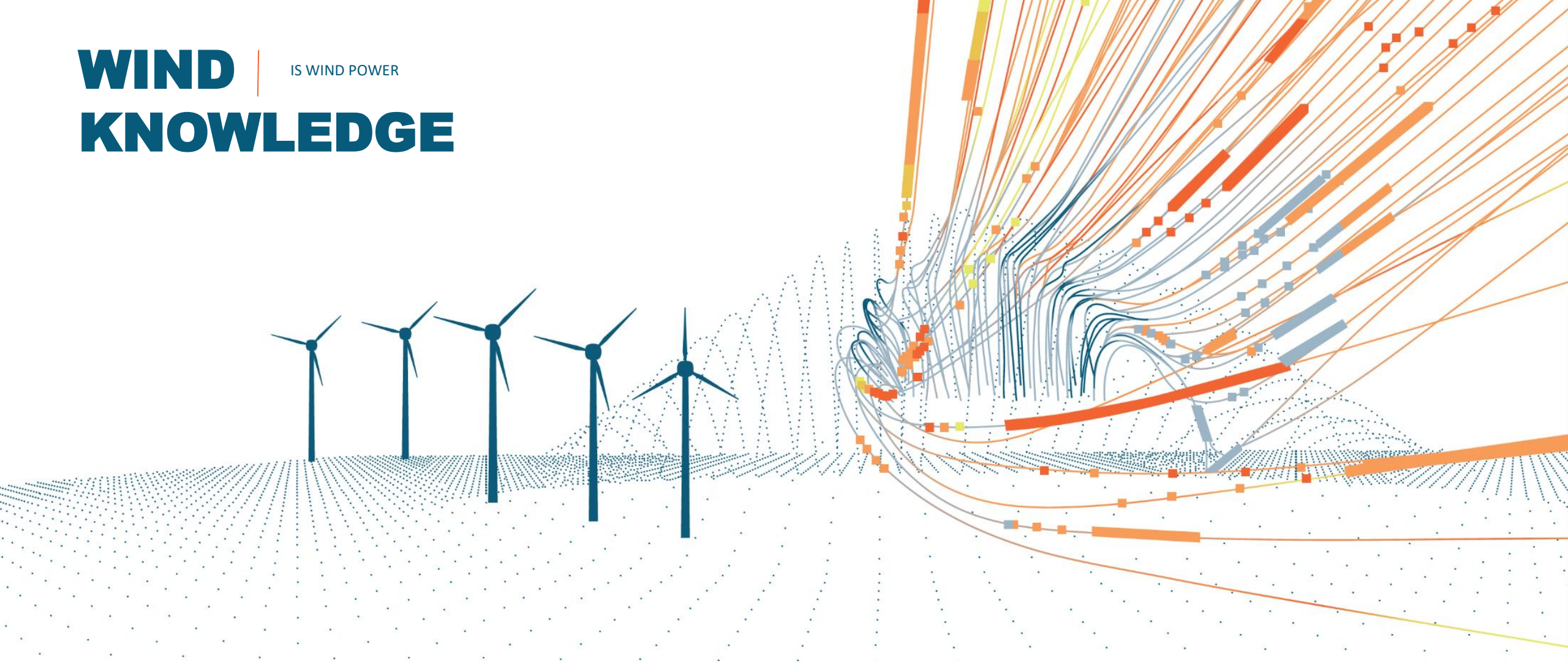
WIND KNOWLEDGE | IS WIND POWER



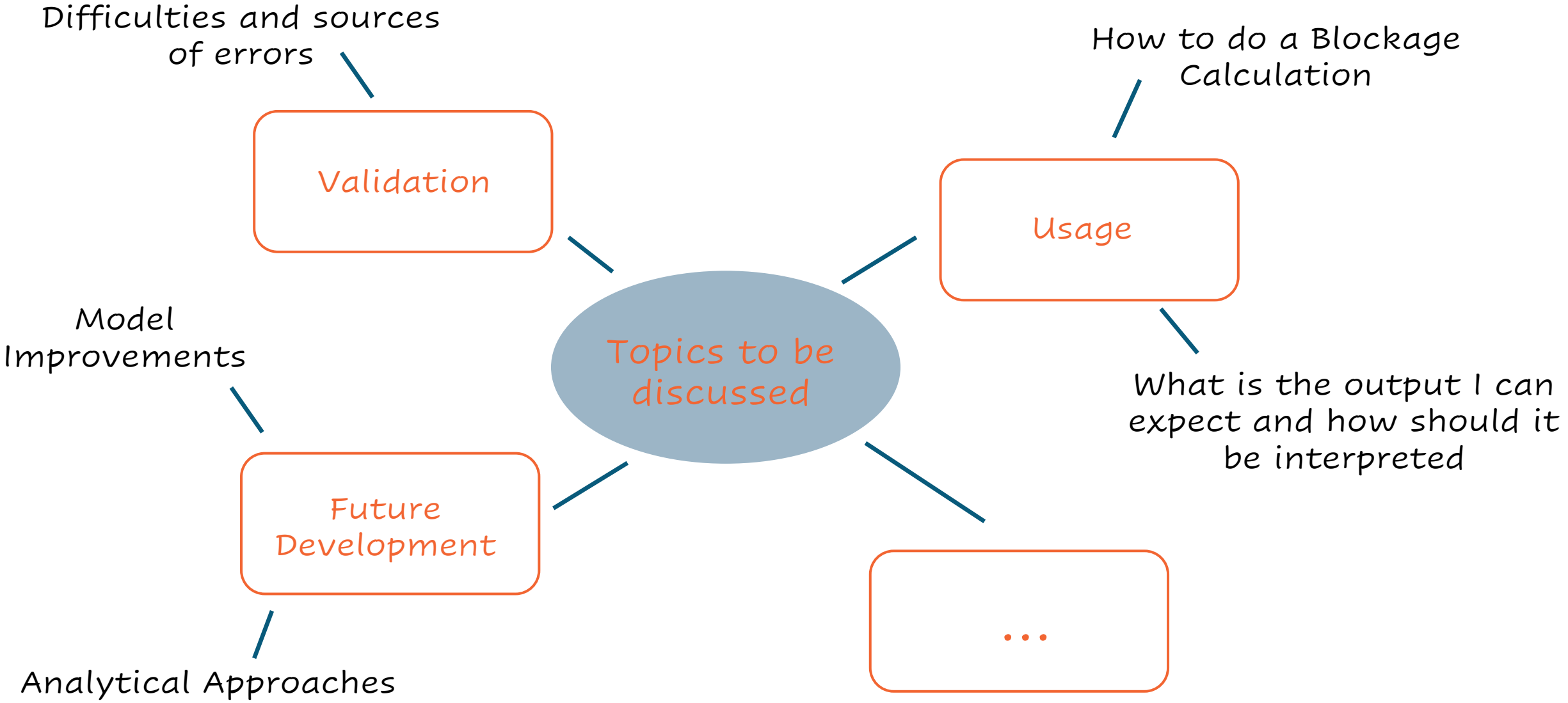
Workshop: AD and Blockage Effect Module

15. User Meeting – 23rd of June 2021

windsim

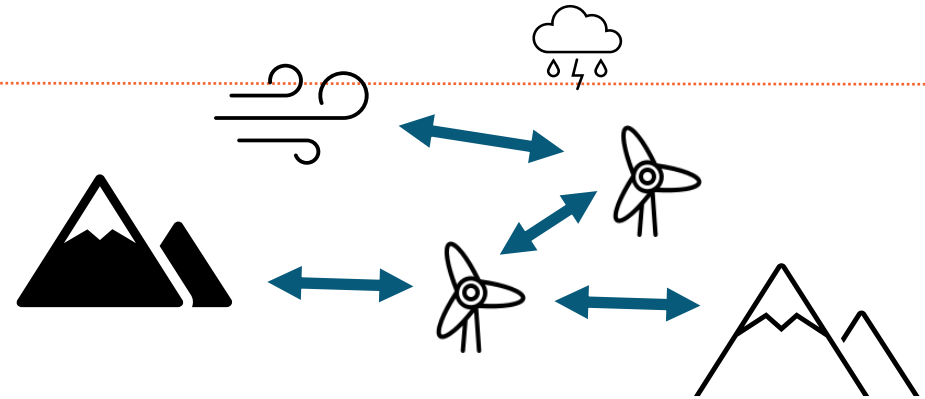
PRESENTED BY: Katja Kleeberg

Workshop: AD and Blockage Effect Module



Motivation

Aim: include turbine interactions and consider them in the wind resource assessment procedure to predict more realistic AEP‘s for a wind farm



1. Model the Turbines in the Windfield → AD Approach
2. Couple CFD Results with Measurements → couple AD results with free stream results & calculations for two different wind speed levels
3. Make an AEP prediction including turbine interactions and find a measure for the bias of a wakes-only approach

Annual Energy Production AEP

Energy production has been calculated for the following climatologies:

Climatology	Distribution	AEP with wake losses	Wake loss %	Wake loss including blockage effect %	Wake loss calculated by actuator disc %
demo	Frequency table	59.2853	3.13	4.29	4.51
demo	Weibull distribution	60.3994	3.19	4.38	4.69

Table 1. Energy production in GWh/y based on climatology represented as frequency table, Weibull distribution and time series (time series are calculated only if power history and IEC classification are active, note that missing values in the time series are treated as 0 speed values in the production calculation).

