



Use of sector-wise MOL settings in a WRA study

A method to account for variable stability conditions with wind direction.

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In this presentation you will see:

- ❖ **Case study:**
 - ❖ **complex, forested**
 - ❖ **Presence of 5 met-masts**

- ❖ **A classification method of stability conditions based on the Monin-Obukhov Length (MOL)**

- ❖ **Cross predictions of met-masts locations with several models and WindSim settings:**
 - ❖ **neutral flow;**
 - ❖ **thermal flow with canopy model;**
 - ❖ **thermal flow without canopy model**

- ❖ **Ranking of flow-models performance with specific error metricses (RMSE and MAE)**

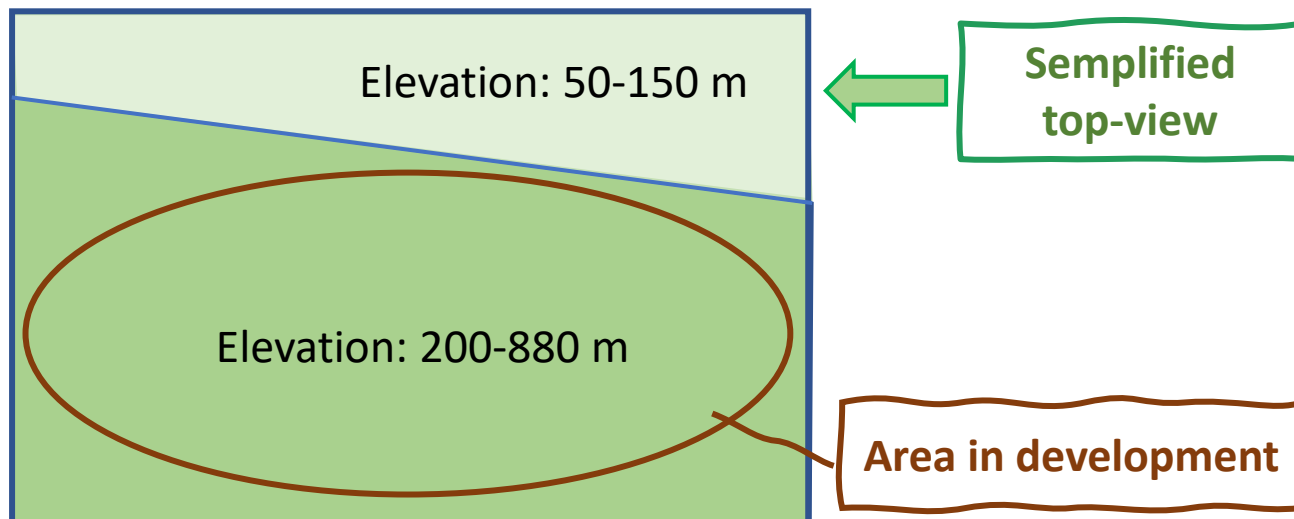
- ❖ **Conclusions and tips for development of WindSim**

Case study: site description

The site is characterized by:

- ❖ a complex orography: a complex system of ridges and valleys at high elevation, an escarpment on the north side of the site. A rather flat area is located NNE of the escarpment.
- ❖ Extended forestry above the whole area;
- ❖ 5 met-masts with top level 118 m;
 - Vertically extrapolated to 149 m (hub height).
- ❖ Average distance between met-masts of 9 km approx.

distance [km]				
Mast1	Mast2	Mast3	Mast4	Mast5
	6.6	6.6	9.6	4.5
6.6		13.1	4.4	8.3
6.6	13.1		15.4	8.5
9.6	4.4	15.4		12.4
4.5	8.3	8.5	12.4	
			Average	8.9 km
			Min	4.4 km
			Max	15.4 km



