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

Purpose:

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

PARK calculates in time steps (hourly) based on meso modeled data, and it utilizes the terrain data that is held in the EMD meso 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 other quick guide:

PARK_Measurement_SCALER_Calculation).

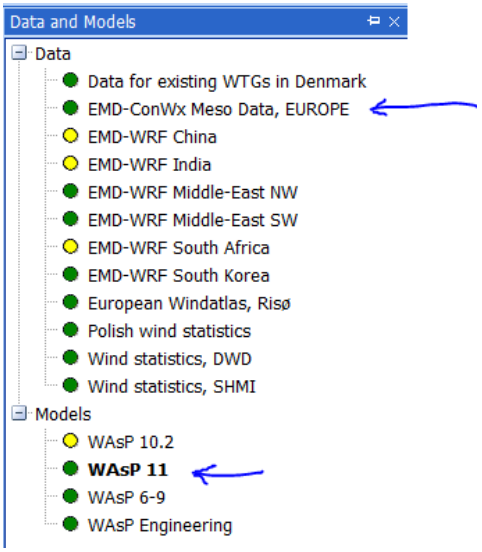
This guide assumes the user is familiar with the basic use of windPRO, establishment of objects and the like, and import of measured data in Meteo objects.

Outline of Guide:

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

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, select the point to download, and choose period (recommended at least recent 20 years) – data will be downloaded.

B) **Based on WRF on demand**: Run a WRF calculation on 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:

- Create the turbines to be calculated (objects).
- Create micro terrain data (roughness and elevation) and make a site data object with link to these. The purpose for the site data object can be, e.g., STATGEN, so no wind statistics 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 SCALER

Having turbines with production data in the region makes it possible to calibrate the Meso scale data to reproduce this production correctly – by turbine, in time, by direction, etc. The more detailed the reproduction, the more trustworthy the calibration.

There are several approaches depending on how detailed the available turbine production data is, which, e.g., can be:

1. Annual production for an entire wind farm
2. Monthly production for each turbine
3. Monthly production and availability for each turbine
4. Detailed (10-min or hourly) production for each turbine

Ad. 1: Set up a calculation with aggregation on annual level. Use the result-to-file to take calculation results to Excel and compare here to measured annual production. Adjust the Post calibration factor in SCALER until the PARK results match a ratio measured/calculated that reflects the expected loss (typically round 95%, but can vary much by project).

Ad. 2 & 3: Here, it is recommended the PERFORMANCE CHECK module is used. A "step 1" can be to make a wind index correction within this module to establish a long term expected production for each turbine. Then, save these values in existing turbine objects on "statistic" tab. After, the calculation report will show the "Goodness" for each turbine in the PARK report. Adjust the Post calibration factor in SCALER until all turbines come up with goodness around 100% (assuming the long term expected production figures are at 100% availability and before grid loss deduction). If the goodness varies much turbine by turbine, there will be a need to look for reasons, e.g., the wake model settings, power curves etc. Another "next step" can be to compare calculated with measured in PERFORMANCE CHECK at different aggregation levels. Here, different filters can be applied.

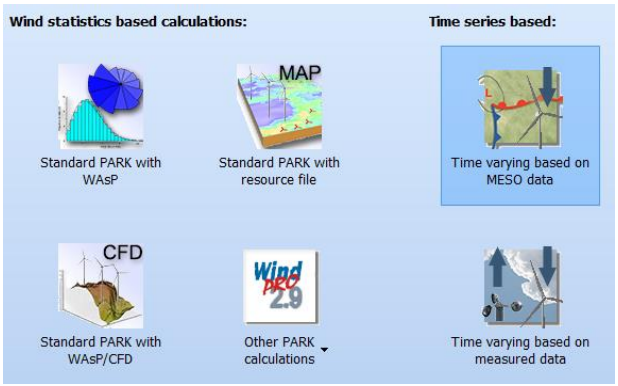
Ad 4: Here, the PERFORMANCE CHECK module is a must since it has all the features for comparing on a detailed time step basis. Aggregation by, e.g., direction, can explain a lot about wake model settings or inefficient roughness description. This is where it is possible to make a very accurate model calculation setup.

Here is illustrated the "simplest" approach (see PERFORMANCE CHECK manual for the more refined options).

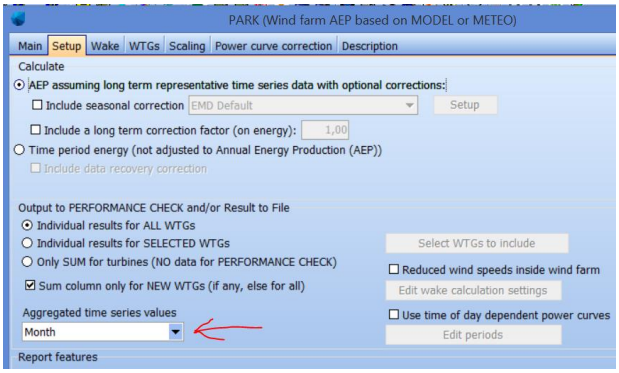
In this example calculation, it is an existing wind farm "Black Hill" that is used. From the British REF, the actual production data can be found:

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.

