# 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,

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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:

iew of He		Data Graphics Substitute Cross predict Time variation Scaling										
Overview of Heights from all Meteo objects with time series data												
Changed	Height	Sector count	Purposes	First data	Last data	Months	Displacement height	Rec rate	Di			
9												
False	50,00m -	36	For Analyzer	10-10-2001	18-09-2006	59,3	0,0	95,6 %	0,6			
False	40,00m -	12	For Analyzer	10-10-2001	18-09-2006	59,3	0,0	81,5 %	0,0			
dConwx_N	55.790_W00	2.440 (2)										
False	10,00m -	12	For Analyzer	01-01-1993	30-01-2016	277,1	0,0	100,0 %	1,6			
False	25,00m -	12	For Analyzer	01-01-1993	30-01-2016	277,1	0,0	100,0 %	1,6			
False	50,00m -	12	For Analyzer	01-01-1993	30-01-2016	277,1	0,0	100,0 %	1,6			
False	75,00m -	12	For Analyzer	01-01-1993	30-01-2016	277,1	0,0	100,0 %	1,6			
False	100,00m -	12	For Analyzer	01-01-1993	30-01-2016	277,1	0,0	100,0 %	1,6			
False	150,00m -	12	For Analyzer	01-01-1993	30-01-2016	277,1	0,0	100,0 %	1,6			
False	200,00m -	12	For Analyzer	01-01-1993	30-01-2016	277,1	0,0	100,0 %	1,6			
False	2,00m -	12	For Analyzer	01-01-1993	30-01-2016	277,1	0,0	100,0 %	1,0			
	False False dConwx_N False False False False False False False False	False         50,00m -           False         40,00m -           Convex_NS5.790_W00         False           False         10,00m -           False         50,00m -           False         50,00m -           False         75,00m -           False         100,00m -           False         100,00m -           False         150,00m -           False         150,00m -	False         50,00m -         36           False         40,00m -         12           Convox, VNS.7900, W002,440 (2)         2         2           False         10,00m -         12           False         25,00m -         12           False         5,00m -         12           False         5,00m -         12           False         10,00m -         12           False         10,00m -         12           False         10,00m -         12           False         20,00m -         12	False         50,00m         36         For Analyzer           False         40,00m         12         For Analyzer           Convxx, VS5.790,V002,440 (2)         For Analyzer         For Analyzer           False         10,00m         12         For Analyzer           False         50,00m         12         For Analyzer           False         50,00m         12         For Analyzer           False         50,00m         12         For Analyzer           False         100,00m         12         For Analyzer           False         100,00m         12         For Analyzer           False         200,00m         12         For Analyzer	False         50,00m         36         For Analyzer         10-10-2001           False         40,00m         12         For Analyzer         10-10-2001           Grows, VSS.799, W002,440 (2)         For Analyzer         10-10-2001           False         10,00m         12         For Analyzer         10-10-2001           False         25,00m         12         For Analyzer         10-10-1903           False         57,00m         12         For Analyzer         10-10-1903           False         100,00m         12         For Analyzer         10-10-1903           False         100,00m         12         For Analyzer         10-10-1903           False         100,00m         12         For Analyzer         10-10-1903           False         200,00m         12         For Analyzer         10-10-1903           False         200,00m         12         For Analyzer         10-11-1903	False         50,00m -         36         For Analyzer         10-10-2001         18-09-2006           False         40,00m -         12         For Analyzer         10-10-2001         18-09-2006           False         10,00m -         12         For Analyzer         10-10-2001         18-09-2006           False         10,00m -         12         For Analyzer         10-10-2001         18-09-2006           False         25,00m -         12         For Analyzer         10-10-1193         30-01-2016           False         50,00m -         12         For Analyzer         10-10-1193         30-01-2016           False         50,00m -         12         For Analyzer         10-11-193         30-01-2016           False         100,00m -         12         For Analyzer         10-01-1933         30-01-2016           False         100,00m -         12         For Analyzer         10-01-1933         30-01-2016           False         100,00m -         12         For Analyzer         10-01-1933         30-01-2016           False         200,00m -         12         For Analyzer         10-01-1993         30-01-2016           False         200,00m -         12         For Analyzer         10-01-	False         50,00m         36         For Analyzer         10-10-2001         18-09-2006         59,3           False         40,00m         12         For Analyzer         10-10-2001         18-09-2006         59,3           Conxux, VS5.790, VW02, 440 (2)         For Analyzer         10-10-2003         18-09-2006         59,3           False         10,00m         12         For Analyzer         01-01-1993         30-01-2016         277,1           False         55,00m         12         For Analyzer         01-01-1993         30-01-2016         277,1           False         57,00m         12         For Analyzer         01-01-1993         30-01-2016         277,1           False         100,00m         12         For Analyzer         01-01-1993         30-01-2016         277,1           False         100,00m         12         For Analyzer         01-01-1993         30-01-2016         277,1           False         100,00m         12         For Analyzer         01-01-1993         30-01-2016         277,1           False         200,00m         12         For Analyzer         01-01-1993         30-01-2016         277,1           False         200,00m         12         For Analyzer	False         50,00m -         36         For Analyzer         10-10-2001         18-09-2006         59,3         0,0           False         40,00m -         12         For Analyzer         10-10-2001         18-09-2006         59,3         0,0           False         10,00m -         12         For Analyzer         10-10-2001         18-09-2006         59,3         0,0           False         10,00m -         12         For Analyzer         01-01-1903         30-01-2016         277,1         0,0           False         50,00m -         12         For Analyzer         01-01-1993         30-01-2016         277,1         0,0           False         50,00m -         12         For Analyzer         01-01-1993         30-01-2016         277,1         0,0           False         100,00m -         12         For Analyzer         01-01-1993         30-01-2016         277,1         0,0           False         100,00m -         12         For Analyzer         01-01-1993         30-01-2016         277,1         0,0           False         100,00m -         12         For Analyzer         01-01-1993         30-01-2016         277,1         0,0           False         20,000m -         12	False         50,00m -         36         For Analyzer         10-10-2001         18-09-2006         59,3         0,0         95,6 %           False         40,00m -         12         For Analyzer         10-10-2001         18-09-2006         59,3         0,0         81,5 %           False         10,00m -         12         For Analyzer         10-10-2001         18-09-2006         27,1         0,0         100,0 %           False         25,00m -         12         For Analyzer         01-01-1993         30-01-2016         277,1         0,0         100,0 %           False         50,00m -         12         For Analyzer         01-01-1993         30-01-2016         277,1         0,0         100,0 %           False         50,00m -         12         For Analyzer         01-01-1993         30-01-2016         277,1         0,0         100,0 %           False         100,00m -         12         For Analyzer         01-01-1993         30-01-2016         277,1         0,0         100,0 %           False         100,00m -         12         For Analyzer         01-01-1993         30-01-2016         277,1         0,0         100,0 %           False         100,00m -         12         For Analyzer			

