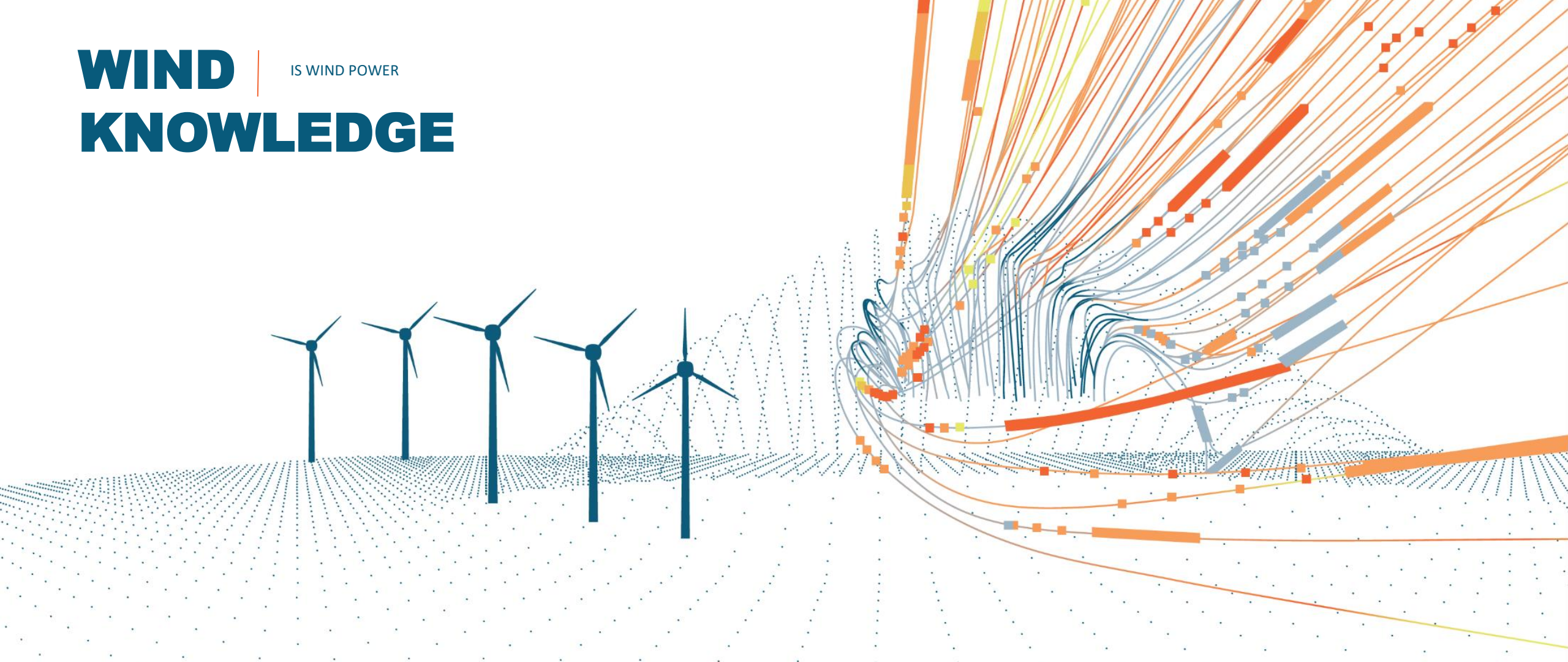


WIND KNOWLEDGE

IS WIND POWER



Actuator Disc and Blockage Effect Module

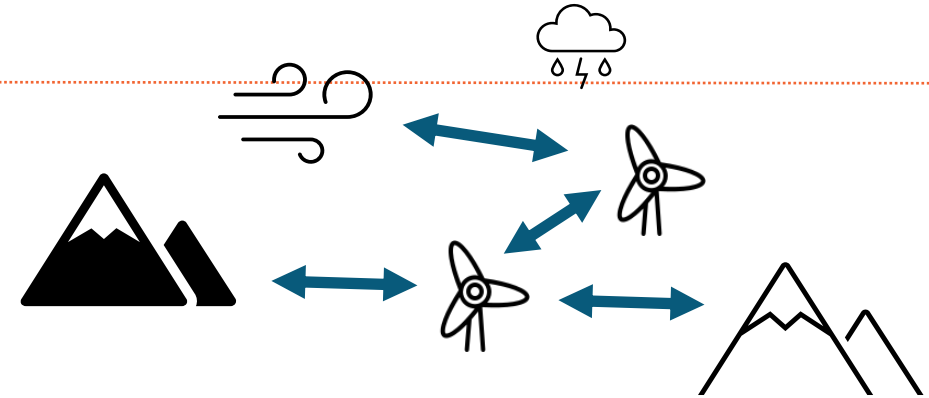
15. User Meeting – 23rd of June 2021

PRESENTED BY: Katja Kleeberg

windsim

Motivation

Goal: 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 %
Hundhammer_83m	Frequency table	124.4019	6.18	7.27	7.54
Hundhammer_83m	Weibull distribution	122.0361	6.49	7.59	7.79

