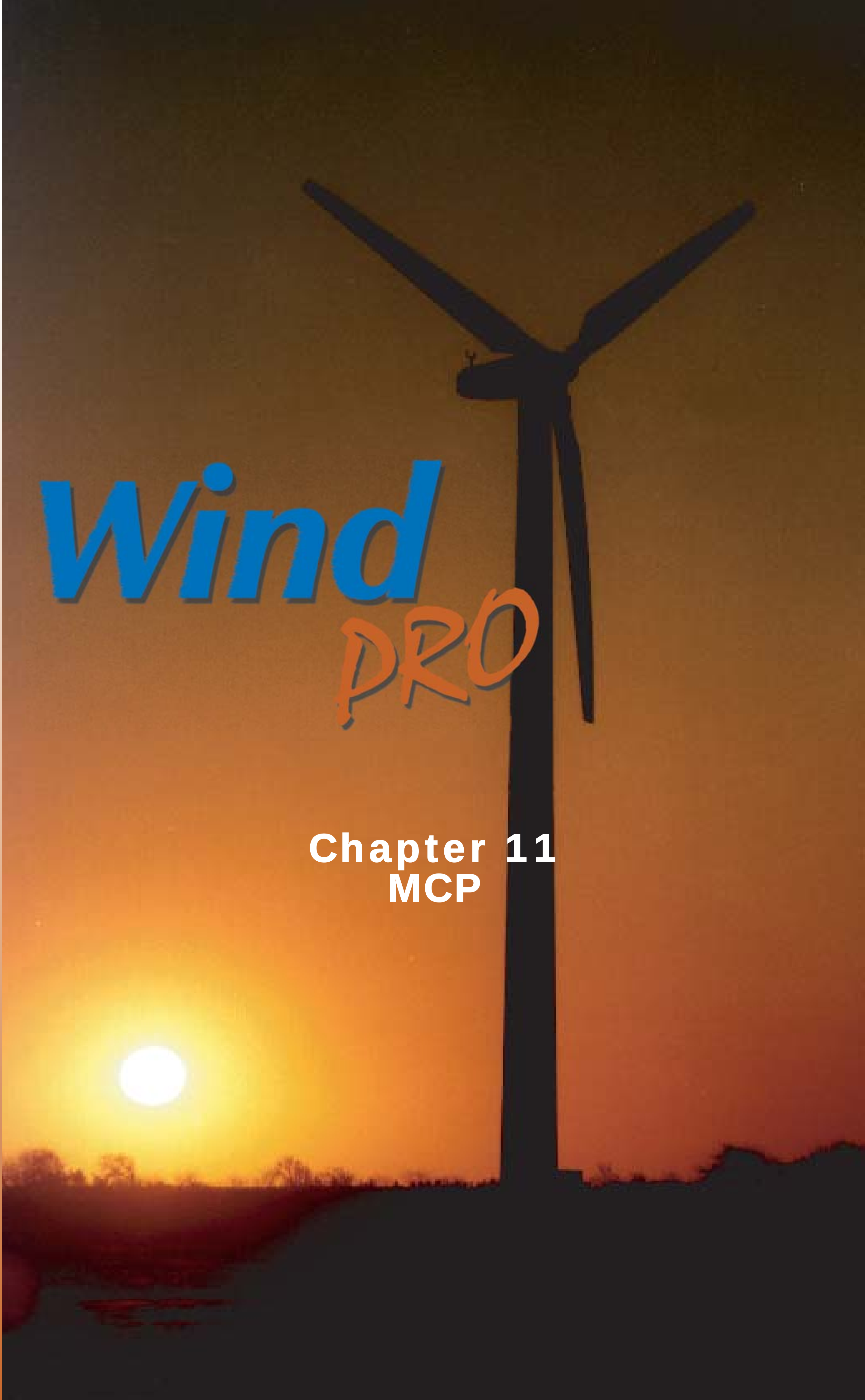


# WindPRO

# Chapter 11
# MCP

EMD
www.emd.dk

# ENERGY - 11 MCP

# 11.0 Introduction to MCP and step-by-step guide

This document gives an introduction to the Measure-Correlate-Predict tools (MCP) that are included in WindPRO. The MCP module in WindPRO consists of the following features:

Included in license is free download of EMD Online data from METEO object
Load of time series data from WindPRO Meteo objects – filtering features available
Correlation: Extraction of concurrent data and correlation analyses on those
Linear Regression MCP
Matrix method MCP
Weibull Scale MCP
Wind Index MCP
STATGEN – generation of wind statistic from MCP result
Write back long term corrected time series to METEO objects

The Measure-Correlate-Predict toolbox in WindPRO (MCP) enables the user to calculate long term corrected wind data directly in WindPRO. The MCP module provides not only a direct access to different MCP-methods, but also provides reporting through overview-reports and detailed reports for each of the methods available. The global set of like NCEP/NCAR long-term reference data as well as SYNOP and METAR data is available for WindPRO users with an Internet connection and license to the MCP module. In addition purchasable data from selected providers are available for easy use for MCP.