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

5							Mete	o analyzer	
Data	Graphics	Substitute	Cross predict Tin	ne variation Scaling	3				
Creat Scale		ata series i	in "to" Meteo obj	ect by scaling dat	a in "from" Me	teo Object	s by down- a	nd/or post	calibration
Mete	o object:	M49			-	Heights: 5	0,00m - , 40,0	0m -	
		Create s	caled data series						
		Credite a	colled data series						
Scale	e from								
Scale	er: EMD D	efault Meso	Scaler		<ul> <li>Setup</li> </ul>				
Color	ct motoo ol	jects to sca	la from						
Nam		<u></u>				4	Data type	Use in scaling	Sample ra [min]
- 2	EmdConv	vx_N55.790_	W002.440 (2)				Meso		
e	10,00m -	-							6
	100,00m	-							6
E	150,00m	-							6
E	2,00m -								6
	200,00m	-						¥	6
	25,00m -							¥	6
11.7	50,00m -							2	6
	75,00m -							2	6

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

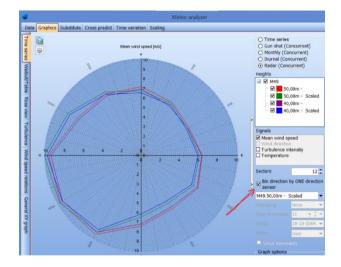
Then "Create scaled data series".