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

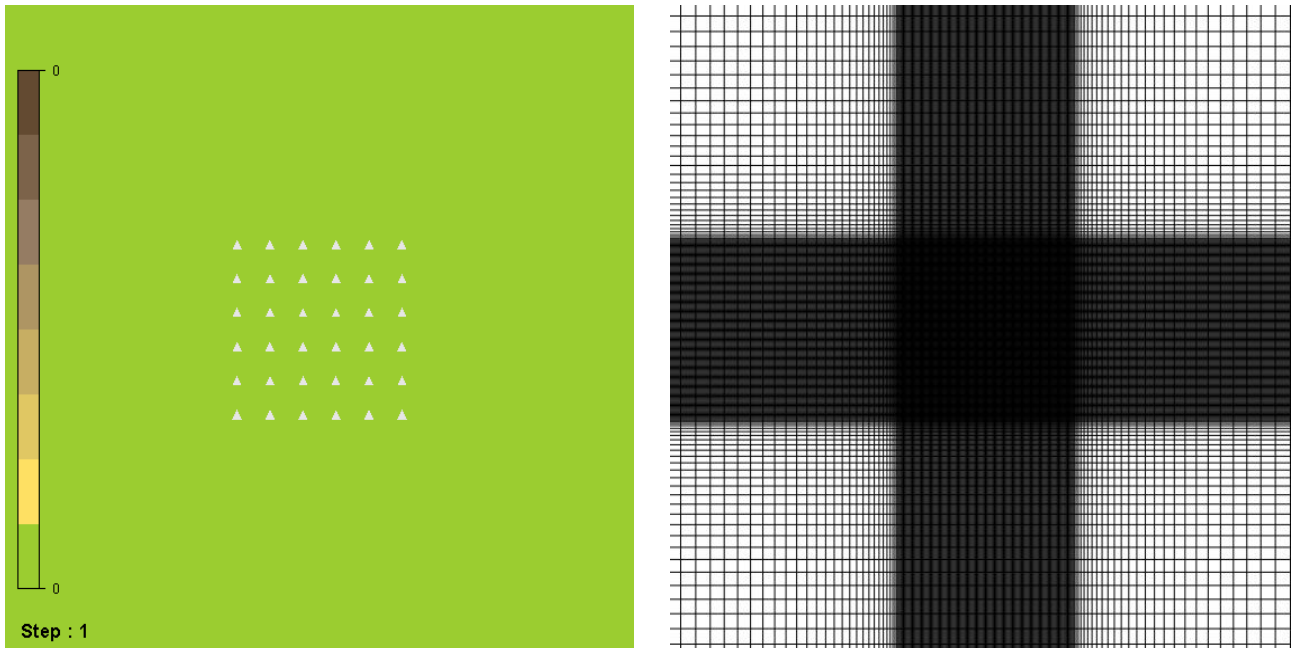
Semi-analytical model

Pure AD Model

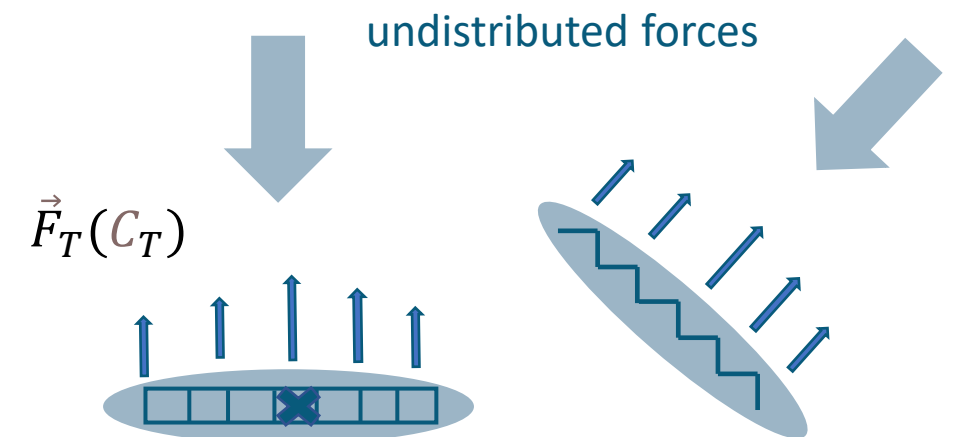
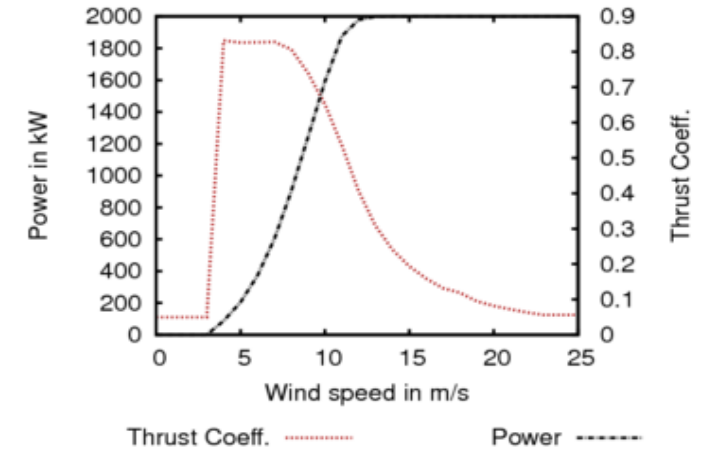
Actuator Disc Model

- Wind turbine modeled as a ,real obstacle‘ in the windfield
- AD model is invoked in WindSim’s Terrain module