Stability classification

According also to WindSim description pages

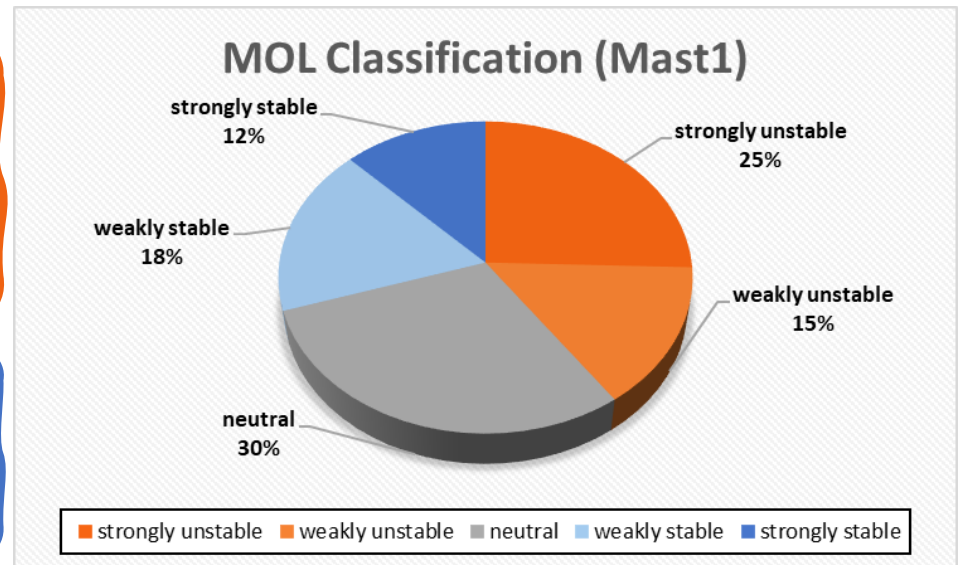
From a VORTEX SERIES of 20 yrs, initiated with ERA5, with RMOL column (Reciprocal of MOL).

- A new column is added $MOL = 1/RMOL$;
- The following classifications is applied:

Not-stable cases



- ❖ $-200m < MOL \leq 0m \rightarrow$ strongly unstable
- ❖ $-1000m < MOL \leq -200m \rightarrow$ weakly unstable
- ❖ $MOL > 1000m$ AND $MOL \leq -1000m \rightarrow$ neutral
- ❖ $200m < MOL \leq 1000m \rightarrow$ weakly stable
- ❖ $0m < MOL \leq 200m \rightarrow$ strongly stable



Stable cases \rightarrow computed MOL sector by sector only for these cases.



Stability classification

According also to WindSim description pages



- ❖ $200\text{m} < \text{MOL} \leq 1000\text{m} \rightarrow$ weakly stable
- ❖ $0\text{m} < \text{MOL} \leq 200\text{m} \rightarrow$ strongly stable

The MOL assigned to each sector in the windfield module is a frequency-weighted average of 1000m (representative for not-stable cases) and the MOL for the stable cases, averaged over all the masts.

Stable cases \rightarrow computed MOL sector by sector only for these cases, and for each time-series available.

- **MOL for simulations = $\text{ROUND}(\text{f.s.UN} * 1000\text{m} + \text{f.s.S} * \text{AVE}(\text{MOLs.S}); 100)$**

MOL Mast1	MOL Mast2	...	...	MOL Mast5	AVE(MOLs.S)	Sectors	wind direction	f.s.UN	f.s.S	f.s	MOL for simulations 100m rounded
227	366	...	...	407	260	1	0	63%	37%	4%	700
257	394	...	...	408	285	2	22.5	74%	26%	8%	800
...
190	271	...	...	357	215	16	337.5	56%	44%	2%	700
STABLE CASES							348.75	69%	31%		700
								Sum frequencies		100%	700