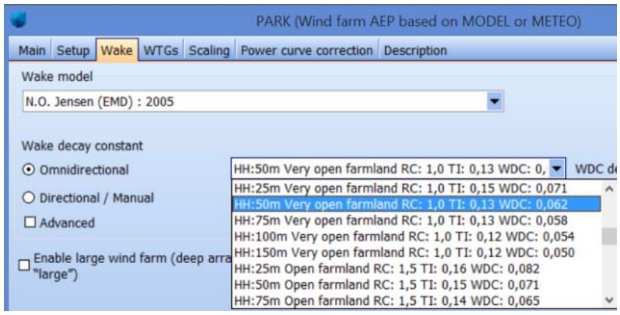


Click the upper right button to choose a time series based Meso data calculation.



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 this case, we use "Month", even though the data is available in years, but only from April to March. Therefore, aggregation on calendar year will not be useful to compare to informed production values.

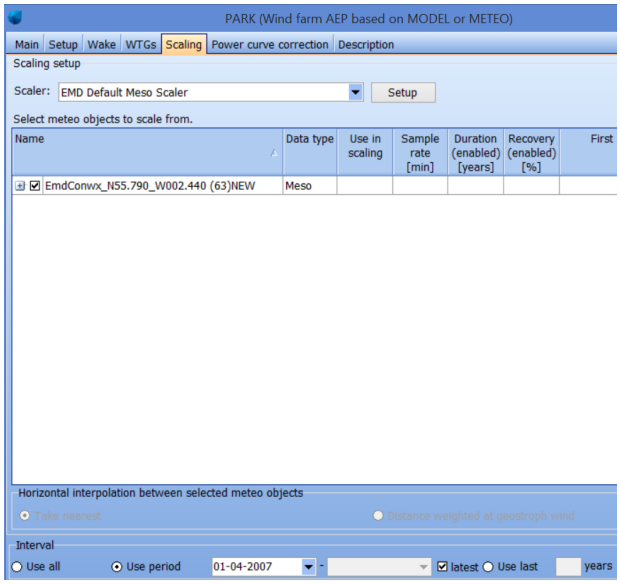
Quick Guide – PARK with MESO data and local measurements for calibration



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 shall, basically, be chosen based on the turbulence, if this is available. If not, different terrain types are described that, in combination with hub height, give reasonable choices.

Here, with Hub height 47m, the logical choice will be "HH 50m, Very open farmland, WDC 0.062".

Now, select the turbines to be calculated.

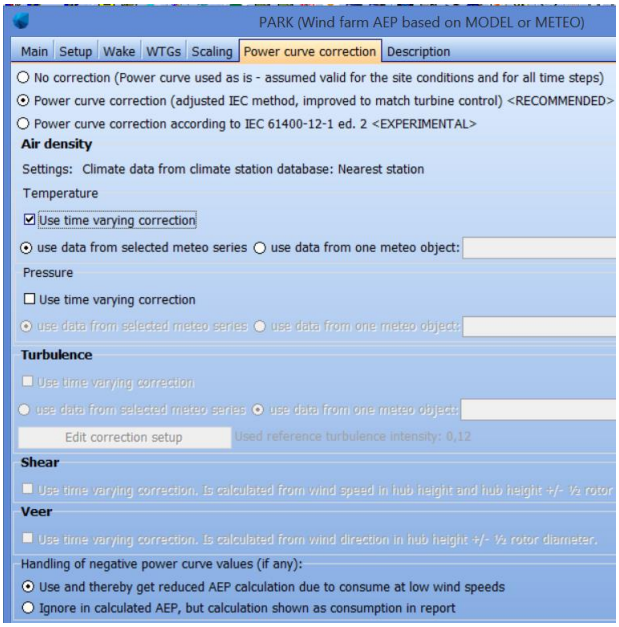


In "Scaling", choose the "EMD Default Meso Scaler" and check the EMDConwx meso data set in the list below.

Choose to calculate from 1.4.2007, since this is where our first complete year with production data starts (see later).

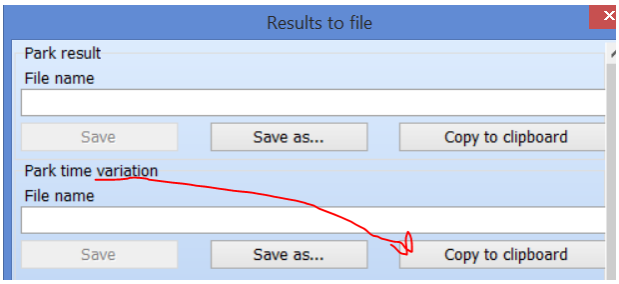
Now, the SCALER will run a downscaling of the MESO data based on the Meso terrain in the Meteo object AND the Micro terrain + model selected in the SCALER setup.