- Needed information: Layout and Thrust Curve → objects file (.ows)
- Thrust Forces are dynamically included

Terrain Module

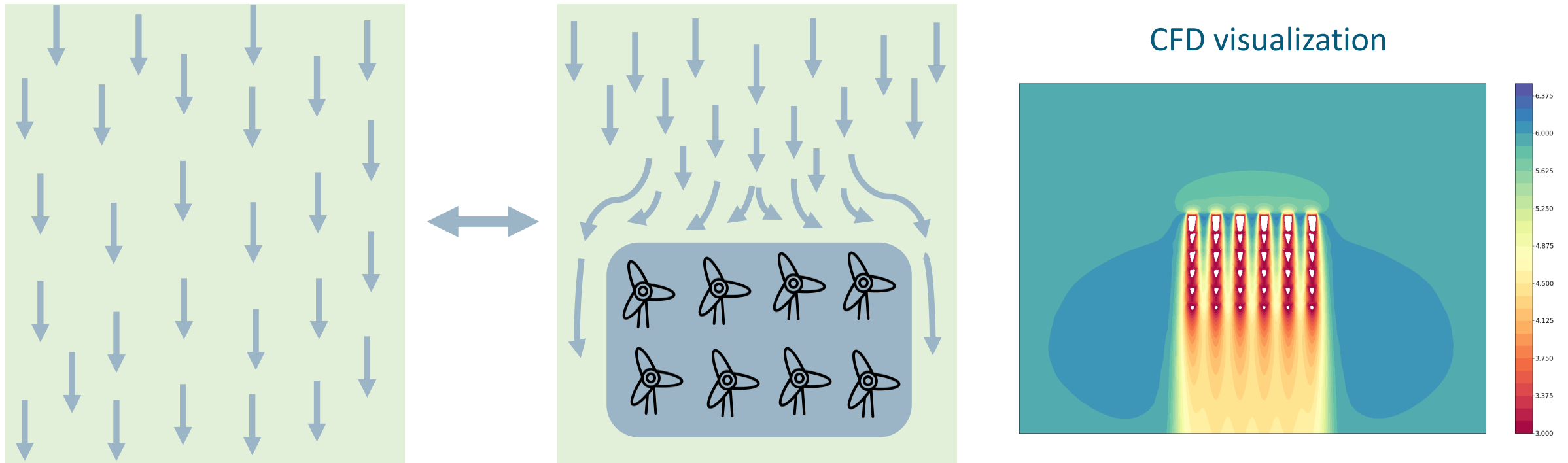


WindFields Module



Blockage Effect

- Collective effects can be taken into account
- Compare the situation with and without AD, before and after the windfarm was erected
- Investigate & quantify the wind farm-wind field interaction