Output of the Blockage calculation

Analytical wake model

Semi-analytical model

Pure AD Model

I. IN-/OUTPUT

Setup

- **Goal:** include the Blockage Effect into the WindSim procedure and find a measure for the bias of a wakes-only approach

  → on the level of Wind Resources and Energy module in WindSim

- How can the *Blockage Effect* calculation be initialized*?*
- → by the presence of blockage_effect.log in the log folder of the Layout

- Run four projects
  1. Default WindSim project with high wind speed
  2. Default WindSim project with low wind speed
  3. Actuator Disc WindSim project with high wind speed
  4. Actuator Disc WindSim project with low wind speed

blockage_effect.log - Editor

Datei Bearbeiten Format Ansicht Hilfe

```
YourPath\WindSim Projects\BlockageExample\Free_high\
YourPath\WindSim Projects\BlockageExample\Free_low\
YourPath\WindSim Projects\BlockageExample\AD_high\
YourPath\WindSim Projects\BlockageExample\AD_low\
```

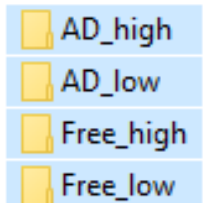
Setup

Terrain

- Example Blockage project with 6x6 turbines in flat terrain
- Create 1 AD and 1 default project
- projects have to be based on the same grid

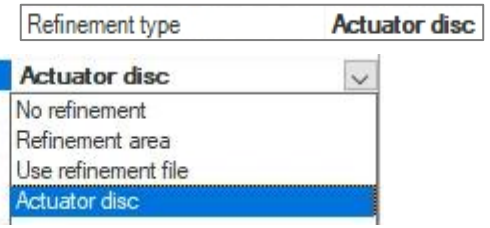
  → Use a refinement file in the default projects

- Make a copy of each project for high and low wind speed case

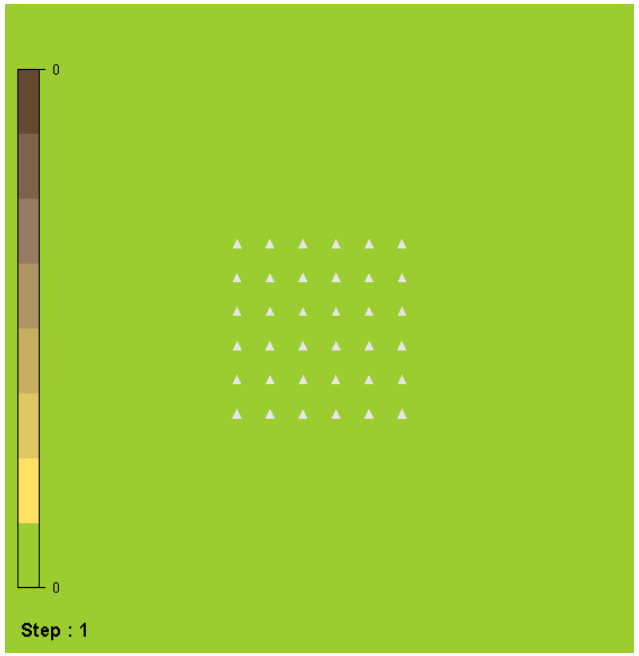


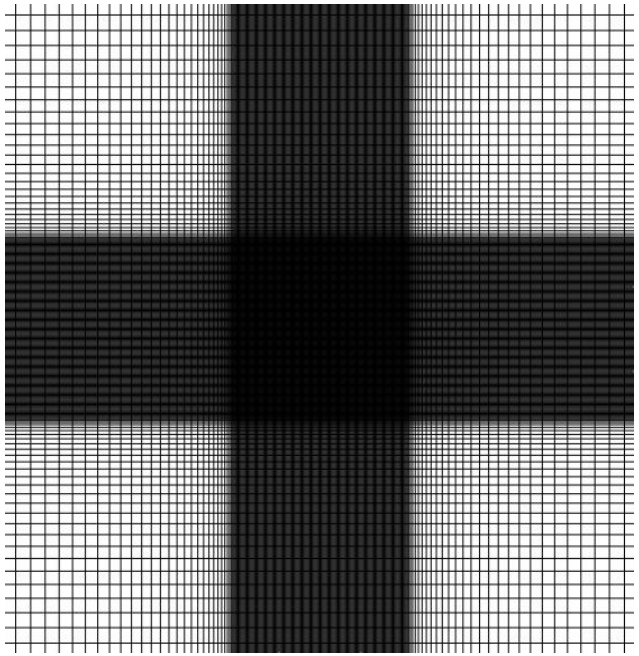
Free Model

AD Model



Turbines.ows → *dtm\actuator_discs.bws*





Setup

Wind Fields

- Run both cases for a representative high and low wind speed above boundary layer

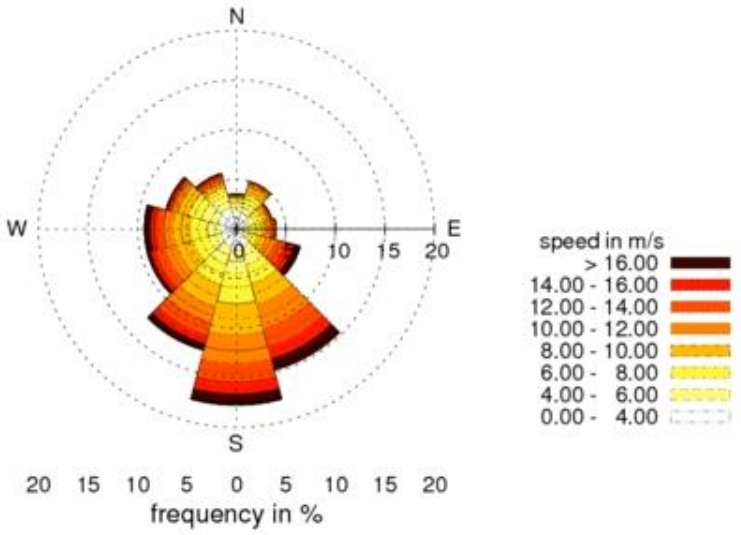
  → approx.17 and 6m/s at hub height level

- Choose a default project (without AD) as working project
- Choose or create a Layout in which the Blockage Effect calculation should take place