This will transfer the Meso data to each turbine position for each hour.



Finally, the power curve correction is entered. The recommendation here 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 do not, in general, affect the AEP result significantly, although at "special sites" with, e.g. extreme shear, there might be some effect.

Now run the calculation.



Right click on calculation and choose "Result to file" and copy to clipboard.

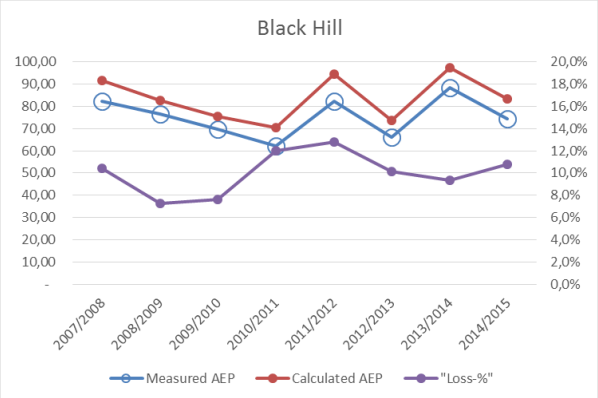
Insert in Excel:

		SIMPLE Meso scal	Scaler:	EMD Def	Meteo dat	EmdConwx_
		01-05-2016 13:56	Total		For reference WTG: [1]	
		Time stamp	Power	Time	Free wind	Reduced w
Period	Month. Prod.	Date-time	[kW]	[h]	[m/s]	[m/s]
1	5839128	01-04-2007 00:00	8109,9	720	7,1	6,9
1	6065609	01-05-2007 00:00	8152,7	744	7,2	7,1
1	2861784	01-06-2007 00:00	3974,7	720	5	4,8
1	5318335	01-07-2007 00:00	7148,3	744	6,7	6,6
1	6451298	01-08-2007 00:00	8671,1	744	7,3	7,2
1	8126352	01-09-2007 00:00	11286,6	720	8,3	8,2
1	5400473	01-10-2007 00:00	7258,7	744	7	7
1	9696384	01-11-2007 00:00	13467,2	720	9	8,9
1	9350071	01-12-2007 00:00	12567,3	744	8,9	8,8
1	10852133	01-01-2008 00:00	14586,2	744	10,3	10,1
1	10127009	01-02-2008 00:00	14550,3	696	10	10
1	11636904	01-03-2008 00:00	15641	744	10,1	10
2	5441328	01-04-2008 00:00	7557,4	720	6,8	6,5
2	2891779	01-05-2008 00:00	3886,8	744	5,6	5,2

The results will be average Power and the column next to date is the sum of all turbines. This must now be multiplied with time (hours) to get the calculated monthly production. Establish, in addition, a "Period" column, so each year from 1.4. – 31.3 can be summarized, either by a "SUMIF" function or by a pivot table.

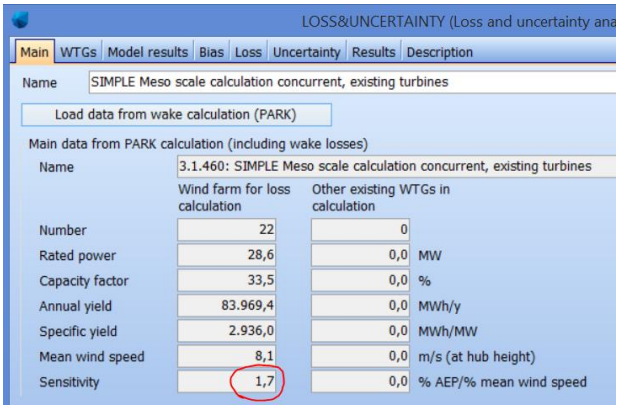
Period	Measured AEP	Calculated AEP	Diff.	"Loss-%"
2007/2008	82,15	91,73	9,57	10,4%
2008/2009	76,69	82,66	5,98	7,2%
2009/2010	69,57	75,29	5,72	7,6%
2010/2011	62,08	70,57	8,50	12,0%
2011/2012	82,33	94,37	12,04	12,8%
2012/2013	66,30	73,79	7,48	10,1%
2013/2014	88,24	97,35	9,11	9,4%
2014/2015	74,53	83,54	9,02	10,8%
Average:	75,24	83,66	8,43	10,1%

Now, we have the period productions as measured and calculated, and the differences are calculated, also, as "Loss-%".