From Wind Fields to Wind Resource Maps & AEP

- Connect CFD results with measurements
- In order to obtain predictive wind resource maps we need to couple CFD calculations to measurements for all wind speeds
 - for example 20 AD calculations, 1 for each speed bin in m/s
- CFD simulations are demanding
- The CFD results should typically be connected to free stream measurements
 - the position of the met mast is affected by wakes and blockage for the AD calculations



Model of WindSim

→ Use two speed levels and interpolate between them

→ Couple AD calculations with corresponding free-stream results

USE IN TOTAL 4 WINDSIM PROJECTS

Setup

- **Goal:** include turbine interactions and consider them in the wind resource assessment procedure to predict more realistic AEP's for a wind farm

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

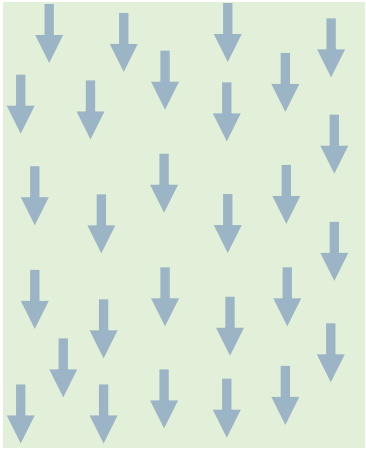


- Run four projects (Terrain+Windfields)
 1. Default WindSim project with high wind speed
 2. Default WindSim project with low wind speed
 3. Actuator Disc WindSim project with high wind speed
 4. Actuator Disc WindSim project with low wind speed
- Choose one default project as working project
- Run Objects+Results as usual

Input to the Wind Fields module

Height of boundary layer	500	Height of boundary layer	500
Speed above boundary layer height	7	Speed above boundary layer height	20

Speed Deficit



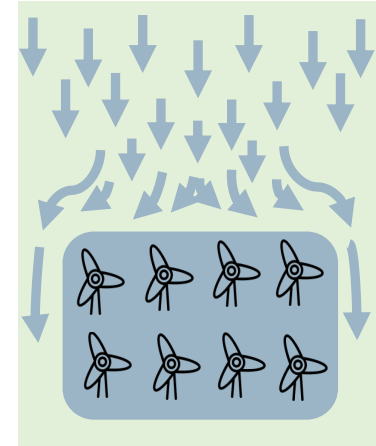
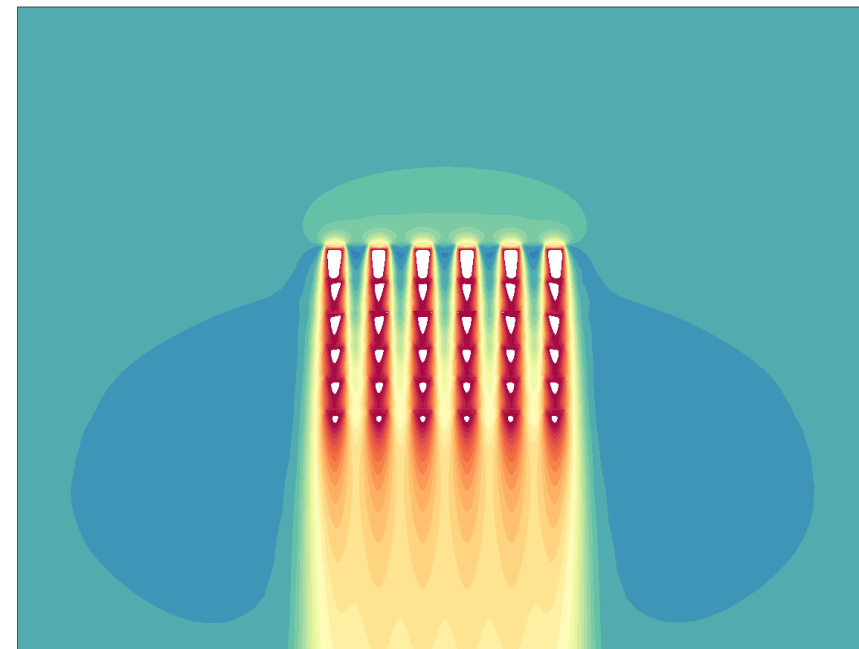
$$D = (v_{AD} - v_{free}) / v_{free}$$