Data that are used by the MCP-methods are contained in the WindPRO Meteo object(s). This object is the data container for wind data saved as either time series data, table data or Weibull distribution parameters. Most MCP-methods require two overlapping time series, each holding a concurrent time series for long-term reference data and site data (local measurements). But the long-term reference data could be divided in a concurrent time series for the duration of the local site measurements and “just” a Weibull distribution or table data (histogram) for the entire reference period.

The result from the MCP analysis is – typically – a wind statistic generated with WAsP based on a terrain description and the long term corrected site data. Then the data can be used directly for WAsP PARK calculations or wind resource map calculations. But for non WAsP use (or further analyses) the long term corrected site data can be written back to an auto generated Meteo object. This Meteo-object is located at the exact same position as the one holding the short-term site measurements.

## 11.1.1 About the Application of MCP

MCP is the abbreviation for Measure-Correlate-Predict techniques, which is widely in use for establishing a long-term wind statistic using limited wind data from the local site and long-term data from a more-or-less nearby site.

The task of any estimation of a long-term wind statistic is to establish a transfer model between the available short-term local data and the concurrent data from a long-term reference data set. The transfer model can be grouped into (at least) four different types:

1. Physical models (e.g. CFD flow models)
2. Statistical models
3. Empirical models
4. Other (combinations of the above, e.g. like WAsP)

MCP-models may belong to any one of the categories or a combination hereof, indicating that the application of MCP-models has a very wide scope:

Some MCP-models operate on large timescales – like index correction methods, where monthly data typically are used. Other MCP-models tries to decode a one-to-one relationship between wind speeds and wind directions on site and at the reference mast, calling for high quality measurements. In some situations, MCP-methods are applied in order to correct the lack of ability for a model to take long-term variation into account. This is the case when using local short-term site data in a WAsP analysis. Unfortunately, not all methods will perform equally well in all situations, calling for the user to get acquainted to the performance and limitations of the individual methods.

In general, the applied MCP method modifies one or more of the following descriptive data:

Wind energy index
WTG energy index (measured production from the WTGs)
Weibull A-parameter + Weibull k-parameter
Wind speed and possibly also wind direction

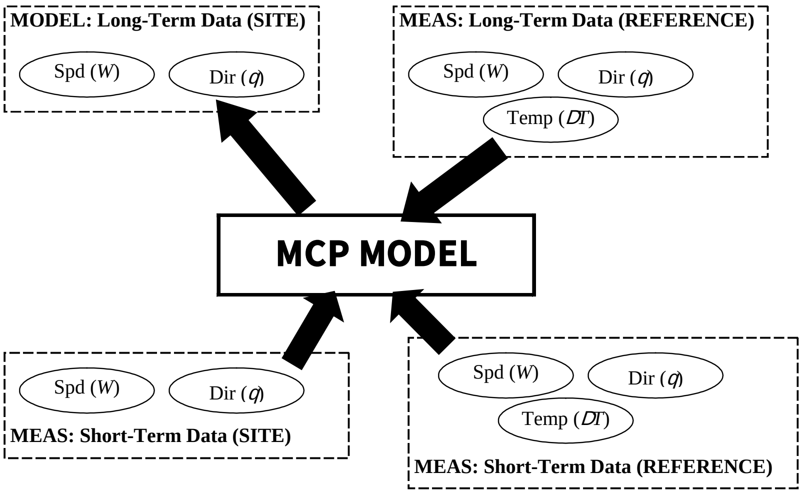
In WindPRO methods working on (1), (3) and (4) are implemented.

### 11.1.2 A Conceptual Model for the MCP-Framework

A conceptual model for the measure-correlate-predict model is shown in the figure below. From this figure it is seen that three potential different measured datasets are input to the MCP-model:

Reference data: Long data
Reference data: Short term data (concurrent data)
Site data: Short term data (concurrent data)

The long-term data could be any type of distribution, e.g. Weibull data, table data (joint wind distribution) or time series data. The concurrent datasets are typically required to be time series data. Not only measurements on wind speeds and wind direction could be used as input to advanced MCP models but also temperature differences could prove useful. However none of the models in WindPRO currently uses other input than wind speed and wind direction.



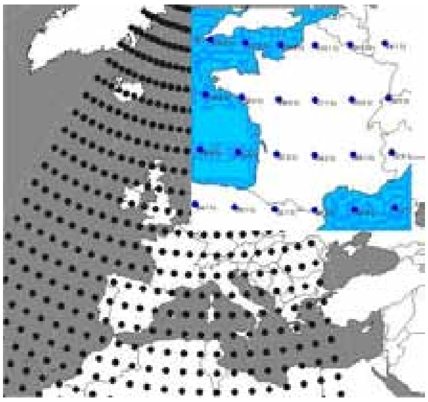

*Conceptual Model for Measure-Correlate-Predict Models.*

Note: When doing MCP calculations in WindPRO, the input data are always internally treated as three different input sources. However, in many cases the long term reference data and the concurrent reference data series may come from the same time series data source. In such situation, WindPRO will automatically select the same series for both input sources.

