QUICK GUIDE – PARK WITH SCALER AND MESO SCALE WIND DATA CALIBRATED WITH WIND MEASUREMENTS

Purpose:

To calculate expected AEP (Annual Energy Production) as time step calculations based on EMD's Meso scale model data, where the Meso data is calibrated against local wind measurements.

PARK calculates in time steps (hourly) based on Meso model data, and it utilizes that the Meso data from EMD download service holds the information of Meso terrain data – therefore at present only Meso data downloaded from EMD server can be used with the described concept. Other Meso data can be used treating the Meso data as "a mast". (see quick guide: PARK_Measurement_SCALER_Calculation).

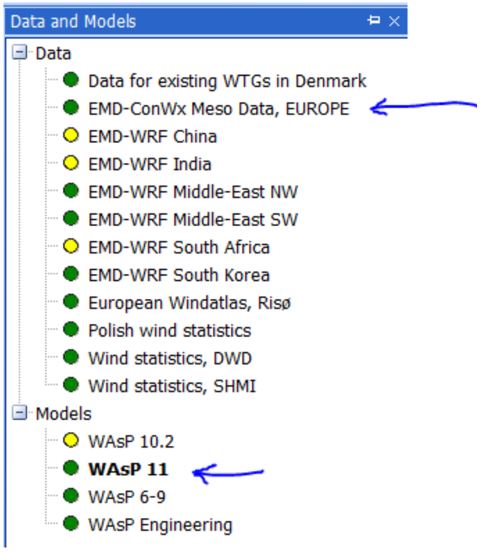
This guide assumes the user is familiar with the basic use of windPRO, establishment of objects and like import of measured data in METEO objects.

Outline of Guide:

1. **License and version requirements**
2. **Setup input data for PARK/MESO**
3. **Calibration of the SCALER**
4. **Calculation**
5. **Results in PARK/MESO**

1. LICENSE AND VERSION REQUIREMENTS

WindPRO 3.0-3.1 with license to the module PARK and a subscription to EMD-WRF (or EMD-ConWx) Meso scale data OR purchase of WRF on demand cluster credits. Also, a WAsP 11 license must be installed.



2. SETUP INPUT DATA FOR PARK/MESO

Establish the Meso scale wind data in METEO objects.

A) **Based on EMDConWx or other pre-run (see list) Meso data sets**: Create a meteo object, choose the "ON-Line" option, and select the point to download, choose period (recommended at least recent 20 years) – data will be downloaded.

B) **Based on WRF on demand**: Run a WRF calculation on the EMD cluster at any location in the world. Receive an email when it is ready, then reopen calculation and choose download. Meteo object(s) are automatically created.

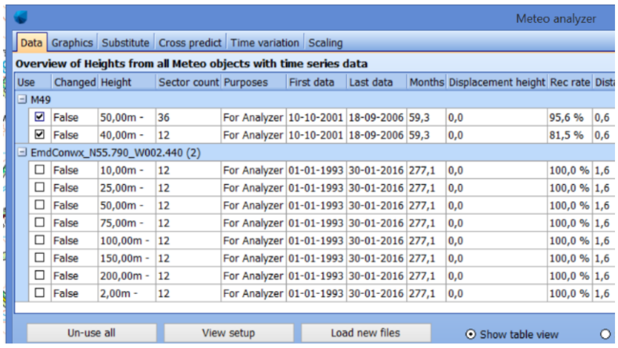
If not already established in project:

- Load the local mast measurements in a METEO object.
- Create the turbines to be calculated (objects).
- Create micro terrain data (roughness and elevation), make a site data object with a link to these. The purpose for the site data object can be, e.g., STATGEN, so no windstatistics is needed in the site data object. Alternatively,

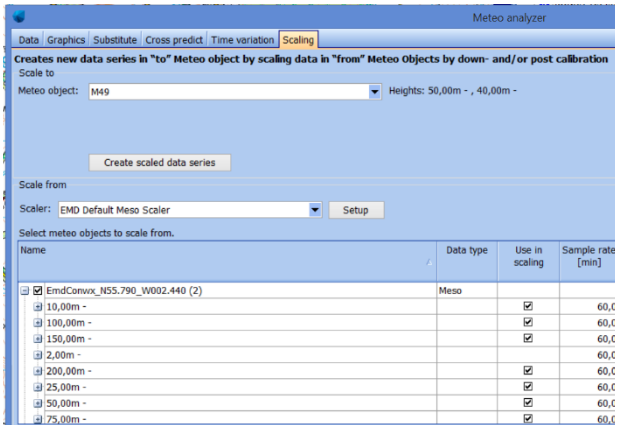
WAsP CFD result files or FLOWRES files from other model providers can be used.