- Wind fields of the input projects are compared at hub height

Default free CFD simulation



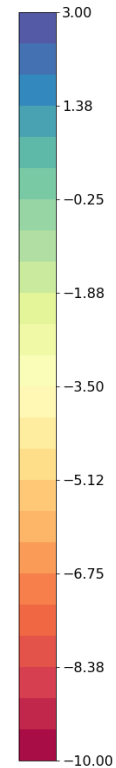
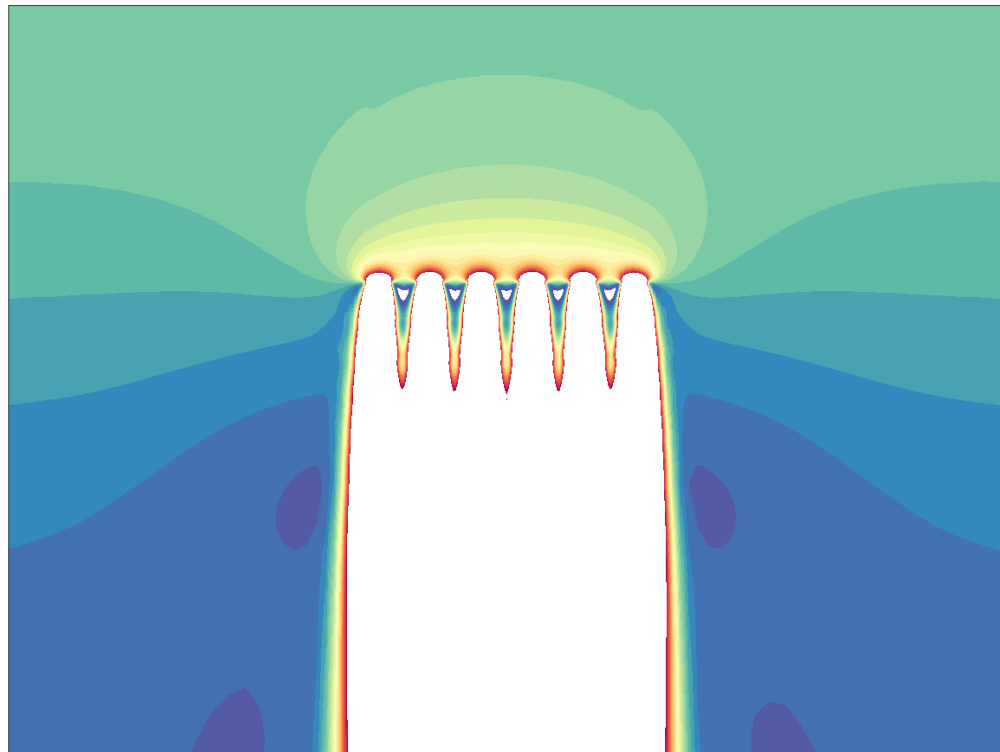
CFD simulation with actuator disc



Speed Deficit Maps (Visualized in the Results Module)