### 11.1.3 The MCP facilities in WindPRO

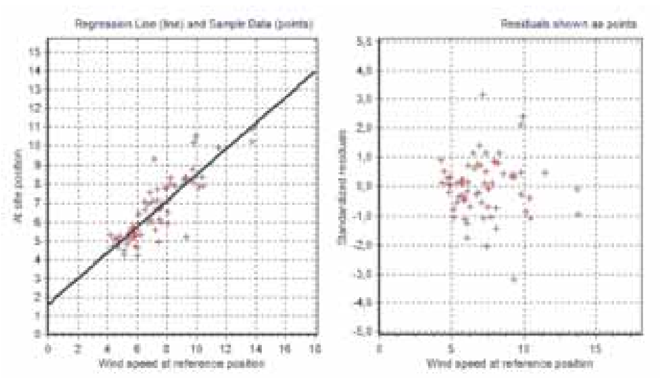
Below is a list of sub-sections briefly outlining the MCP facilities, which are available in WindPRO

#### 11.1.3.1 ON-Line data extraction



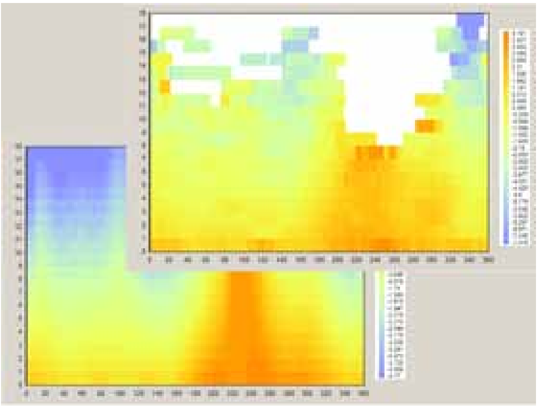
Data from the several different sources like NCEP/NCAR reanalysis project is available to users of WindPRO if the local PC has access to the Internet. The download is started from a METEO object, choosing option “ON-Line data”. A list of available data sources for the project site is generated and specific data sets can be selected and downloaded. Also purchasable data are available. The available data sources are constantly improved and more added. When new data are available thee are included in the online generated list – no local software update is required.

#### 11.1.3.2 Linear Regression MCP



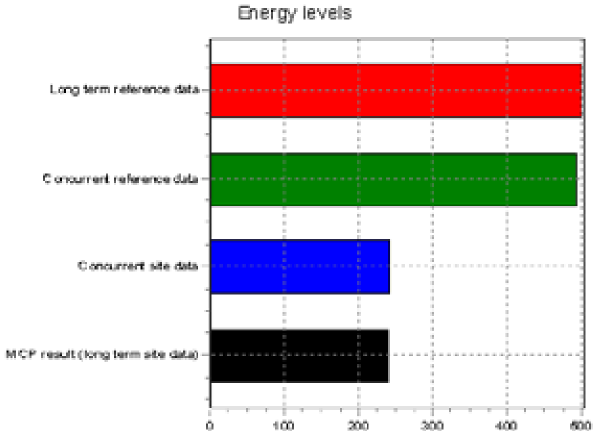

The (Linear) regression tool enables the user to inspect the fit directly through an animated graph. If the fit is not satisfactory, a wide range of parameters may be fine-tuned to provide a better fit. The regression tool is not limited to linear regression, but also higher order polynomials may be used in modeling wind speeds and wind veer.

#### 11.1.3.3 Matrix Method MCP



The matrix method in WindPRO models the changes in wind speed and wind direction through a joint distribution fitted on the ‘matrix’ of wind speed bins and wind direction bins. The user may choose to either use polynomials fitted to the data statistics or – where appropriate - to use the measured samples directly when doing the matrix MCP.

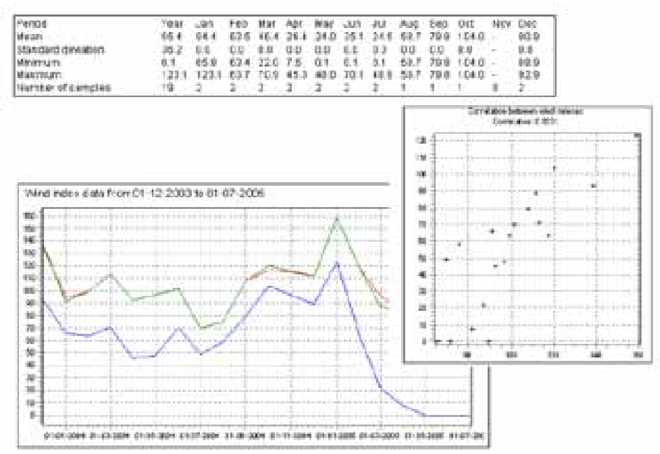
### 11.1.3.4 Weibull Scale MCP




The Weibull Scale method is a very simple empirical method, which does its manipulation directly on the Weibull form and scale parameters (A,k) as well as on the frequency distribution.

The Weibull scale method has the advantage, that it will match the nature of the wind at most places, but beware that application of this method should be done with caution on locations with significant non-Weibull distributions.

### 11.1.3.5 Wind Index MCP



The index correlation method is a method typically making the MCP analysis by using monthly averages of the energy yield, thus disregarding the directional distribution of the winds. Even though this method may seem rather crude and primitive when comparing to other more advanced MCP methods, it has its advantages in stability and performance – even in the cases where other MCP methods seem to fail.

