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A CFD based wind atlas method

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Abstract

Almost every country has created wind resource maps to find potential windy places to build new wind farms. The range of methods used for these wind resource maps is huge and includes mesoscale modelling, linear methods and computational fluid dynamics (CFD).

Using mesoscale models has the advantage that the area of interest can be fully covered by one model area while using other approaches leads to several simulation areas which need to be combined afterwards. But mesoscale modeling still does not reach the horizontal resolution necessary for a reliable wind resource map. Therefore it has become quite common to use CFD to produce wind resource maps and to combine the different simulation areas into one big area in the end.

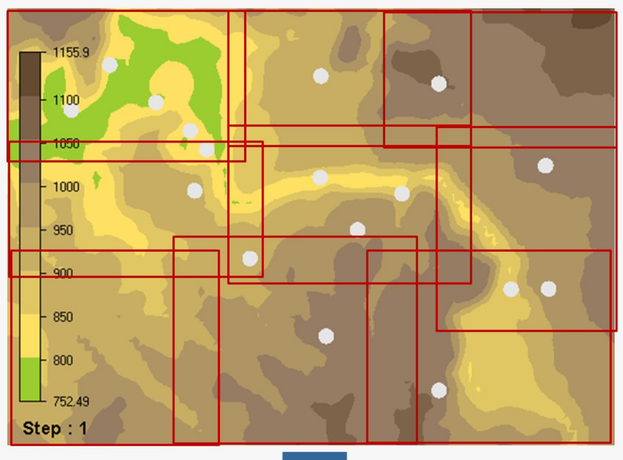
Method

CFD can simulate the wind flow with a horizontal resolution of 10 m and can therefore predict the flow pattern within smaller valleys and in very difficult terrain where mesoscale models reach their limits due to the too coarse resolution of about one kilometer and the simplified orography therein.

Different approaches can be chosen to combine the CFD results obtained for every simulated area:

- Combining the already weighted wind resource maps has the advantage that those maps can be created for every project individually and the processing gets much easier as the weighting against the measurements is done before the combination of the maps. The draw back is that the differences between those maps can be huge where they cover the same area as they are weighted against different measurements.
- Combining the wind fields of the individual areas is the physically more precise approach as the simulated wind field is combined before it is weighted by any measurements. The approach is as follows:

WindSim CFD models: each red rectangle is one simulation area



Up to 36 sectors with different atmospheric stability

3D CFD wind flow model

Direction dependent interpolation

Interpolation of all results to obtain one wind map

weighting with measurements according to distance and representativeness

Scaling of CFD results with measurements

Validation

Applying the new method on a real project reveals that the user has to pay attention to the following details:

- There needs to be enough quality measurements throughout the area otherwise it is needed to incorporate mesoscale model results as virtual climatologies
- The boundary area of each domain needs to be large enough such that boundary effects can be cut away
- The roughness and terrain data for all areas should be provided from the same data source and it should be checked on the consistency for the whole area of interest
- The boundary conditions in the CFD describing the behavior on the top of the domain should guaranty that the wind flow gets maintained throughout the area as this is usually done by the geostrophic wind for large areas
- A clever interpolation and decision technique needs to be used to have smooth transmissions at the border of every area to the next area

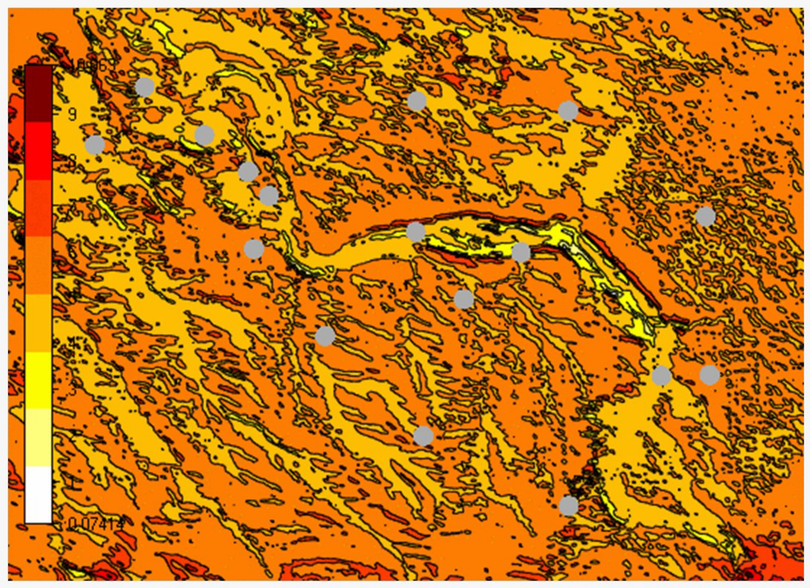


Fig. 2: Wind speed in m/s for the entire domain including the weather stations which are used to weight the results.

Conclusions

- A new wind atlas method has been developed by the CFD software WIndSim to fit the needs for dynamic line rating which expans over several hundreds of kilometers.
- The method combines the tiles on the wind speed and wind direction level to be as accurate as possible and is based on scaling against measurements where available.
- The method will be used in the coming years to do dynamic line rating over the US.