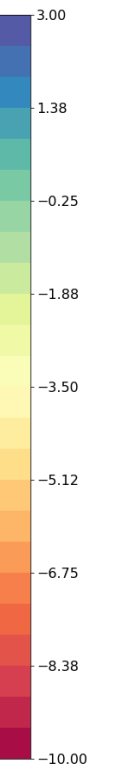
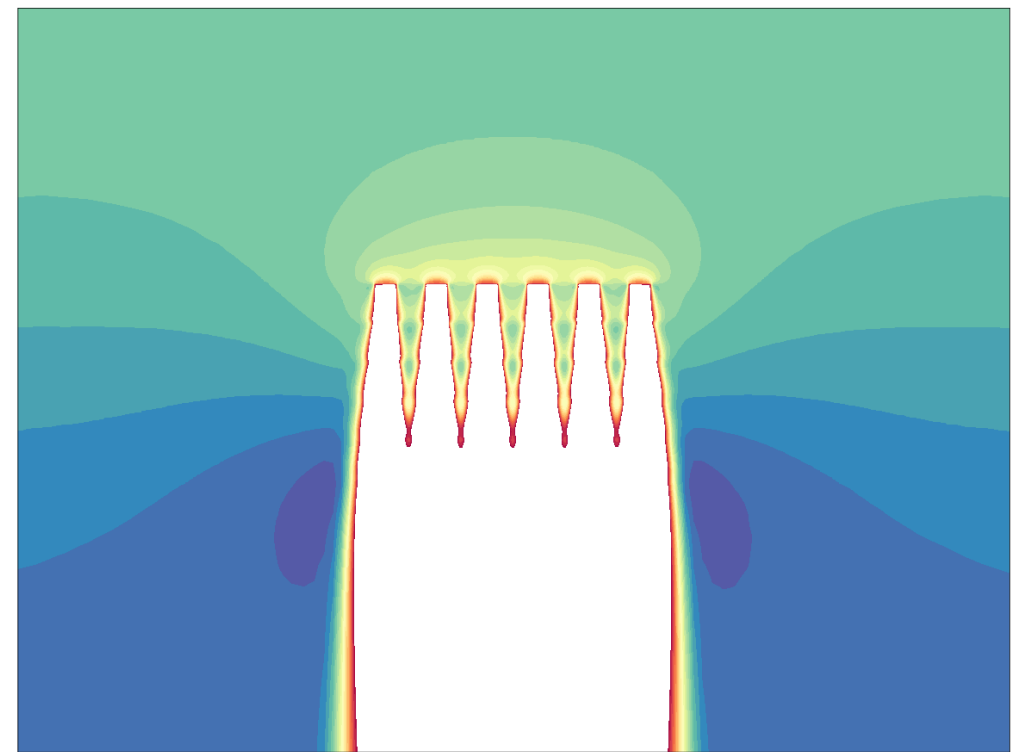
Low wind speed level

$$D_{low} = (v_{AD}^{low} - v_{free}^{low}) / v_{free}^{low}$$



High wind speed level

$$D_{high} = (v_{AD}^{high} - v_{free}^{high}) / v_{free}^{high}$$



WindSim Model

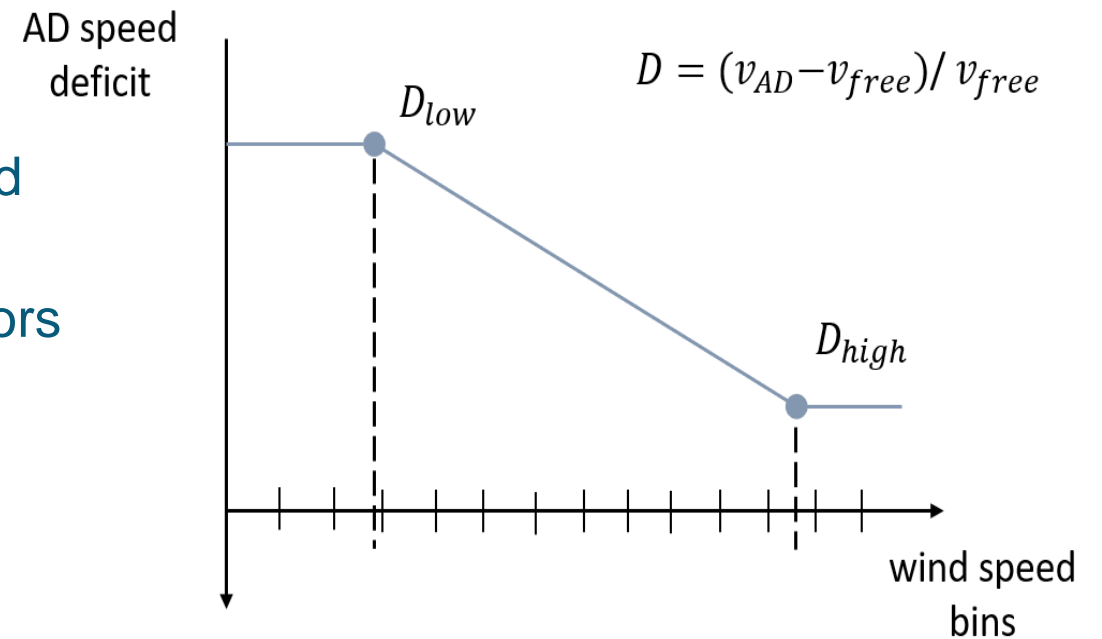
- Highly speed dependent effect
 - Linear interpolation for wind speed bins
- speed deficit factor per speed bin and sector
- wind speeds of your working project (free) are scaled against the climatology data
- Include turbine interactions via speed reduction factors