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:

Setup	Report Headers	Measure	Correlate	Predict					
• Use	a short term time :	series as s	ite and a l	ical measurements) from the tal ong term time series as reference					
O Use	a short term time :	series as s	ite and a s	short term time series and a long ter	m tab			ution as refe	eren
				Meteo object and height		in grap h	First date	Last date	T 5 [1
1: Loca	l measurements (s	ite data) N	449.50,001	n -	-		10-10-2001	18-09-2006	

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

		MCP (	Measure C	orrelate Predi	ct - long term correction - STATGE
Setup Report Headers Measur	Correlate	Predict			
Local measurements (site data)	M49.50,00r	n -			
Long term reference (time series)	M49.50,00r	n - Scaled			
First observation	10-10-2001	10-10-2001 14:00			um difference in time stamps allowed
Last observation	18-09-2006	02:00		10	minutes
For enabled data	Wind (site)	Wind (ref)	WS ratio	Wind Veer	Minimum wind speed and maximum
Mean	8,33 m/s	8,31 m/s	1,019	-0,5 [deg]	used for mean and standard deviati
Standard deviation	4,11 m/s	4,03 m/s	0,226	20,7 [deg]	ratio and Wind veer
Weighted mean of sector wise co	rrelations	0,8697	1		min 4,0 m/s max 99 deg

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.

	Α	В	С	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	6 Create scaled series in MET and lyser in "measure" object based on										
7	DEFAULT r	meso dowr	nscaling (N	O post cali	b)						
8	Load the r	neasures a	nd scaled i	in MCP							
9	Print from	correlate	tab what y	ou see to t	he right:	>					
10	Enter the	data in inp	ut felds ab	ove							
11	Use the so	ale and of	fset calcula	ated above	as post ca	libration a	nd				
12	you will g	et an almo	st perfect v	veibull ma	atch betwe	en scaled a	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

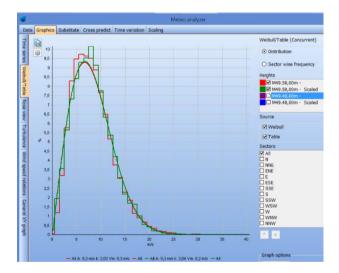
Offset: =+B3-((B4/C4)\*C3)

It should be noticed that, at this location, the Meso data is VERY close to measurements and the post scaling,

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":

4			Scaling sele	ection		
Scalers	Scaler setup					
EMD Default Meso Scaler EMD Default Measurement Mast Scaler	Name: Calibrated Meso Scaler <ul> <li>Terrain scaling</li> </ul>					
Calibrated Meso Scaler	Terrain scaling	Rix setup Dis	placement height	Turbulence	Post calibratio	
	Wind speed co	rrection facto	ors multiplied (of	fset added)	) on terrain s	
	Main scale:	1,0200	Main offset	:	-0,14	
	Include:	Sector	Month	D	iurnal	

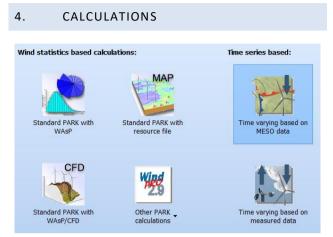
Then perform again. the "Create scaled data series". Afterwards, the weibull fits for the measurements and downscaled Meso data will be very close:



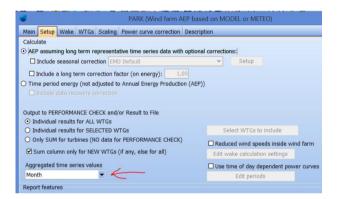
This might not be the case for the eventual additional heights, which can be explained by model issues, the measurements or the Meso modeled data. There are several additional features that might handle this, like the displacement height model, RIX, etc. The "hunt" can start for making additional "fine 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

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

Wake model		
N.O. Jensen (EMD) : 2005	-	
Wake decay constant		
<ul> <li>Omnidirectional</li> </ul>	HH:75m Very smooth RC: 0,5 TI: 0,10 WDC: 0,045	WDC d
O Directional / Manual	HH:25m Very smooth RC: 0,5 TI: 0,11 WDC: 0,056 HH:50m Very smooth RC: 0,5 TI: 0,10 WDC: 0,049	^
Advanced	HH:75m Very smooth RC: 0,5 TI: 0,10 WDC: 0,045	
	HH:100m Very smooth RC: 0,5 TI: 0,09 WDC: 0,043 HH:150m Very smooth RC: 0,5 TI: 0,09 WDC: 0,040 HH:25m Very open farmland RC: 1,0 TI: 0,15 WDC: 0,071	
"large")	HH:50m Very open farmland RC: 1,0 TI: 0,13 WDC: 0,062 HH:75m Very open farmland RC: 1,0 TI: 0,13 WDC: 0,062	

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.