3. CALIBRATION OF THE MESO DATA

Having the local mast data and the MESO data in METEO objects, the calibration can be performed in the Meteo Analyser:



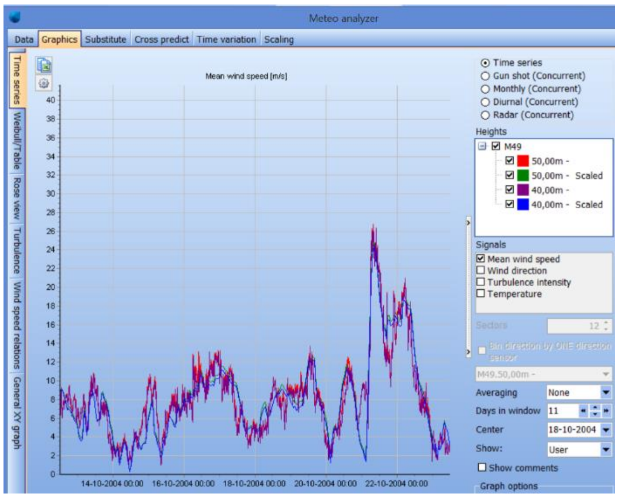
Check ONLY the mast (1 or more heights), then go to "Scaling":



Choose the "EMD Default Meso Scaler" and check the EMDConwx Meso data set in the list below.

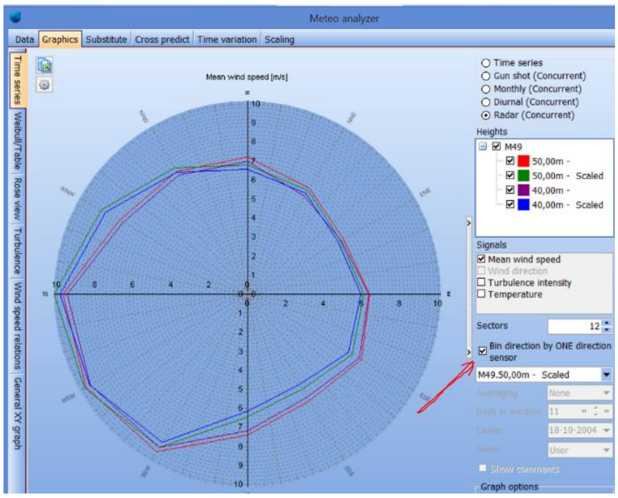
Then "Create scaled data series".

Now, the SCALER will run a downscaling of the Meso data based on the Meso terrain in the METEO object AND the Micro terrain + model selected in the SCALER. One height will be created with "scaled Meso data" for each height with measurements (here, 40 and 50 m). These will be established by interpolation from the 25 and 50m Meso scale data and transformed to the measurement mast position based on terrain/model.



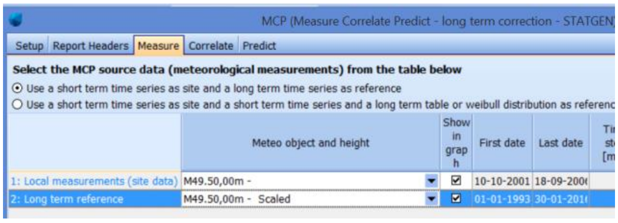
Here a part of the time series are seen with the measurements and the downscaled Meso data. The downscaled Meso data will exist for the entire period with Meso data.

Now, the data can be further checked. One of the interesting tools is the Radar graph:

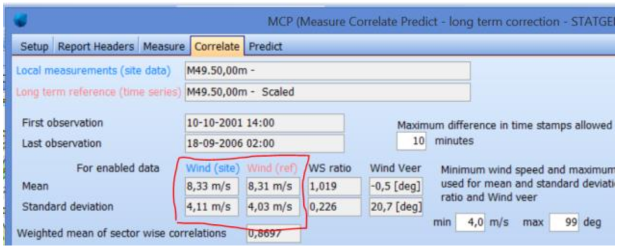


IMPORTANT: Check the "bin direction by ONE direction sensor" and use one of the Scaled. If it not checked, the graph shows the result concerning the eventual calibration difference of direction than concerning concurrent wind data in the different direction sectors. As observed here, measurements are higher in SE directions but lower in NW directions compared to Meso data. This could be due to Meso model bias but, also, could be related to the model's incorrect handling of the downscaling. Also, tower shadow could be a reason. It is possible to compensate for bias by direction in the scaler (see windPRO manual 3.8.5 Post calibration).