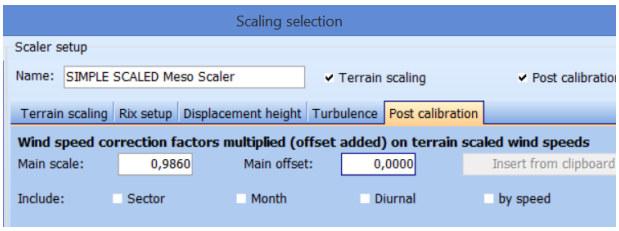


A graphic presentation makes the picture clearer. It is obvious that Meso based calculations catch the annual variations well, but there seems to be an over prediction.

A 10% loss for the 8 year period seems high. Looking at individual years, it is a minimum of 7.2%. Is this realistic? It might be depending on which losses, how well the wind farm has been operated, etc. We are informed that, in the "better years", only a 5% loss should be observed. We, therefore, now calibrate our scaler to reach round 5% loss from 2008-10. We, thereby, have to get the AEP calculation down to around 2%.



If we load the calculation in the LOSS & UNCERTAINTY module, we can see the "Sensitivity" is calculated to 1.7. In order to bring down the AEP by 2.4% (to get the average 5% loss for 2008-10), we shall scale the wind speed by 2.4/1.7 = 1.4. We reopen the calculation and enter a scaling factor of 0.986 (reduced 1.4%):



Then recalculate and paste the new results, and the table is updated:

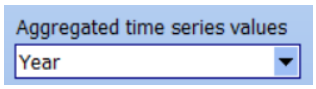
Period	Measured AEP	Calculated AEP	Diff.	"Loss-%"
2007/2008	82,15	89,48	7,33	8,2%
2008/2009	76,69	80,39	3,70	4,6%
2009/2010	69,57	73,03	3,46	4,7%
2010/2011	62,08	68,44	6,37	9,3%
2011/2012	82,33	92,23	9,90	10,7%
2012/2013	66,30	71,64	5,34	7,4%
2013/2014	88,24	94,87	6,63	7,0%
2014/2015	74,53	81,54	7,02	8,6%
Average:	75,24	81,45	6,22	7,6%

We do not hit exact 5% in average for 2008-10 due to non-linearity, and might, therefore, change the factor 0.986 to 0.988 to get exact what is wanted. Here, we accept the results as okay – to make it better we must contact the wind farm management for more detailed information.

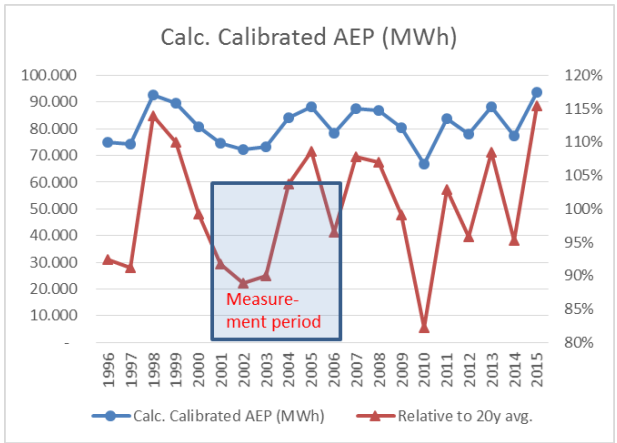
4. CALCULATIONS AND RESULTS

As the calculation setup is now ready, the only modification for a long term expectation would be to set the period to 20 years.

Here the calculation is setup for 1996-2015.



The aggregation is changed to Year, and the results are:



The time step based calculation offers, as seen, the benefit of illustrating the annual variations based on historical data - how much can be expected in variations year by year. It is also illustrtated here how the wind conditions were during measurements on the site (clearly below long term average).

		MWh/y	
Calc. last 20y		81,32	
First 10		80,48	99,0%
Last 10		82,16	101,0%

And, as support for using 10 or 20 years as the long term reference period, the table above is informative. In this case, using only the last 10 years would give 1% higher calculated AEP.

To finalize the AEP study, a loss and uncertainty evaluation must be performed. Due to the coarse nature of the production data, the uncertainty will be higher than if more detailled data had been available.

It will be difficult to judge the uncertainty, but it is defenitely lower with this calculation concept than based on the traditional wind statistic concept - partly since weibull fit problems are handled better and partly since it gives much more confidence in being able to evaluate the model results against measurements in time instead of just having one average value to calculate with.

It should be noted that the calibration process illustrated here does not provide a refined model calibration – all is put into scaling the meso scaled wind speed. Other issues, like the wake loss model settings, are not possible to fine tune when only sum production for all turbines is available (see other PARK guides where the same project is recalculated using local measurements, which gives a better feedback for model calibration.

It is especially important to calibrate the right parts in the model of a new project when very different turbines and hub heights will be calculated.