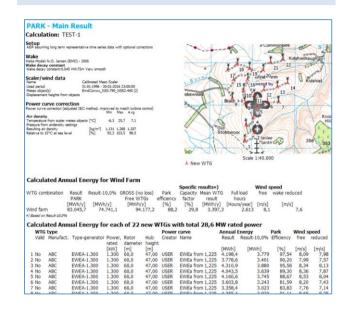
	Setup	Wake V	TGs	Scaling	Power curve	correction	Description					
Scaling setup												
Coalo	Scaler: Calibrated Meso Scaler Setup											
Select meteo objects to scale from.												
Name	Name Data type Use in Sample Duration Recovery First Last scaling rate (enabled) (enabled) [min] (years) [%]											
- 2	EmdCo	nwx_N55.	790_W	002.440	(2)	Meso			-, -			
٠	10,00m	1 -					Y	60,0	23,1	100,0	01-01-1993 00:0	30-01-2016 2
۲	100,00	m -					Y	60,0	23,1	100,0	01-01-1993 00:0	30-01-2016 2
۲	150,00	m -					Y	60,0	23,1	100,0	01-01-1993 00:	30-01-2016 2
- T	2,00m							60,0	23,1		01-01-1993 00:	
- T	200,00						Y	60,0	23,1		01-01-1993 00:0	
	25,00m						V	60,0	23,1		01-01-1993 00:0	
- T	50,00m						Y	60,0			01-01-1993 00:0	
۲	75,00m	1 -					Y	60,0	23,1	100,0	01-01-1993 00:	30-01-2016 2
Horizontal interpolation between selected meteo objects												
			n betw	een sele	cted meteo ob	jects		listanco wa	inhted at a	enstrunk w	und	
			n betw	een sele	cted meteo ob	jects	• (	istance we	ighted at g	eostroph w	ind	
	ake nea val		n betw		cted meteo ob	ects	• (		ighted at g latest <b>O</b> U		ind 20 years	

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.

	PARK (Wind farm A	EP based on MODEL or METEO)
Main Setup Wake WTGs Scalin	g Power curve correction	Description
		e site conditions and for all time steps) natch turbine control) <recommended></recommended>
Power curve correction (adjusted     O Power curve correction according		
Air density	to lec 01400-12-1 ed. 2 <	EAF ERIMENT AL>
Settings: Climate data from climate	e station database: Neares	t station
Temperature		
Use time varying correction		
• use data from selected meteo se	ries 🔾 use data from one	meteo object:
Pressure		
Use time varying correction		
use data from selected meteo se		meteo object:
Turbulence		
		meteo object:
Edit correction setup	Used reference turbulence	
Shear		
Veer		
Handling of negative power curve va		
Use and thereby get reduced AEI		
<ul> <li>Ignore in calculated AEP, but calculated AEP</li> </ul>	culation shown as consump	tion in report

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.

#### 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.

Now, run the calculation.

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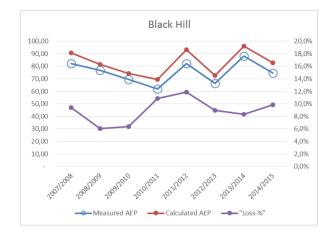
Period	Measured AEP	Calculated AEP	Diff.	"Loss-%"
2007/2008	82,15	90,69	8,54	9,4%
2008/2009	76,69	81,65	4,96	6,1%
2009/2010	69,57	74,29	4,72	6,4%
2010/2011	62,08	69,62	7,54	10,8%
2011/2012	82,33	93,40	11,07	11,9%
2012/2013	66,30	72,84	6,54	9,0%
2013/2014	88,24	96,23	7,99	8,3%
2014/2015	74,53	82,65	8,13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

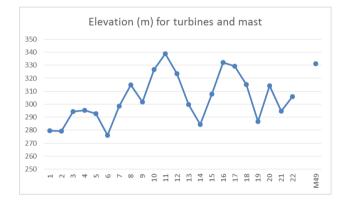
- > Grid
- High wind hysteresis
- Icing
- > Availability

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.