The most important calibration, although, is to bring the Meso data as close to the measured wind distribution (weibull fit) as possible. This can be done thusly:



Load the measurements and the Scaled data (based on "pure" downscaling, no post calibration), in the MCP module.



In the "Correlate" tab, the 4 important figures for calibration can be found: the mean and standard deviations for the two concurrent data series. At the same time, it can be observed how well the data series correlates, and, e.g., how large the Veer is. If this is high (> 5 degrees), it should be considered if the measurements might have a directional bias that need to be corrected.

	A	B	C	D	E	F	G
1	How to post calibrate downscaled Meso data - and what to be aware of!						
2		Meas	Model				
3	Mean	8,33	8,31		Scale	Offset	
4	St.dev	4,11	4,03		1,02	-0,14	
5							
6	Create scaled series in MET analyser in "measure" object based on						
7	DEFAULT meso downscaling (NO post calib)						
8	Load the measures and scaled in MCP						
9	Print from correlate tab what you see to the right -->						
10	Enter the data in input felds above						
11	Use the scale and offset calculated above as post calibration and						
12	you will get an almost perfect weibull match between scaled and measured						

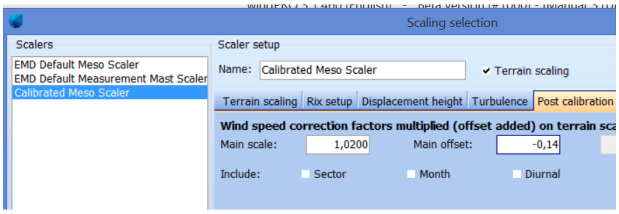
Create a small Excel sheet for making the calculation of the needed Scale and Offset for bringing the Meso data in level with the measurements. Formulas are:

Scale=+B4/C4

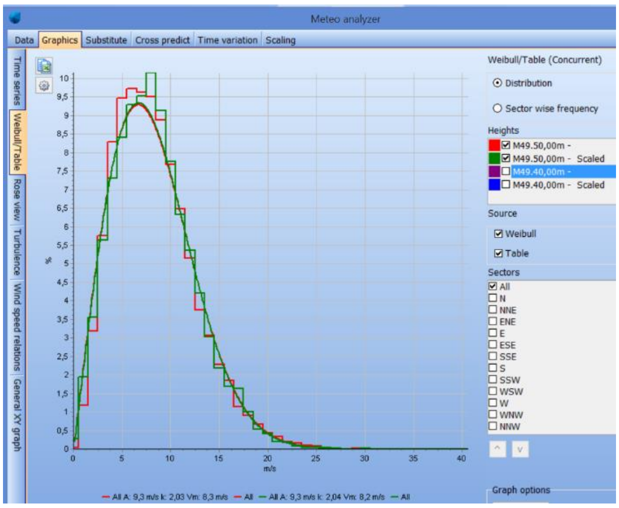
Offset: =+B3-((B4/C4)*C3)

It should be noticed that, at this location, the Meso data is VERY close to measurements and the post scaling, thereby, will be small. In some regions, the necessary scaling can be higher and, therefore, it is NOT recommended to just use the Meso data "as is" but always calibrate using wind measurements or turbine production data (see other guide PARK_MESO_SCALER_TurbineProductionCalibration on how to use turbine production).

Now, return to Meteo Analyser. In the Scaling tab, enter the "Setup" for the scaler and make a copy of the "EMD default Meso scaler". Name it, e.g., "Calibreted Meso Scaler". Enter the determined Scale and Offset under "Post Calibration":



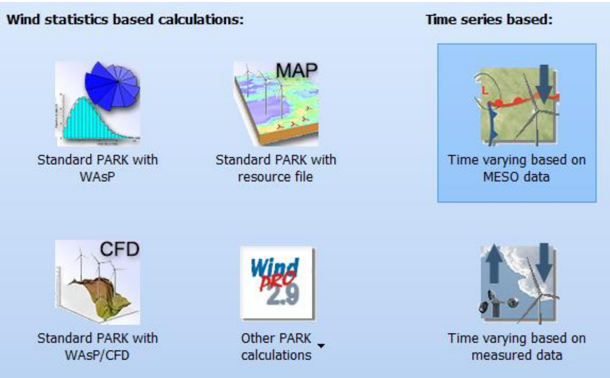
Then perform again. the "Create scaled data series". Afterwards, the weibull fits for the measurements and downscaled Meso data will be very close:



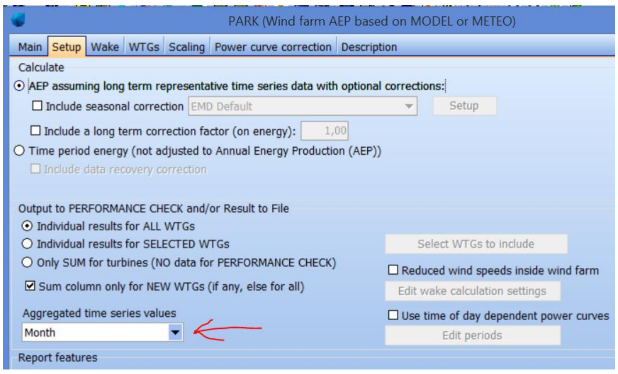
This might not be the case for the eventual additional heights, which can be explained by model issues, the measurements or the Meso modeled data. There are several additional features that might handle this, like the displacement height model, RIX, etc. The "hunt" can start for making additional "fine tunings", but, for this example, we accept the current result and now have a CALIBRATED SCALER that reproduces measurements well during the concurrent data period. If the Meso data is long term consistent (which many experiments show they are, se validation examples in manual: 8.1

Meso data long term consistency), we then have a very long data series and can perform long term wind based calculations.

4. CALCULATIONS

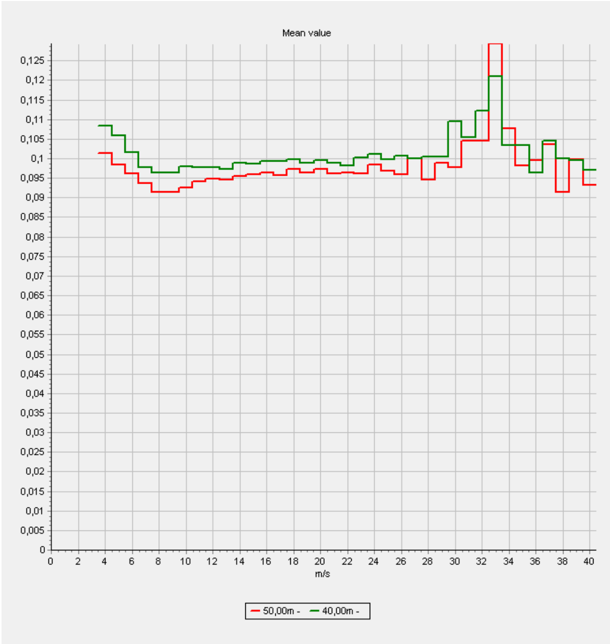


Click the upper right button to choose a time series based Meso data calculation.



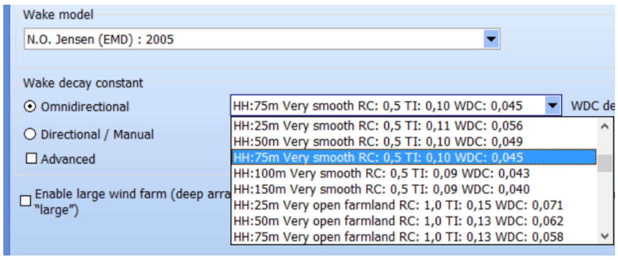
In **Setup**, note especially the “Aggregate” level. This is, by default, Month, partly to save memory. But, if there is a need for the hour by hour values (for use in PERFORMANCE CHECK or for some detailed calculations in LOSS & UNCERTAINTY), this must be changed to “none”.

In **Wake,** the only wake model available is the N.O.Jensen model. It is not as much the wake model that decides the accuracy of the wake loss calculation as the parameters that are used. For this model, the Wake Decay Constant (WDC) decides the results. The WDC should, basically, be chosen based on the turbulence, if this is available. If not, different terrain types are described that, in combination with hub height, suggest reasonable choices.