Input to the Wind Fields module

Height of boundary layer	500
Speed above boundary layer height	7

Height of boundary layer	500
Speed above boundary layer height	20

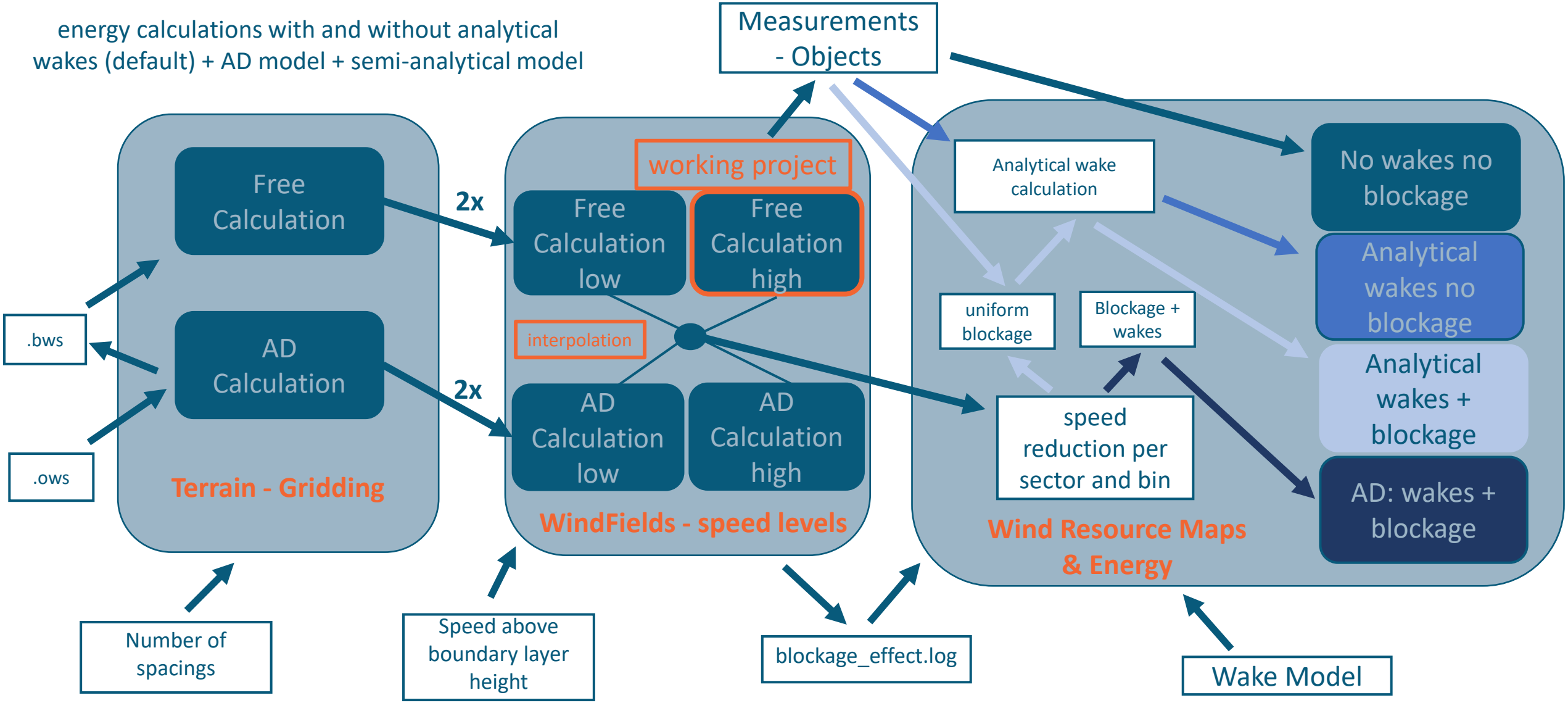


Objects

- Include the turbines (.ows) and the climatology
- Run the Objects module

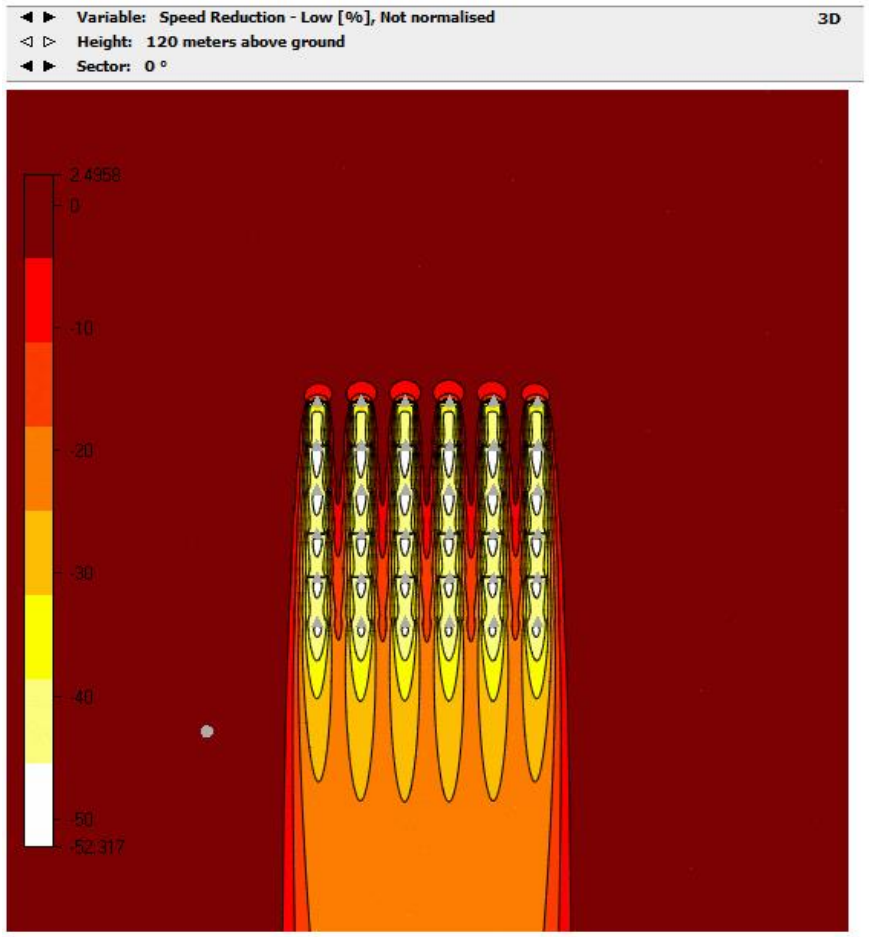
Workflow – AD & Blockage Effect Add On Module

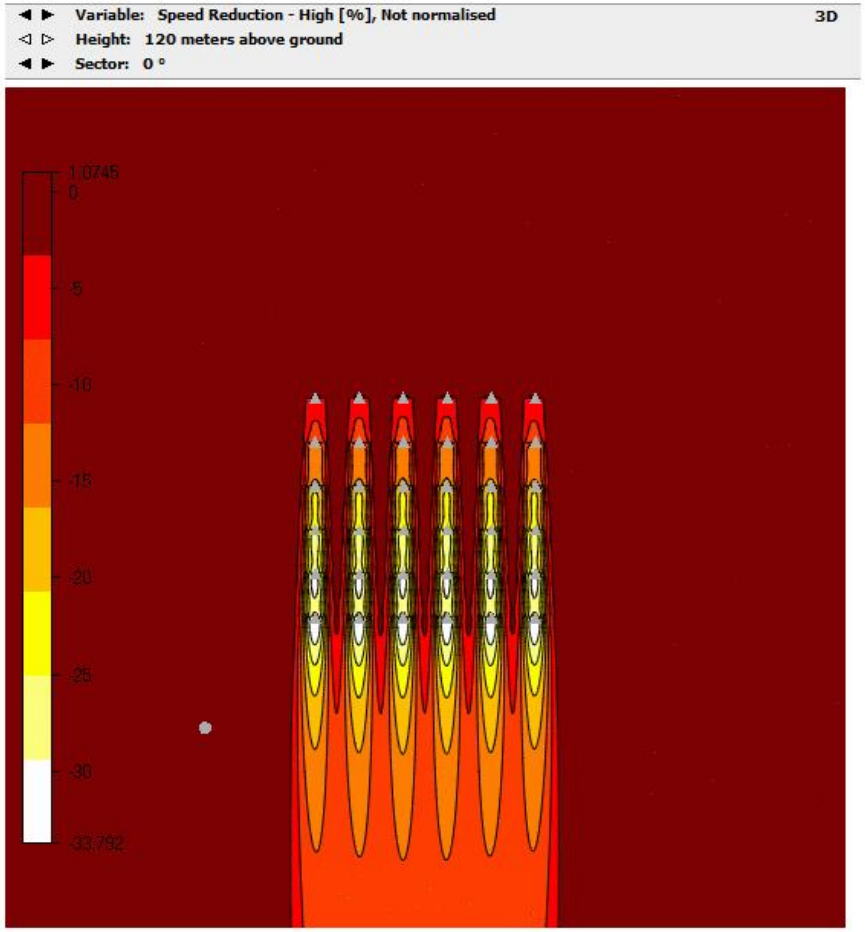
energy calculations with and without analytical wakes (default) + AD model + semi-analytical model



Output - Results

- By running the Results module WindSim will automatically visualize the percentual speed deficit due to the AD, for the high and low wind speed case

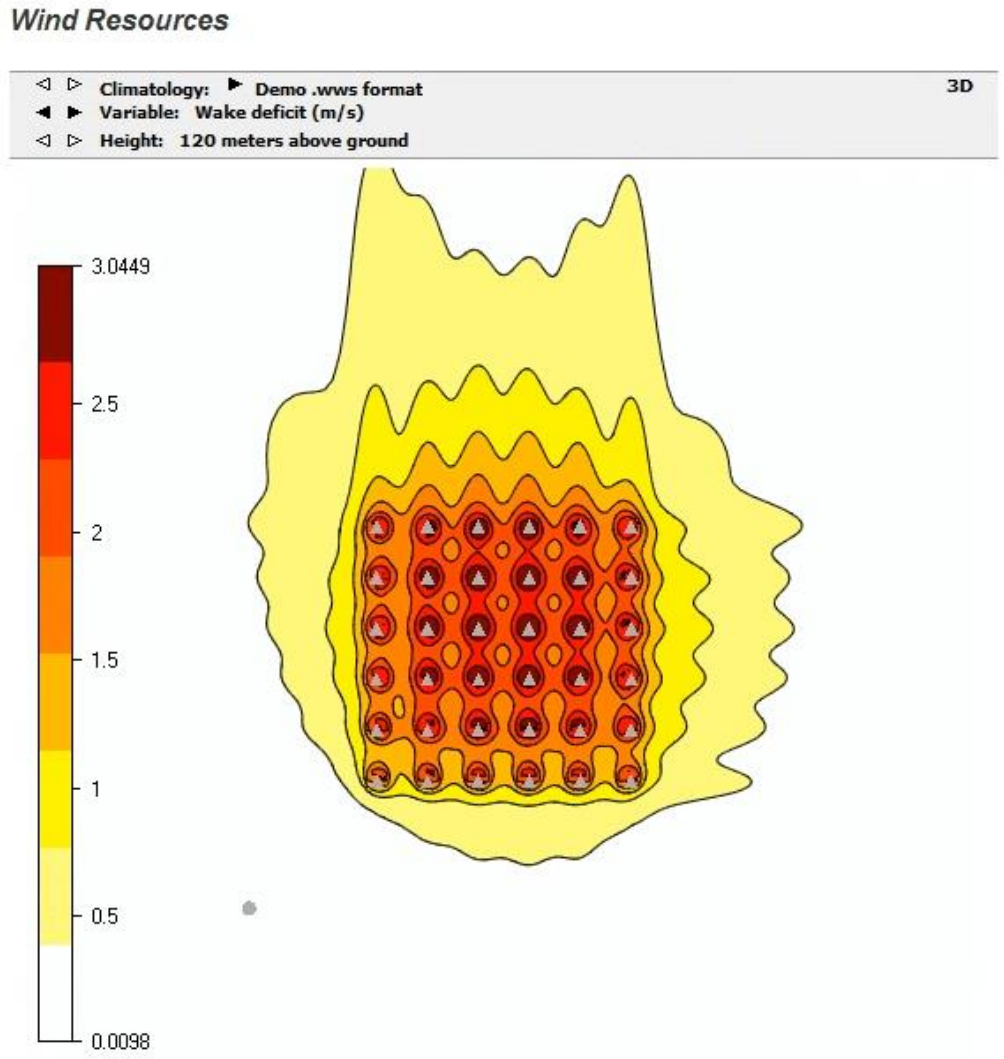




Output - Wind Resources

- The wake deficit is connected to Pure AD Model (A)
- Choose the analytical wake model for the semi-analytical model (B) separately in Wind Resources and Energy
- Compare the wake deficit from Model A with the same Layout where the blockage_effect.log is not present

  → to see the wind resource map predicted with the analytical wake model



Output

Energy

- Automatically three AEP's are calculated

Wake Loss %

→ analytical wake model with all speed reduction factors equal to 1

Wake Loss including blockage effect %

→ analytical wake model with blockage effect, Semi-analytical Model (B)

→ compare with **Wake Loss %** to measure the blockage

Wake Loss calculated by actuator disc %

→ wake and blockage from AD, Pure AD Model (A)

Annual Energy Production AEP

Energy production has been calculated for the following climatologies:

Climatology	Distribution	AEP with wake losses	Wake loss %	Wake loss including blockage effect %	Wake loss calculated by actuator disc %
demo	Frequency table	**266.2861**	22.80	24.76	22.90
demo	Weibull distribution	**269.1340**	23.24	25.24	23.46

Table 1. Energy production in GWh/y based on climatology represented as frequency table, Weibull distribution and time series (time series are calculated only if power history and IEC classification are active, note that missing values in the time series are treated as 0 speed values in the production calculation).