The Wind Index MCP method in WindPRO offers the opportunity to calculate the wind indexes using real power curves from the wind turbines included in the wind turbine catalogue in WindPRO. Also a generic power curve may be chosen.

### 11.1.4 Step by step guide

Prepare two time series in one or two Meteo objects: a local data series (short) and a reference data series (long). See chapter 3.3.2 for details. Prepare eventually several long term reference data series, where more ON-Line data sources typically are available.
Set up a site data object for purpose Statgen with link to roughness, orography and obstacle description. See chapter 3.3.1.1 for details. (Only needed if you want to use the WAsP method later)
Start calculation module MCP from the main menu.
On **Measure** tab sheet, select the local data series and the reference data series and press Load data.
Inspect the time series and make any necessary filtering of the local or reference data. If any filtering has been selected press "*apply filter values to time series*".
Go to **Correlate** tab sheet and press Load data to get the time series of the concurrent data points.
Inspect the data and test for correlation. There are many options for that. Use e.g. the Graphics - Correlation feature or print the Report. That might give feed back on periods with erroneous data. These can be disabled, easiest at the Graphics – time series by right clicking on the graph for isolating and disabling of data periods.
Go to the **Predict** tab sheet. Select a prediction method: Regression, Matrix, Weibull scale or Wind index method.
Each method has individual settings, but all has reasonable default parameters, so it is possible to click next through the pages without selecting any specific parameters.
Linear regression and Matrix produce a graph comparing observed and predicted values for the concurrent period. Wind index compares local and reference monthly index.
Run a **Statgen** calculation producing a wind statistic by default at the end of the prediction run. Note: Requires a Site data object for Statgen and the WAsP software.
Run eventually additional methods (or change to other long term reference data, which require you go back to "load" on the Measure tab). Each result is listed in the Predict table for easy comparison.
It is possible to go back to the Measure tab sheet and select a different reference and then repeat the process and compare results both based on different methods and reference data.
View reports on individual combinations of reference data and methodology and hopefully get an idea of what seem to work best or find an average between the ones you feel comfortable with.
Select the best qualified and either **Save wind statistic** or **write to METEO**, which will create a Meteo object at the location of the local Meteo object with the long term corrected data.
Exit the MCP module with OK and "Start calculation" (Generate report and save the settings/results for later inspections/modifications).
Create a Site data object for WAsP calculation selecting the newly produced wind statistic. You can now perform an energy calculation (e.g. PARK or wind resource map).

## 11.2 MCP users guide

### 11.2.1 Preparation for a MCP

#### 11.2.1.1 Meteorological data

Before running an MCP calculation, data must be prepared. Essentially the MCP requires four sets of data:
Site data
Long term reference data
Concurrent site data
Concurrent reference data

If data exist as time series it is only necessary to specify the site data and the reference data. But if the long-term reference is only available as an accumulated distribution (a .tab file or weibull) then the concurrent part of the reference must be available as a time series and thus three data sets are needed (two for the reference and one for the local data).

The data sets are prepared in the Meteo object. For details, please refer to chapter 3.3.2. It is important that the Meteo object with site data is located on the actual location of the mast and with the correct measurement height; but the position for the reference data is irrelevant.

#### 11.2.1.2 Site data object

In order to get the full use of the MCP module the user can prepare a Site data object for purpose Stat-gen. Here a description of roughness, orography and obstacles around the local mast must be defined. The reason for this object is that the MCP module can calculate a wind statistic based on the long term corrected data and thus save you the extra step of running a STATGEN calculation. If you do not have WAsP interface module or do not wish to calculate a wind statistic from the MCP module you can skip the Site data object and instead write a long term corrected time series data set to a Meteo object. For details on the Site data object please refer to chapter 3.3.1.

## 11.2.2 Measure

#### 11.2.2.1 Loading data

Start the MCP calculation from the main menu by left-clicking the MCP text or by the green arrow. If the arrow is yellow you do not have a valid license for this module.

You enter the MCP calculation on the Measure tab sheet and will work your way through the tab sheet towards the right. The Measure tab looks like the window below.