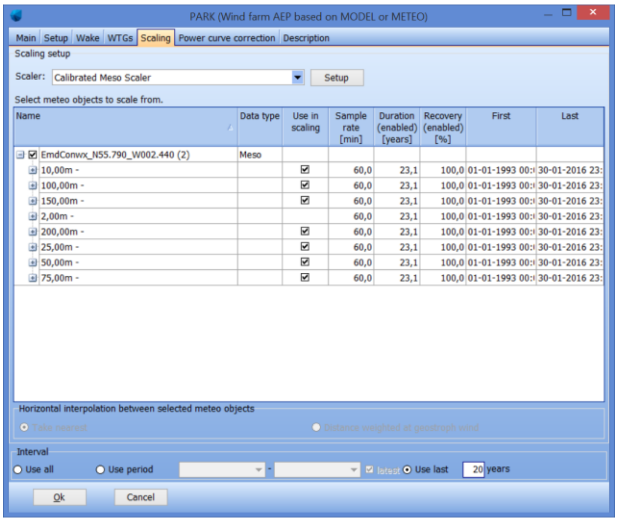
Here, turbulence measurements are available and are used as support for the decision to use the WDC . The average turbulence is observed to be around 0.1, measured close to hub height (47m for this project established).

Using the list below, at the results from above suggest a wake decay constant of around 0.045 for the site. (The importance of the choice is that TI= 0.1. The remaining details are unimportant).

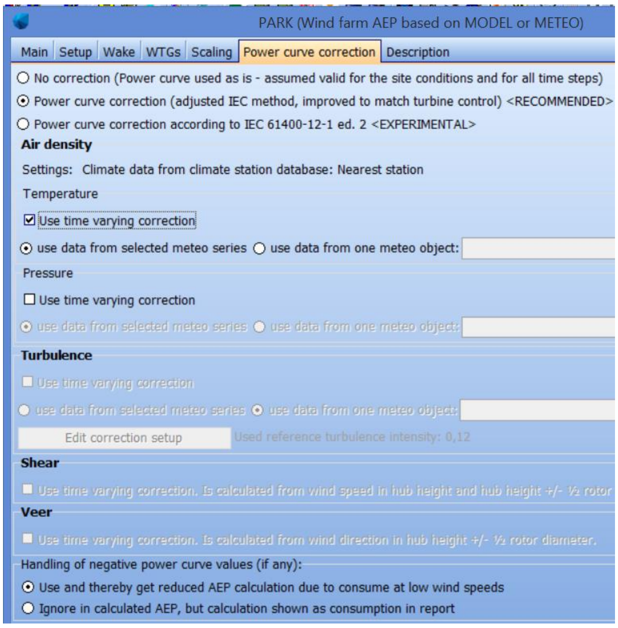


More detailed options are available. If turbulence data is available for the entire calculation period (which it, unfortunately, is not in the EMDConwx Europe data set before 2013.All other EMD WRF datasets have turbulence data for the full period), the WDC can be controlled by turbulence for each time step. This is the easy and “safe” choice. For very large wind farms (+5 rows), deep array model corrections are available, the use of which is highly recommended.

After choosing the turbines for calculation, the SCALER must be defined.



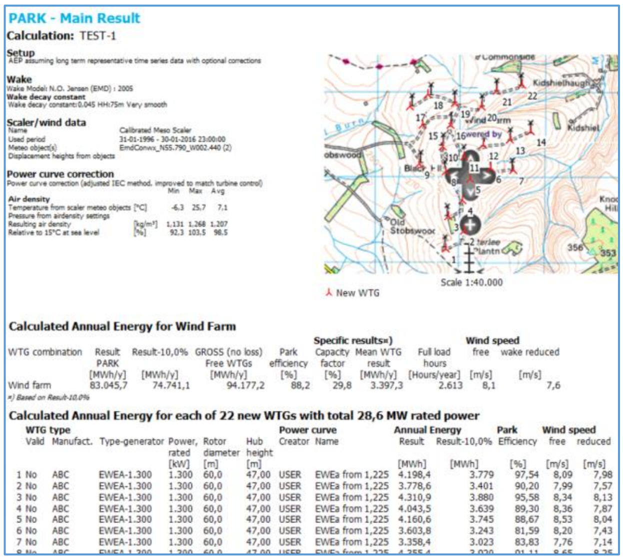
Here, simply choose the "Calibrated Meso scaler" as was previously determined. Choose the Meso data and calculate, e.g., for the last 20y (which EMD recommends – at least for Northern Europe). For other parts of the world, the recent 10 years might be a better choice since the Meso data quality might be poorer further back in time.