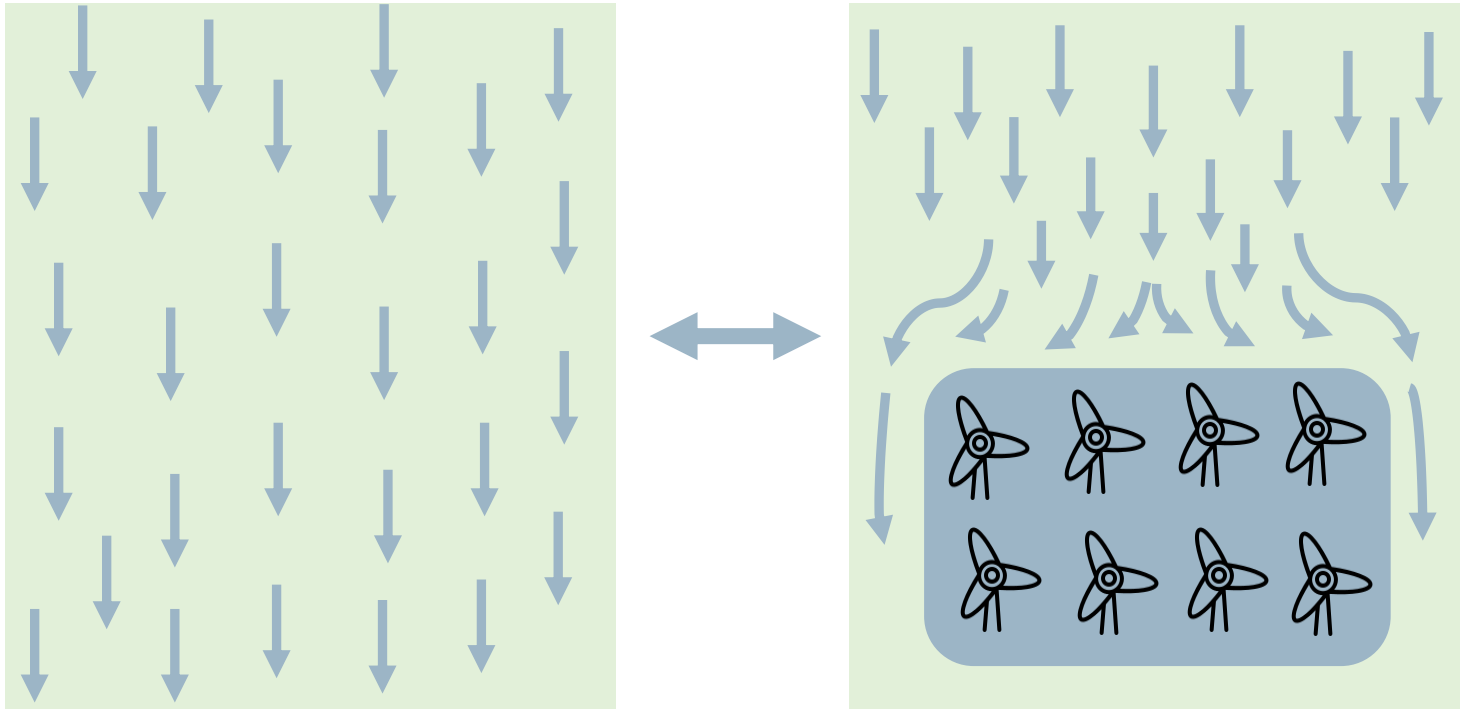
Air density (kg/m^3)	Wake model	Multi-wakes model	Roughness (m)	Amb. Turb. Int. (%)	Sub-sectors	Influence range (Rotor diameter)
No correction	3	2	-	Variable	30	1.0 - 50.0

Table 2. Site and wake characteristics.

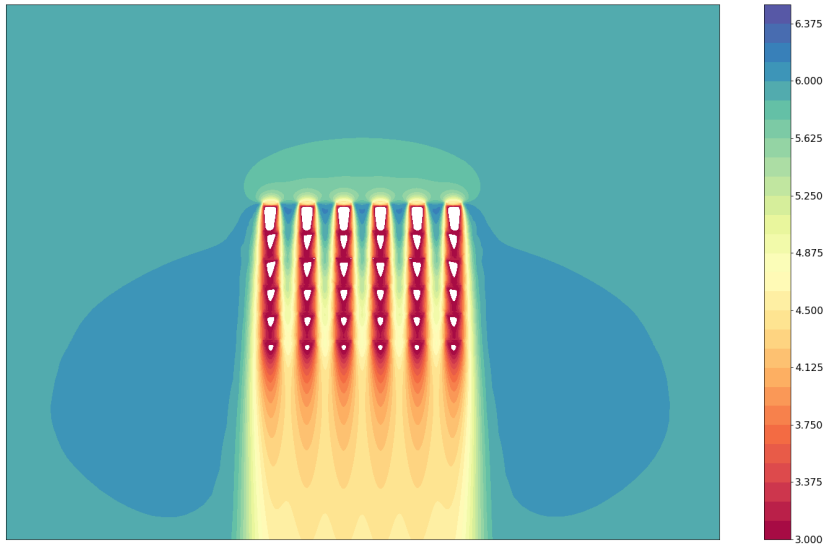
II. VALIDATION

Blockage Effect

- Validation follow the procedure of Bleeg et al. (2018, DNV GL)
- Compare the situation before and after the erection of a windfarm
- Aim: investigate the wind farm-wind field interaction



CFD visualization



Idea and Requirements

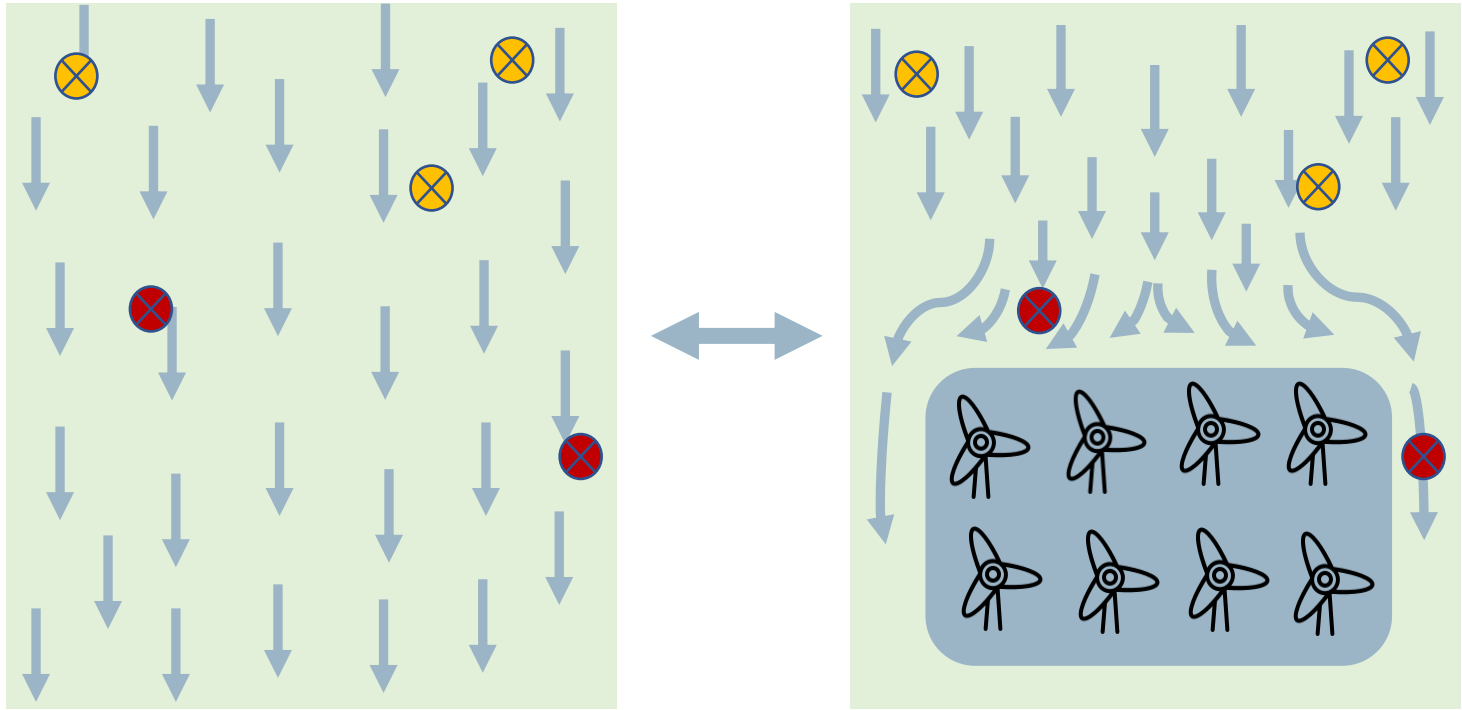
Minimal requirements:

1. One mast upstream (prevailing wind direction) → affected by blockage P
2. One mast farther away or lateral to the wind farm → reference mast R
3. Concurrent measurement period before and after COD

$$\Delta U_{P,R} = \frac{\left(\overline{U_P}/\overline{U_R}\right)_{after} - \left(\overline{U_P}/\overline{U_R}\right)_{before}}{\left(\overline{U_P}/\overline{U_R}\right)_{before}}$$

→ Change in speed up

(mean over wind speed time series)



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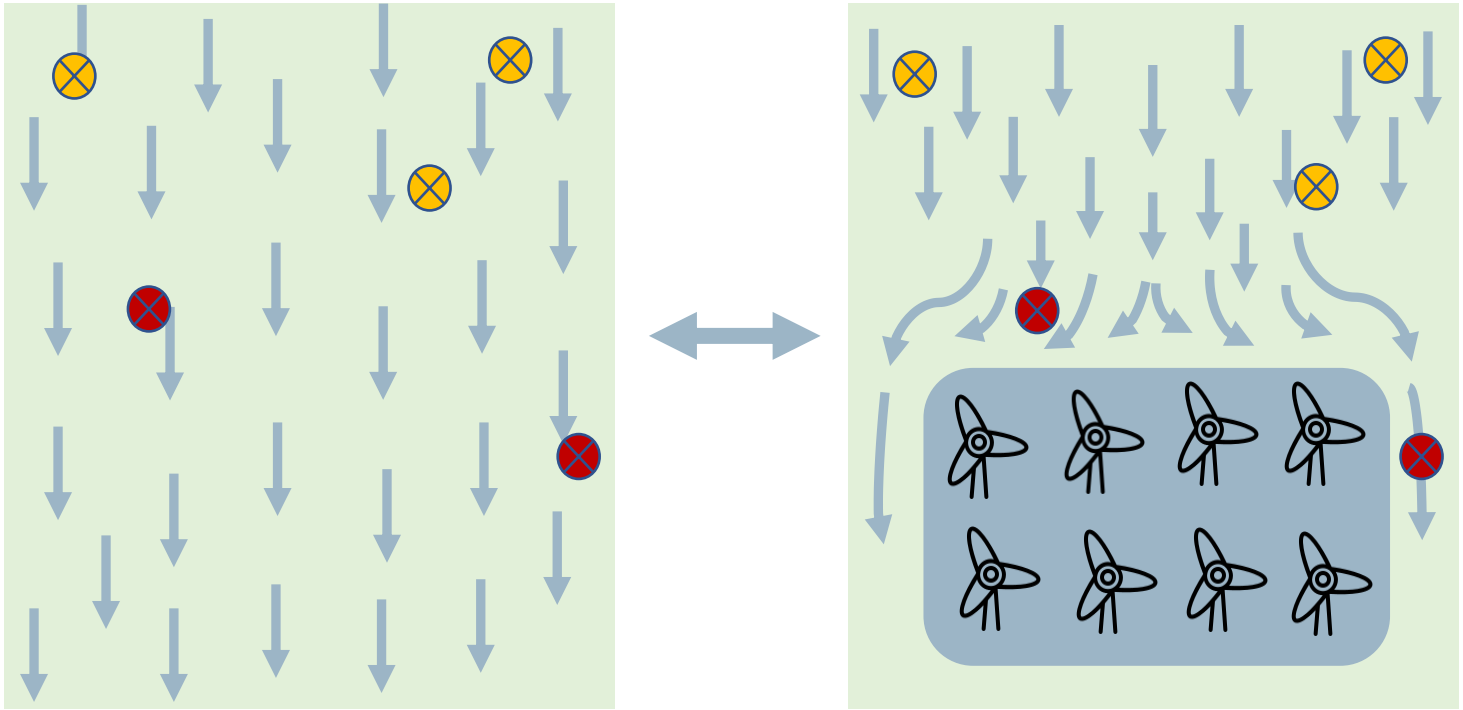

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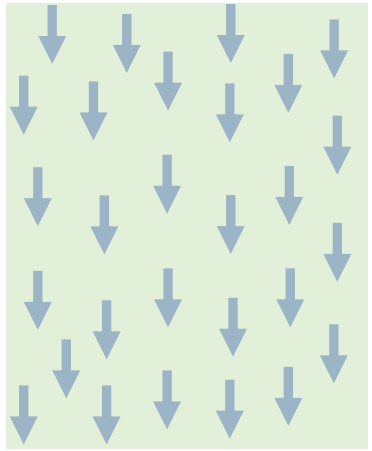
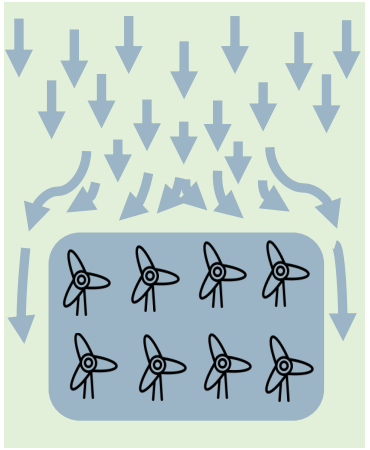


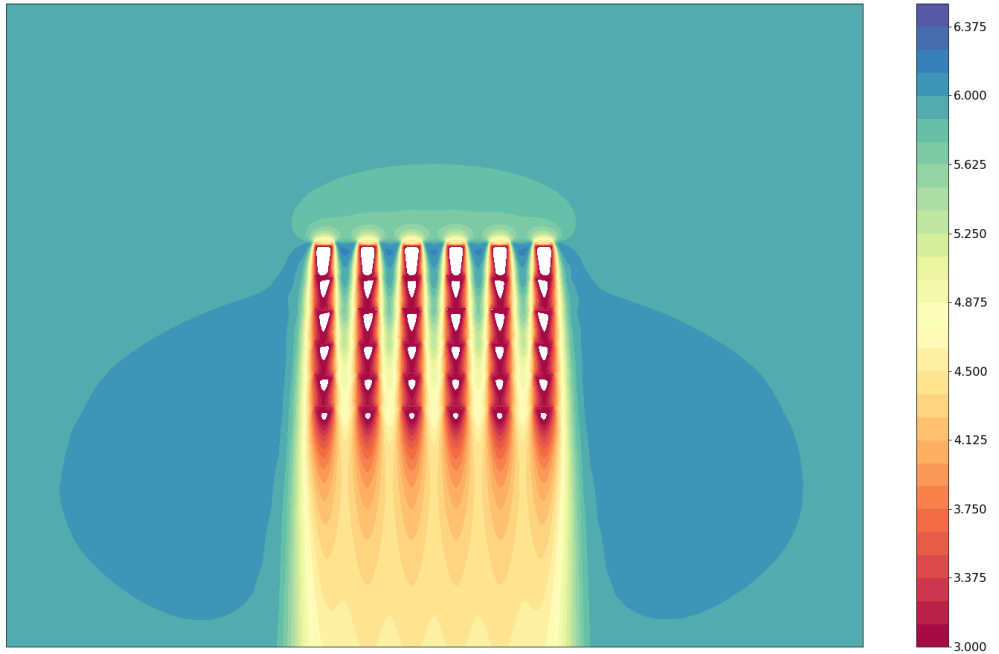
Representing the same situation in CFD simulations

(example for flat terrain)