Cross-predictions

Error matrix, RMSE and MAE on mean wind speed

- ❖ A WRG is exported for each mast;
- ❖ Each generated WRG is imported to OpenWind and adjusted to the generating mast;
- ❖ The mean wind speeds at all masts are extracted and inserted in a matrix predictors-predicted:
- ❖ the Root Mean Squared Error (RMSE) and Mean Absolute Error (MAE) are computed on the percentage error on the wind speed:

		<i>Predictors</i>						
		Mast1	Mast2	Mast3	Mast4	Mast5	<i>with diagonal</i>	
Predicted	Mast1	0.0%	4.1%	-0.9%	0.9%	2.2%	RMSE	MAE
	Mast2	-1.9%	0.0%	0.4%	-1.8%	-3.0%	2.34%	1.74%
	Mast3	1.5%	5.9%	0.0%	1.8%	2.6%	<i>w/o diagonal</i>	
	Mast4	0.0%	2.2%	2.0%	0.0%	-1.2%	RMSE	MAE
	Mast5	1.2%	2.9%	5.2%	1.9%	0.0%	2.61%	2.18%

- ❖ The diagonal of the cross-predictions matrix is not populated by zeros without masts adjustments.
 - This could be partially explained with extrapolation/interpolation errors in the WindSim’s export and the other tool’s import. Worthy to check;
 - RSF export decoupled from the WRG export; additionally, the RSF at turbines locations?



Cross-predictions

Error matrix, RMSE and MAE on mean wind speed

- ❖ The performances of the flow-models used (linear “WindMap”, meso “WRF”, meso-linear coupled, CFD “WindSim”), or different settings for same flow models, are compared by using the metrics RMSE and MAE as drivers for final flow-model choice.

flow model	RMSE masts VE LTA (w/o diagonal)	MAE masts VE LTA (w/o diagonal)	Canopy model
WRF+WindMap	5.03%	3.48%	no
WindMap	3.28%	2.77%	no
WindSim neutral	10.86%	6.39%	yes (only C2)
WindSim neutral	8.94%	7.02%	no
WindSim thermal	4.21%	2.78%	yes (only C2)
WindSim thermal	2.61%	2.18%	no

VE: Vertical extrapolated (to hub height);

LTA: Long-Term Adjusted.

Conclusions

- ❖ A new methodology to estimate the MOL parameter to be assigned in the windfield module has been tested;
- ❖ The methodology accounts for varying MOL sector by sector and it is based on a weighted average of stable and not-stable conditions (neutral and unsteady);
- ❖ It is also presented a criterion to classify performance of flow models in a wind development area counting several met-masts;
- ❖ The WindSim models showed a significant improvement from neutral flow to thermal flows, with MOL computed in the presented way;
- ❖ The use of the canopy model for the forested area did not bring any improvement to the CFD simulations (C2 assigned starting from the trees species);
- ❖ Probably another improvement could be brought by running two or more levels of stability per sector (classified as stable and not-stable, the stable conditions modelled with a MOL parameter, the not-stable conditions modelled without including the energy equation). Or clustering of MOL sector wise.

Tips for WindSim

- ❖ Give also the possibility to give in the GUI variable MOLs;
- ❖ The options for the insertion of the MOL could be:
 1. One single value of MOL (as now)
 2. A list of N integers, where N is the sectors (or cases for MMC) to be run, Ex. «100;500;700» if we're running three sectors;
 3. MOL computed from local measurements (not tested).
 4. Give the possibility to introduce more MOL per sector, e.g. by clustering data or with fixed classes width.
- ❖ *The generation of WRG when weighted over all masts is really slow!!*
 - *Separate WRG with RSF export (already this will halve the time), speeding the algorithm anyway of the WRG export; give the option to extract RSF at turbine locations.*
- ❖ *The GCV parallel is not as numerical stable, and fast depending on the number CPUs, as the serial GCV.*
 - *The GCV serial is faster than HYPRE serial, it looks to me that the improvement in the rate of convergence is given by the parallelization, it is worthy to see if there is any issue with the parallel GCV.*