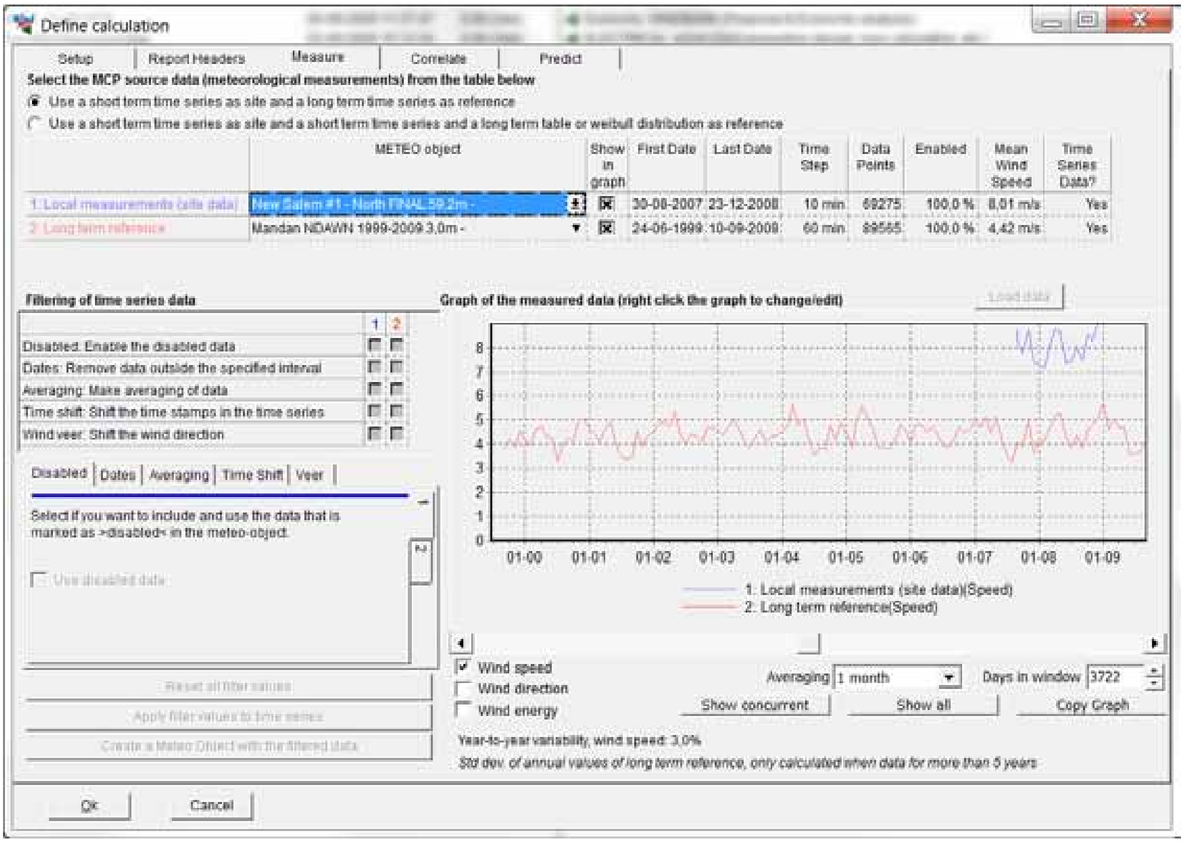



*Figure 1 Note that the Year-to-year variability is calculated for the long term reference (if at least 5 y) and shown in the lower part of the screen. This can be used later in the LOSS & UNCERTAINTY module.*

The first thing to do is selecting local measurements (site data) and long-term reference. Click on the little arrow by Select data next to Local measurements to select the Meteo object and height holding the local data. It may take three clicks to activate, select and open the selection menu. Repeat this for the long-term reference data. Press LOAD data to accept the selection and load the data. The full period time series will now appear in the graph window.

NOTE: In case that your long term reference data is available as table data only; then – in addition – you will also have to select two concurrent time series for your local mast and the reference mast respective-ly. This must be done to establish the relation (correlation, transfer function) between the two sites. When you have selected all three datasets - then press LOAD data button once again.

The local data are identified with a blue color and the reference with a red color.

Use the selection buttons below the graph to select between wind speed, wind direction and wind energy index (using generic power curve unless otherwise specified). As default an averaging of 1 month is used on the data for display purpose, but this can be changed with the Averaging selection. Also the number of days in window can be changed. A more useful view can be obtained by pressing the Show concurrent button, which limits the view to the concurrent period. Show all reverts to the full period as defined by the long-term reference.

NOTE: The most important task at this screen is to evaluate if the long-term data seem to be consistent. Often long term reference data from meteorological offices has a trend. E.g. trees have grown up around the reference mast over the years and the wind speed decrease continuously. Such data cannot be used for long-term correction! One way to see if it is so can be to start loading an alternative source for long-term data, e.g. the EMD-Online data from NCAR as “Local data” and then compare the two long-term data series.

#### 11.2.2.2 Filtering the data

The blue and the red graph provide a first visual indication of correlation. Matching graphs mean that variations in climate are represented in both data sets, which is a minimum requirement for correlation.

However data can be offset in different ways that can hide or spoil a good correlation. Such offsets can be compensated using the filtering options on the left side.

The upper part contains check boxes for each type of filtering, where it can be selected whether the filtering should be done to the local data or the reference data. The combinations selected become active in the lower part.

The lower part holds five small tabs referring to five different kinds of filtering. Each tab is divided into two vertical tabs referring to local data (blue) and reference data (red). The possible filter settings are:

Disabled
Here it can be selected whether the data, which was disabled in the Meteo object, should be included in the MCP calculation. By default the disabled parts are not included.