A. Pure AD Model

- Use speed deficit factors for blockage + wake

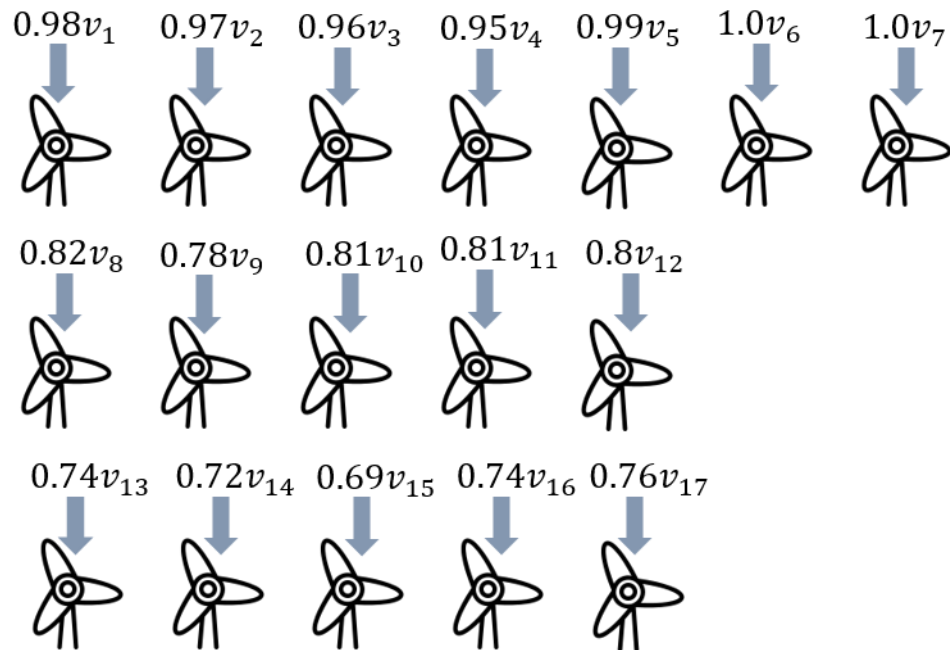
B. Semi-analytical Model (Uniform Blockage)

- Use speed deficit factors for blockage + analytical wake model
 - bias of a wakes-only consideration