Finally, the power curve correction is entered. The recommendation is only to check the Temperature correction since this gives a more precise month by month calculation. The other corrections are more for "experimental use". These, in general, do not affect the AEP result significantly, although at "special sites" with, e.g., extreme shear, there might be some effect.

Now, run the calculation.

5. RESULTS OF PARK/MESO CALCULATION



The standard report document of the calculation provides assumptions and gives the expected AEP as an average for the period calculated. Note that the free wake reduced wind speeds are presented as well. The park efficiency is calculated to be 88,1%, meaning a wake loss of 11.9%.

The strongest feature when calculating based on Meso scale data is the very detailed calculation validations it offers. With the "result to file" output, the result in time can be taken into, e.g., Excel, for further processing or analyses. Also, the use of windPRO module PERFORMANCE CHECK can be used, which offers very comprehensive tools for comparing measured and calculated production. In this calculation, it is an existing wind farm, "Black Hill," that is calculated. From the British REF, the actual production data can be found:

http://www.ref.org.uk/generators/index.php

The data is annual production (AEP) for the full wind farm with 22 Bonus (now Siemens) 1300 kW turbines with 60m rotor diameter and 47m hub height. The AEP periods are 1. April to 31.March with 8 full years (2007-15) available.

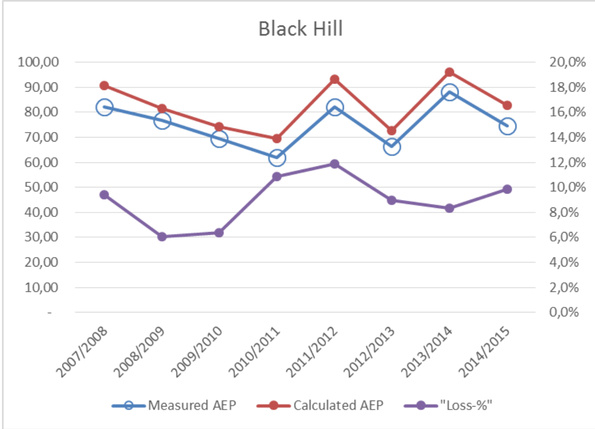
Period	Measured AEP	Calculated AEP	Diff.	"Loss-%"
2007/2008	82,15	90,69	8,54	9,4%
2008/2009	76,69	81,65	4,96	6,1%
2009/2010	69,57	74,29	4,72	6,4%
2010/2011	62,08	69,62	7,54	10,8%
2011/2012	82,33	93,40	11,07	11,9%
2012/2013	66,30	72,84	6,54	9,0%
2013/2014	88,24	96,23	7,99	8,3%
2014/2015	74,53	82,65	8,13	9,8%
Average:	75,24	82,67	7,44	9,0%
Calc. last 20y		83,04	100,4%	

Here, the period productions (April-March) are compared to the calculations. The difference between calculated and measured, based on Meso data, is long term expectations of 9% and can (at least partly) be explained by losses. It is known that there are the following loss "components" not deducted in the calculations:

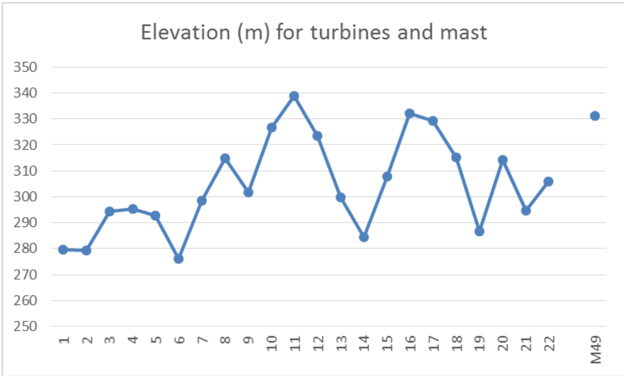
- Grid
- High wind hysteresis
- Icing
- Availability

These could explain the 9% difference, although this might not be the full explanation. The "real loss" is not known. An obvious reason for possible over prediction is that the mast is located at a higher elevation than the turbines. This is a well-known model problem. Another possible reason for over prediction could be the power curve.

It is observed how the long term (20y) calculated result only differs 0.4% from the 8 years calculation as seen in the table above.



Graphically illustrated, it is clear that the Meso scale calculation captures the annual variations very well.



The mast is elevated 25m higher than the average turbine elevation. This can explain why the model might calculate higher AEP than measured, apart from the loss "components" mentioned earlier.