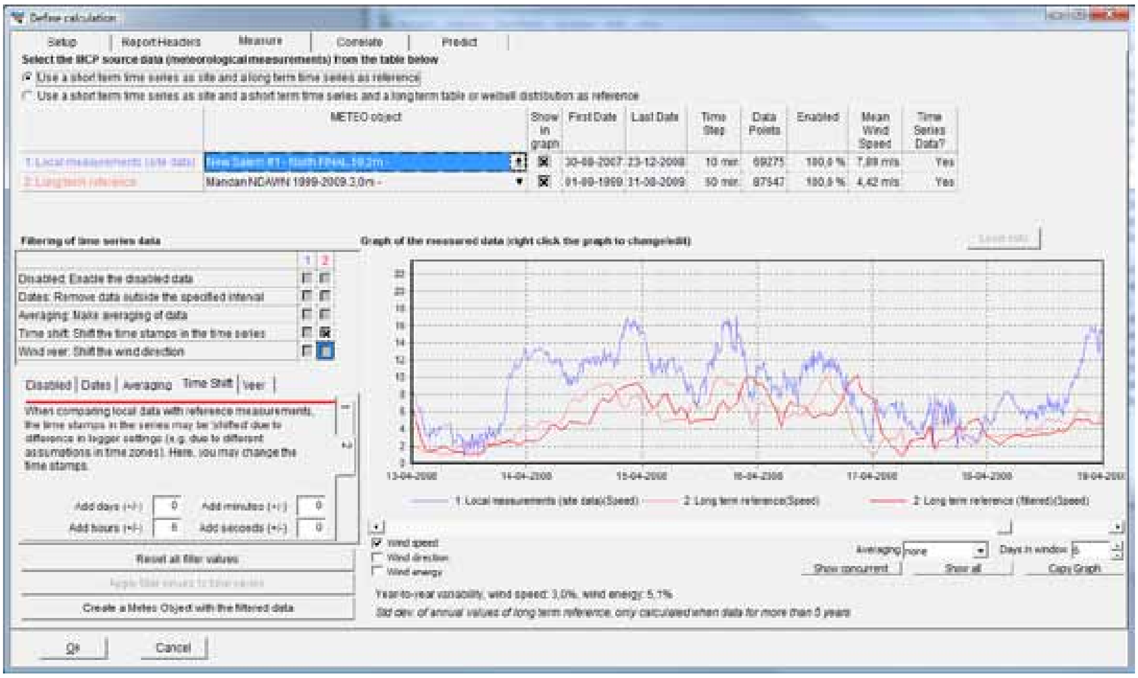
Dates
A specific period can be selected, which excludes data outside this period.

Averaging
This averages the data selected and it is possible for example for create hourly average values based on 10 minute data series. The averaging is a moving average and is made on the preceding period up to the time stamp indicated. Since the averaging time for local data should be the same as for reference data. This function is particularly useful when the reference data are hourly or 3-hourly data, but an average of the period and not the standard last 10 minutes of the period.

Time shift
If there is a time shift between local and reference data this can be corrected here. Days, hours, minutes or seconds can be added or subtracted. Since some of the correction methods build a transformation between matching concurrent data, it is important that the time stamps refer to the same moment in time.

Wind veer
Adds or subtracts an offset in the direction to local or reference data.

When one or more filtering options have been selected and specified, press Apply filter values to time series. You will now notice that the time series you filtered have split in two: a fat graph, which is the filtered values and a thin line, which is the unfiltered data.




Reset all filter values will reset your settings. Create a Meteo Object with the filtered data will just establish a Meteo object at the location of the Local data with the filtered data time series at local data measurement height.

## 11.2.3 Correlate

The idea with the Correlation tab sheet is to test for the correlation of the concurrent datasets. Actually this is a process that started in the Measure tab and will continue in the Predict tab when the individual prediction method has been chosen (and thereby also different correlation methods), but the Correlation tab is the place where much of the correlation analyses will be done.

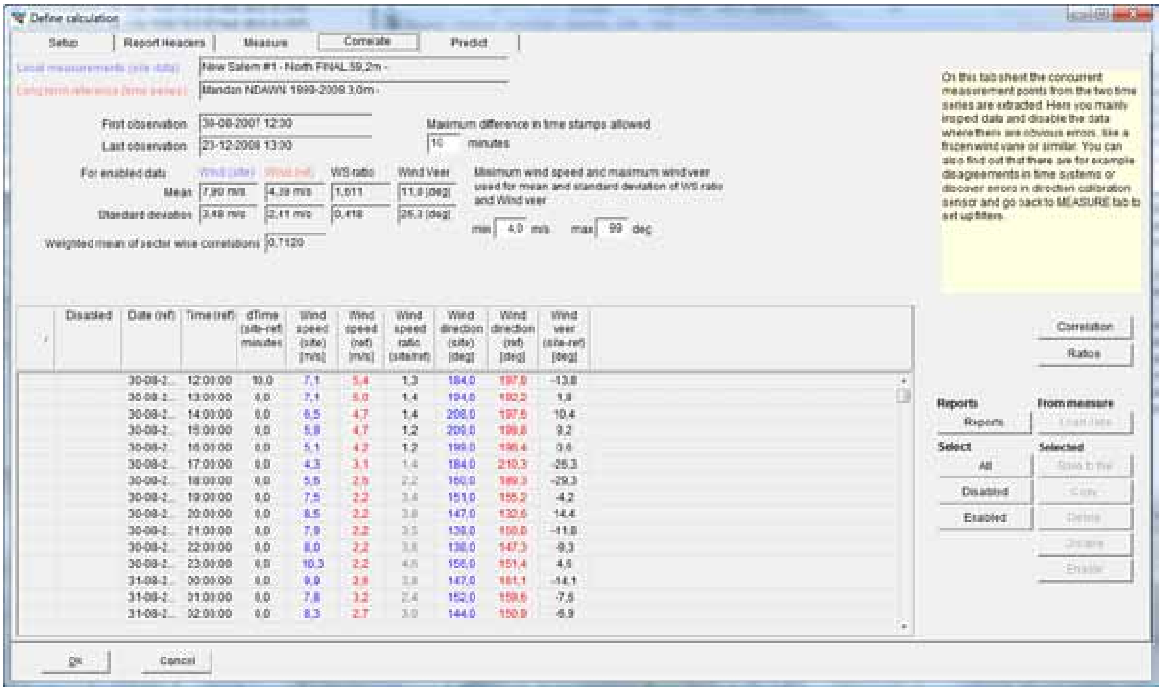
Correlation is simply when a systematic relation between the two data sets can be found. This relation can be linear, polynomial, nonlinear or on an aggregated monthly level. The point in analyzing the correlation is that if the correlation between the local and reference data are too poor, the long term prediction will also be poor, and in worst case give massive errors in the later calculated energy production. Reasons for poor correlation can be that the reference mast has another wind climate than the local mast, e.g. at the other side of the mountain, where wind conditions could be totally different. But poor correlation could also be due to poor data quality based on e.g. systematic errors in data collection equipment. If just parts of the concurrent data do not correlate well, these can be disabled. A reason could be temporarily frozen equipment in one of the data sets. Then only the well correlating data will proceed to the prediction models.