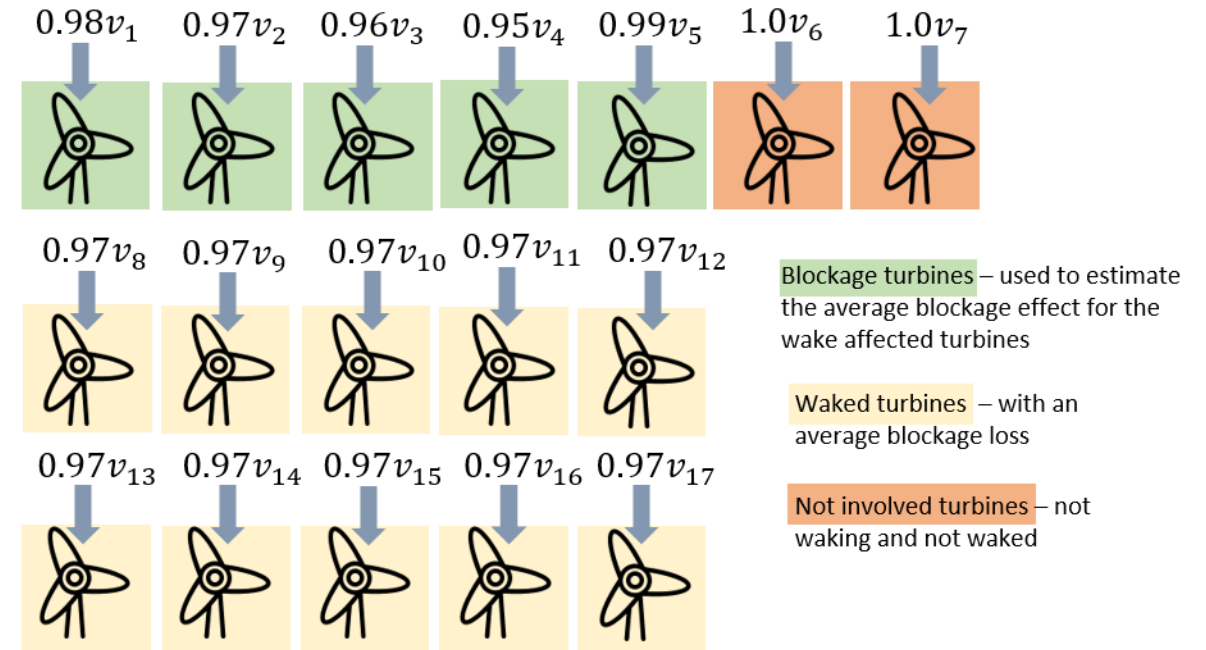


WindSim Model

Pure AD Model (A)



Semi-analytical Model (B)



- Speed reduction tables resulting from the 4 input projects
- Decouple blockage and wake for the semi-analytical model

Energy

- Automatically three models 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)

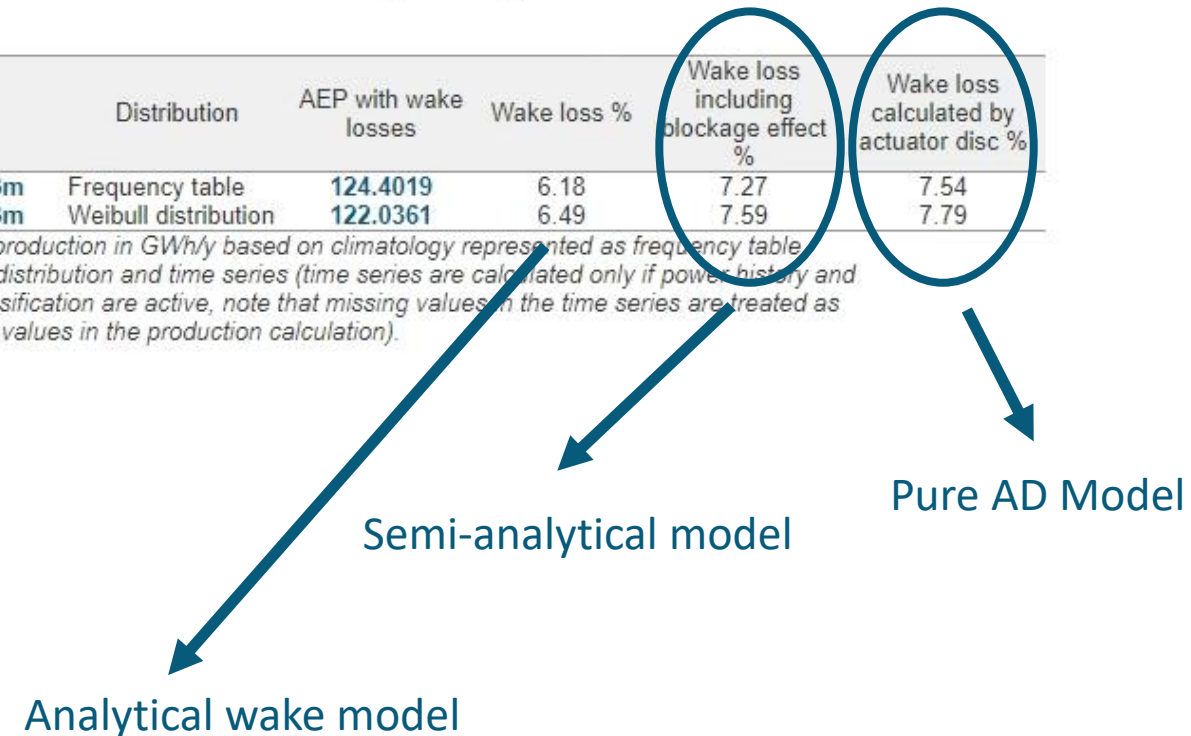
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Output of the Blockage calculation



Thank you



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