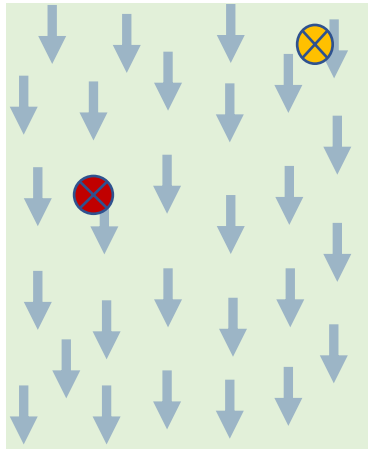


Default free CFD simulation

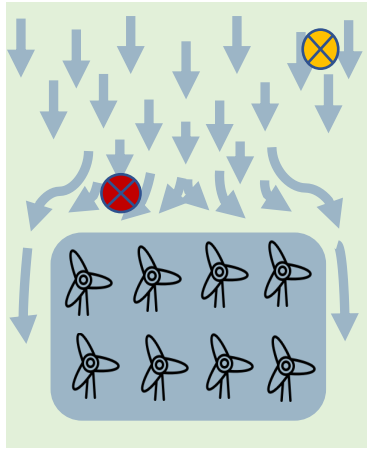
CFD simulation with actuator disc



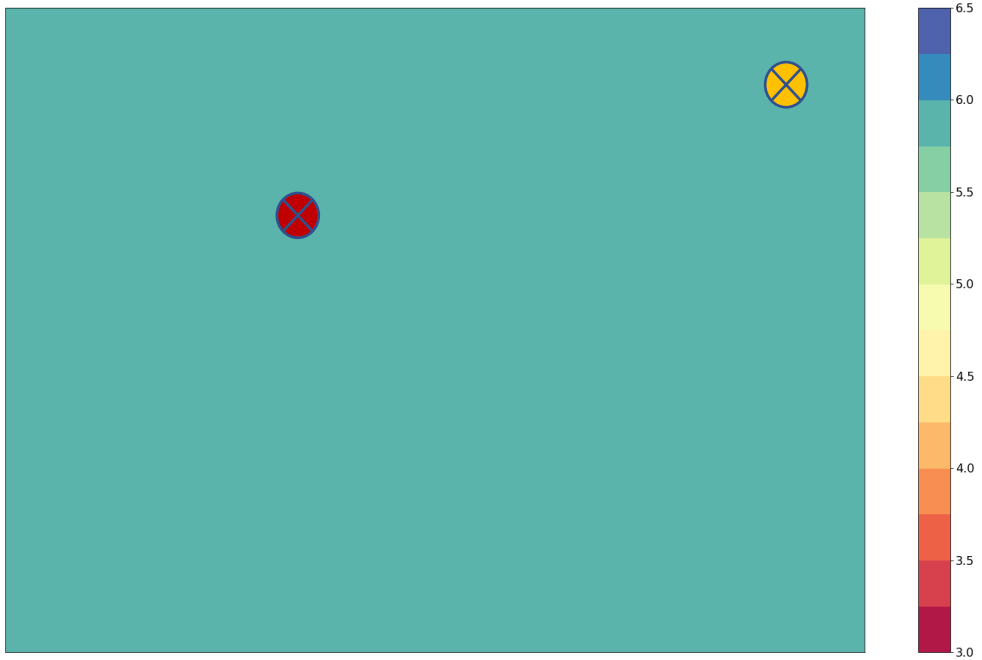
Idea and Requirements



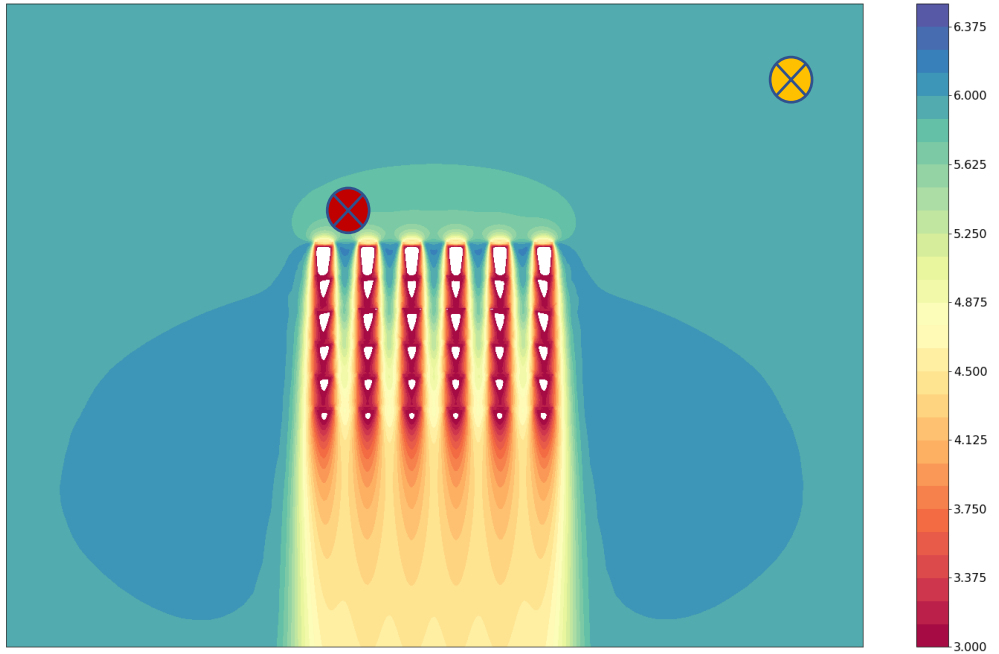
$$\Delta U_{P,R}^{CFD} = \frac{(U_P/U_R)_{AD} - (U_P/U_R)_{free}}{(U_P/U_R)_{free}}$$



Default free CFD simulation

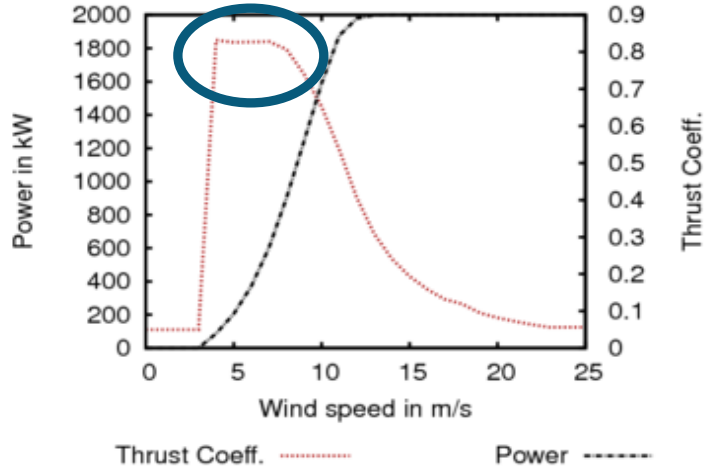


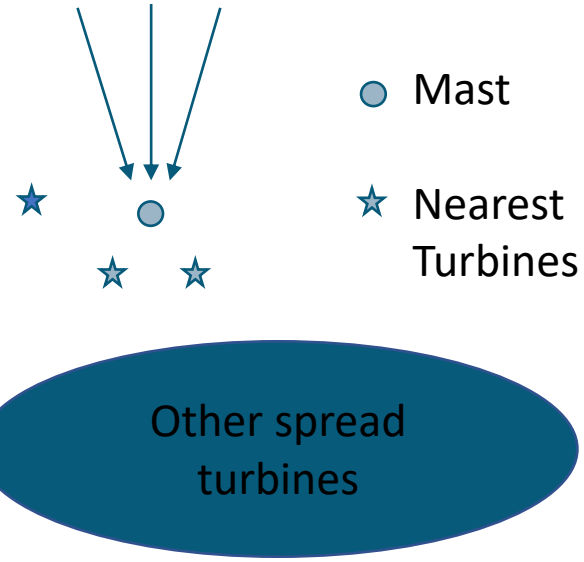
CFD simulation with actuator disc



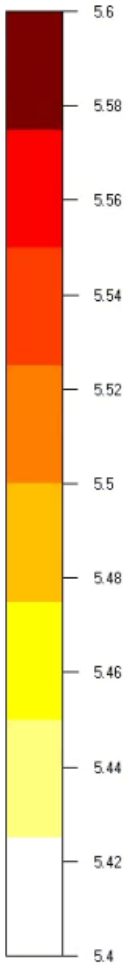
Validation - Data Quality

- **Speed level**: wind data are filtered for the speed in 5-9m/s
- **Concurrent measurement period**: 1 year of pre and post construction data
- **Wind data verification**: both Reference and Perimeter mast data have good quality.
- **Wind direction**: wind data are filtered for the direction of interest +-15 deg
- **Wind farm turbines**: 95% of the wind farm is up and running
- **Nearest turbines**: the nearest turbines to the Perimeter mast are up and running