NOTE: The purpose of the correlation analyze is NOT just to disable all non-correlating data. This would give a false basis for the prediction. If the correlation in general really is poor an extract of the few good correlating data for the prediction might result in large errors!

### 11.2.3.1 Loading data

Go to the Correlate tab sheet and press Load Data. This will extract the concurrent period of matching time stamps from the Measure tab. If a filtering has been applied it is the filtered data, which are loaded.

WindPRO can allow a specified deviation in the time stamp between local and reference data and still call them concurrent. This allowance can be specified in the Maximum difference in time stamps allowed box.



The concurrent data are organized in a long table, which can be inspected directly in the table. Sort the table by columns by clicking on the column header. While all concurrent data are included in the table wind speeds less than a specified velocity and records with difference in wind direction larger than a specified veer are grayed out and not included in the calculation of the correlation. Standard limits are 4 m/s and 99 degrees.

### 11.2.3.2 Correlation

At the tab “Correlate” some basic statistics on the wind speed, wind speed difference and difference in wind direction (Wind veer) is shown. Below these is the key figure “The weighted mean of sector wise correlations”. This is the correlation boiled down to a single figure. It comes from the correlation calculated for each 30-degree direction bin weighted with the frequency of that particular sector at the reference.

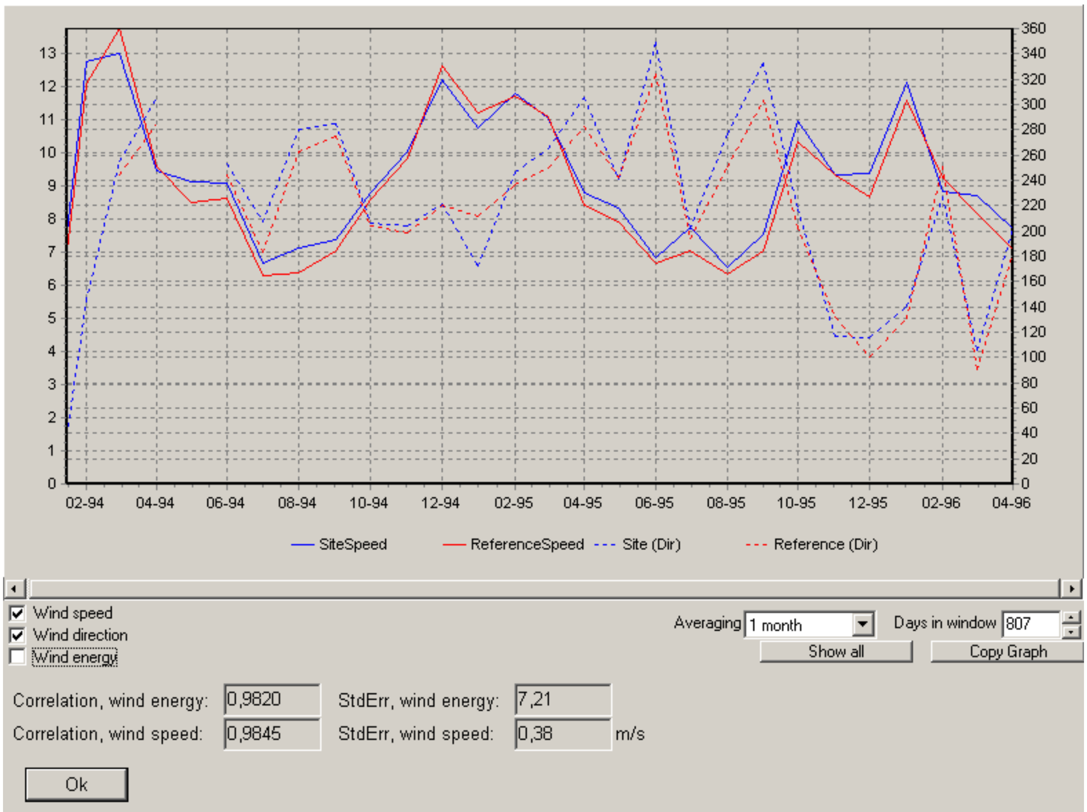
| Correlation Coefficient | Quality of reference |
|---|---|
| 0,5 to 0,6 | Very poor |
| 0,6 to 0,7 | Poor |
| 0,7 to 0,8 | Moderate |
| 0,8 to 0,9 | Good |
| 0,9 to 1,0 | Very good |

