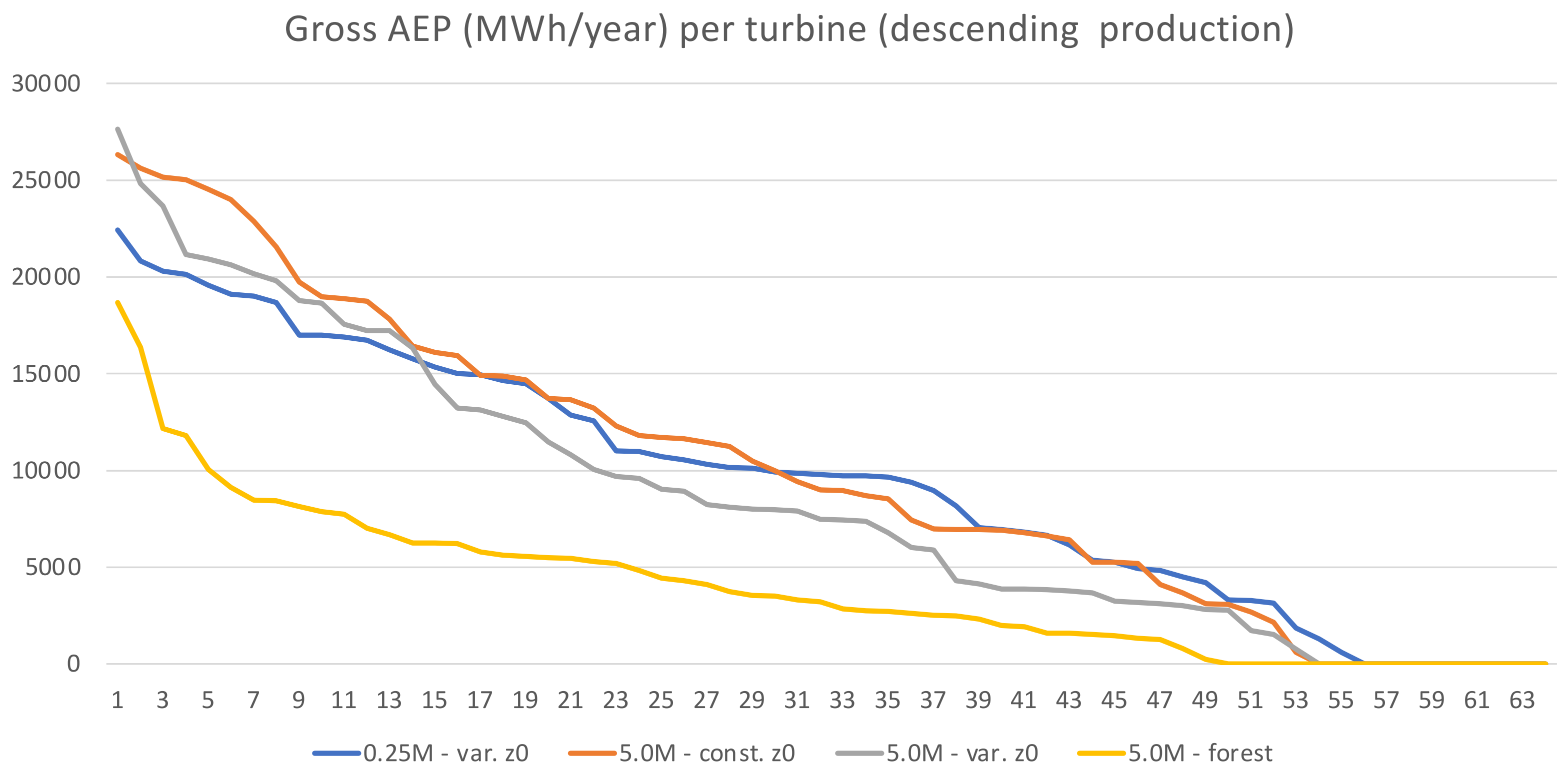
- The case with a forest shows lower wind resources. The forest is up to 30 meters high and typically increased hub height could have been used. Also, the inlet conditions changes reducing the wind speed at locations along the border where a forest is present

Parametric study – Gross AEP per turbine



wiΛdsim

Parametric study – Gross AEP per turbine – Descending production



- Higher resolution datasets display larger variability, that is higher maximum values and lower minimum values, allowing for an improved layout optimization