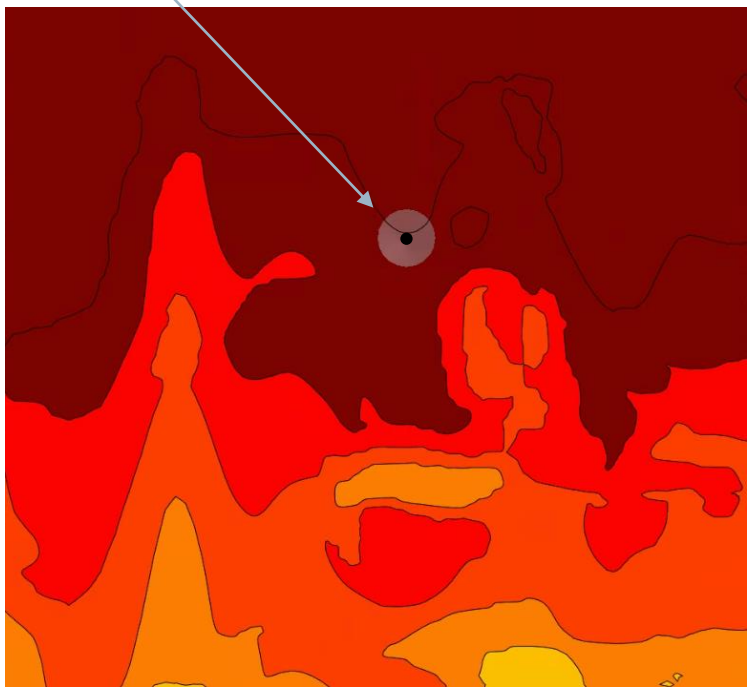


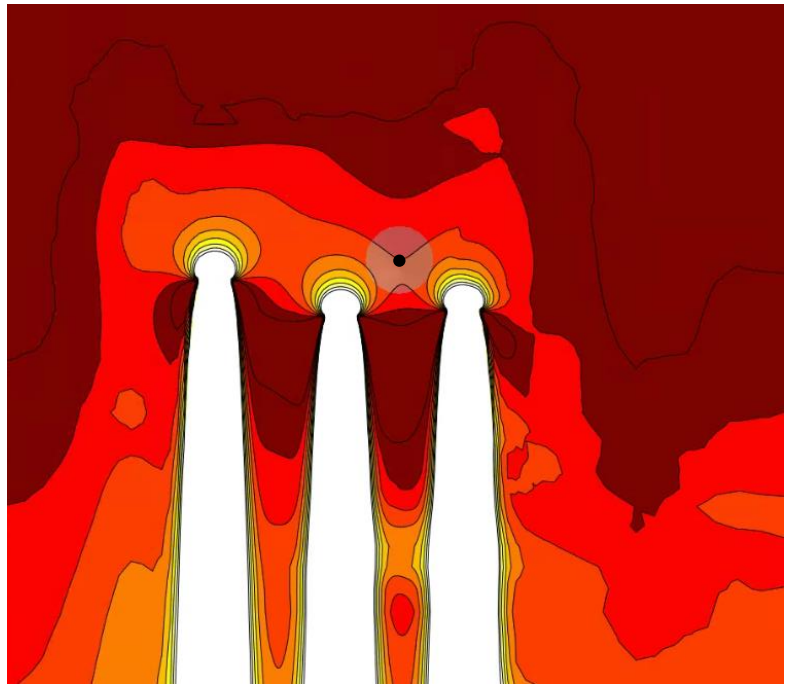
Validation Example



Hub height 2d wind speed

Climatology position

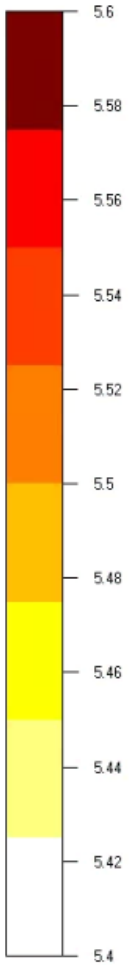




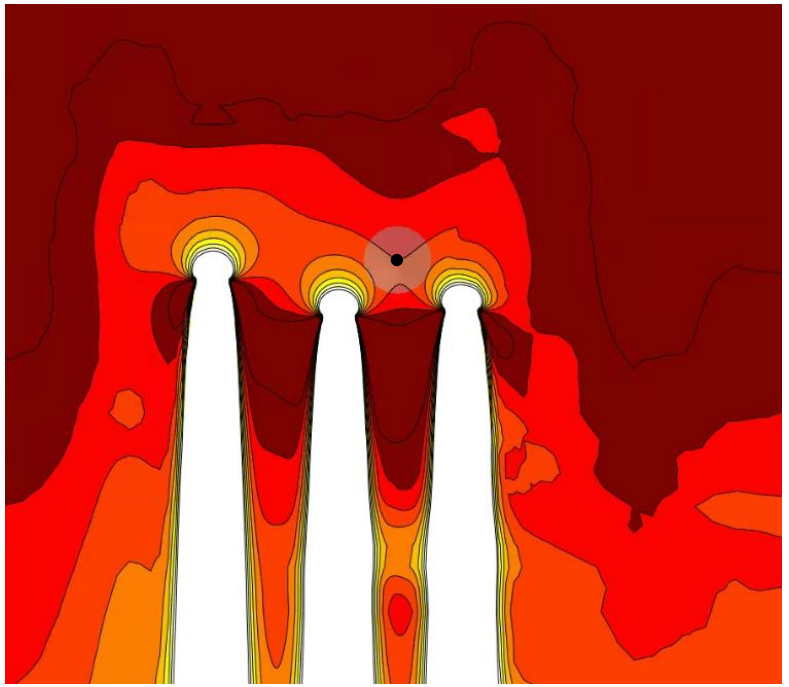
Empty model (Base)

3 Turbines (3t AD)

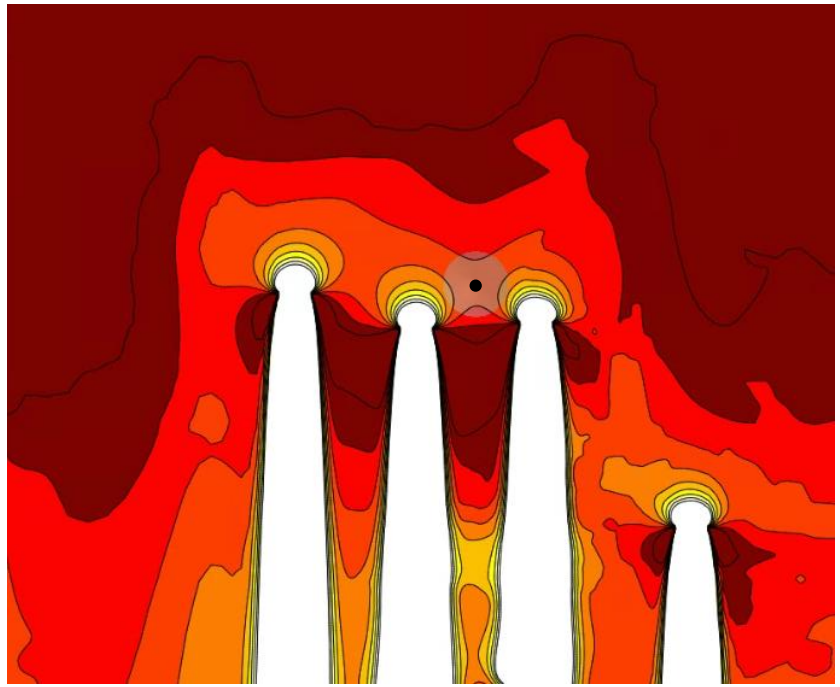
Validation Example



Hub height 2d wind speed

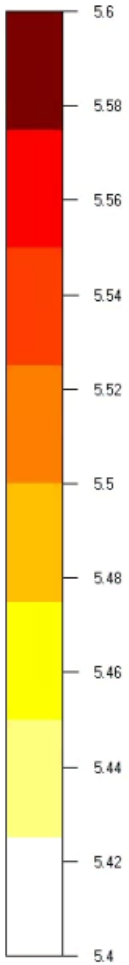


3 turbines (3t AD)

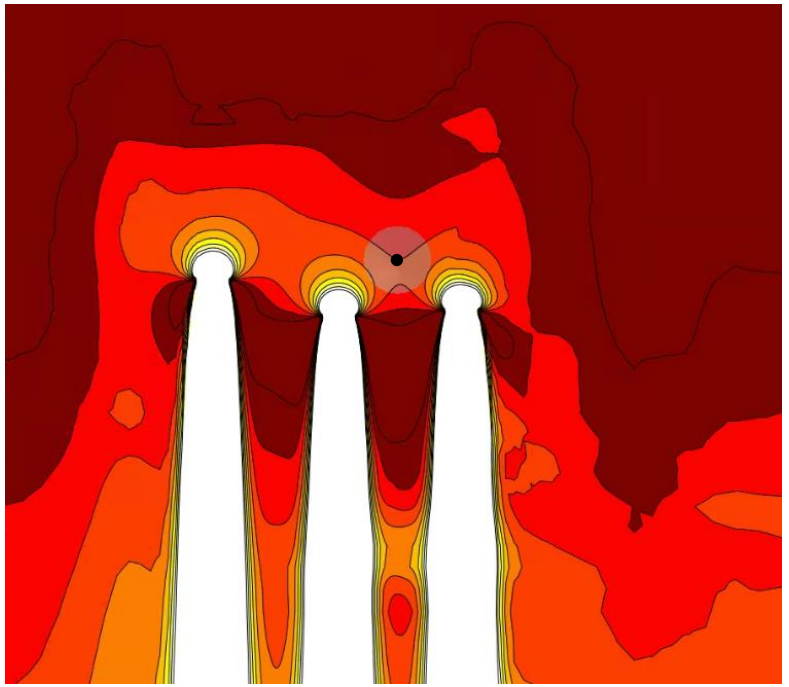


6 turbines (6t AD)

Validation Example



Hub height 2d wind speed



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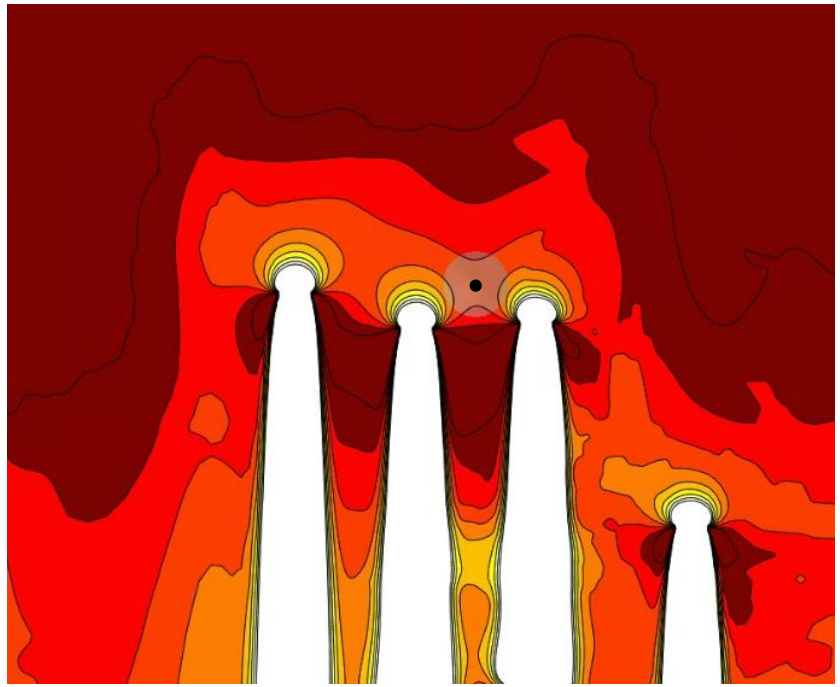
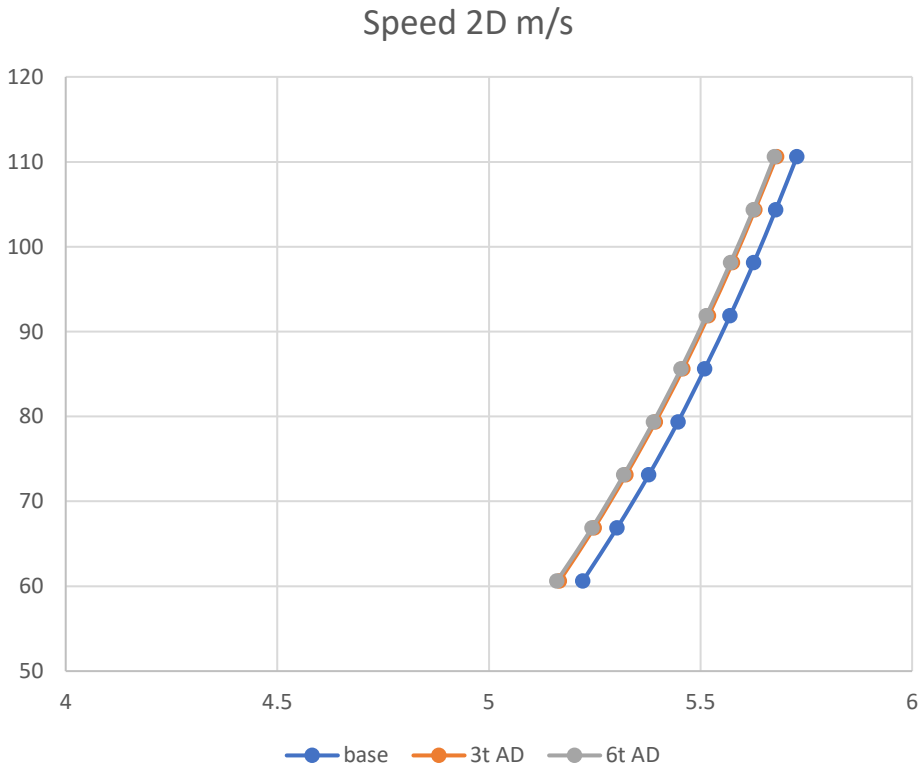


6 turbines (6t AD)

Validation Example



Vertical profile at the measurement point

Speed variation at climatology point

Modelled

3t AD: $\Delta U_{P,R}$= **-0.89%**
6t AD: $\Delta U_{P,R}$= **-0.98%**
19t AD: $\Delta U_{P,R}$= **-1.01%**

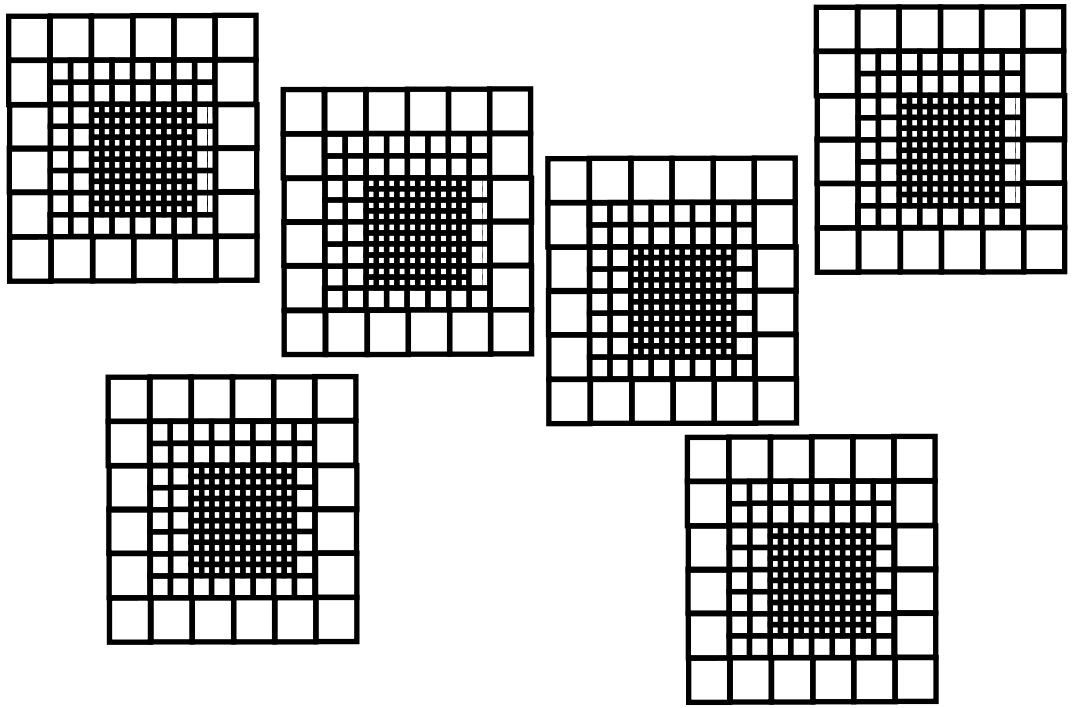
Observed $\Delta U_{P,R} = \frac{(\overline{U_P}/\overline{U_R})_{after} - (\overline{U_P}/\overline{U_R})_{before}}{(\overline{U_P}/\overline{U_R})_{before}}$ = **-0.76%**

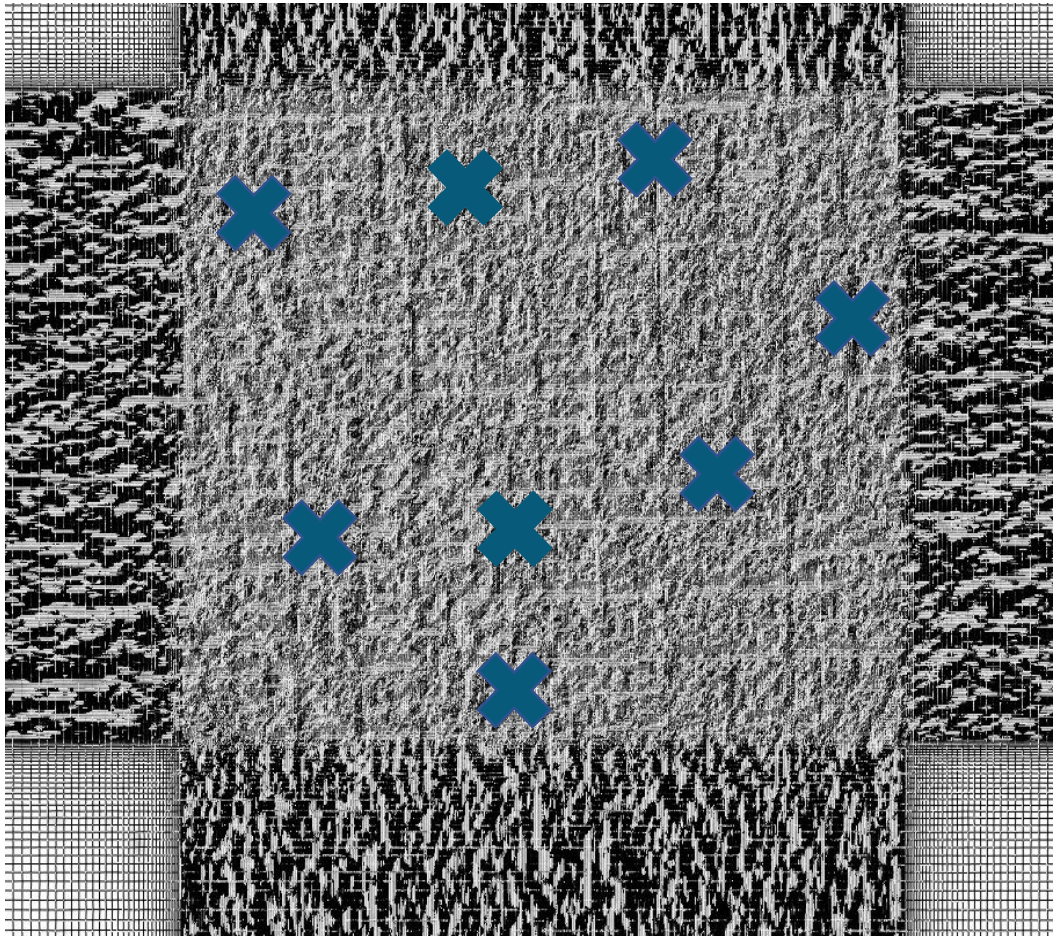
Difficulties

- Nearest turbines are the main source of blockage
  → Extracted blockage Effects below 1%
- Only two months of preconstruction data
- Bad statistics – only one data point

- huge grid sizes $\sim 100.000.000$ cells (50-60 turbines)
  → Simulation of large windfarms with the actuator disc requires new strategies

Gridding





→ **Unstructured grid**

→ **Cloud calculation**

→ **Parallelization with Multigrid Solver**

Thank you

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