The table gives a qualitative rating of the quality of the reference as a function of correlation value. It is not certain that a high correlation means that the reference is good and likewise, a poor correlation can be sufficient for a good prediction. However, the correlation coefficient is a good indication of quality.

If a linear regression is performed, the correlation coefficient is identical to the “r” parameter. In Excel “$r^2$” is often given when doing regression analysis, but the connection to the correlation coefficient is only valid when the regression is linear.

The right side buttons on the Correlate tab

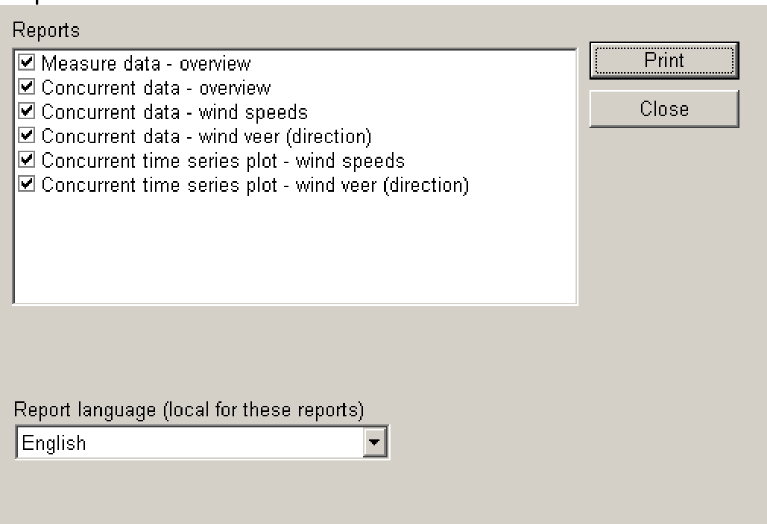
The “Correlation” button presents the concurrent period as yearly, monthly, weekly or daily averages, or not averaged at all.




It can be selected to show the wind speed, wind direction or wind energy index (calculated by specifications on the Setup tab sheet). Correlation and Standard error is calculated based on the chosen averaging.

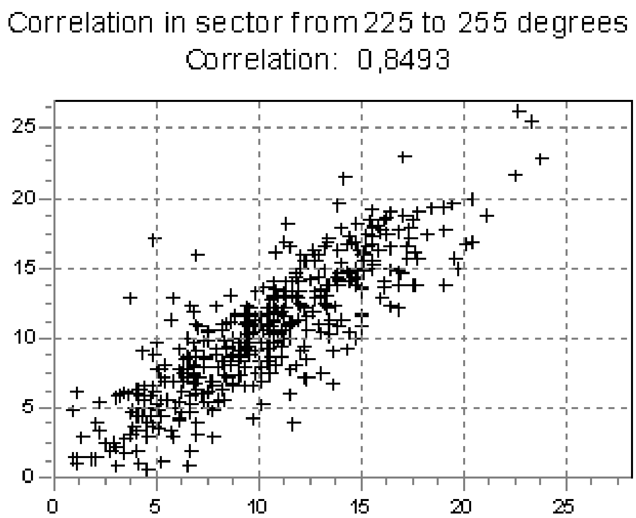
The object of this display is to give a visual impression on the correlation during the concurrent period. The two datasets must hint at the same climate and so catch the same highs and lows. With the wind energy index a representation is given on what kind of relative production can be expected for each month, as this is often what really matters.

Report



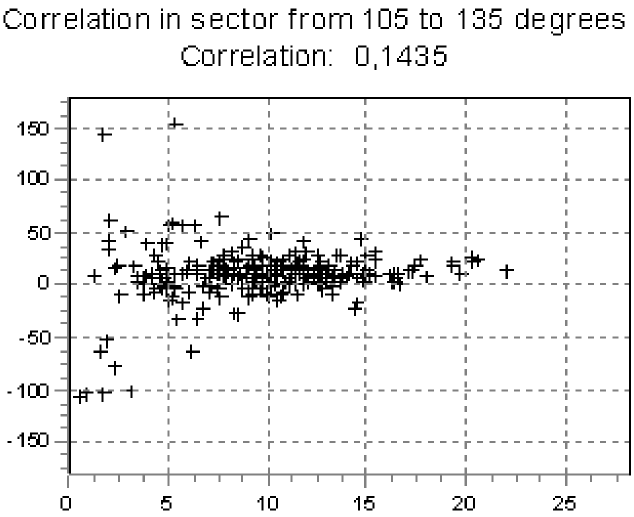

The report button gives a number of detailed results of the analyses visualized and documented.

A few examples are shown here, but the reports are in general self-explanatory.



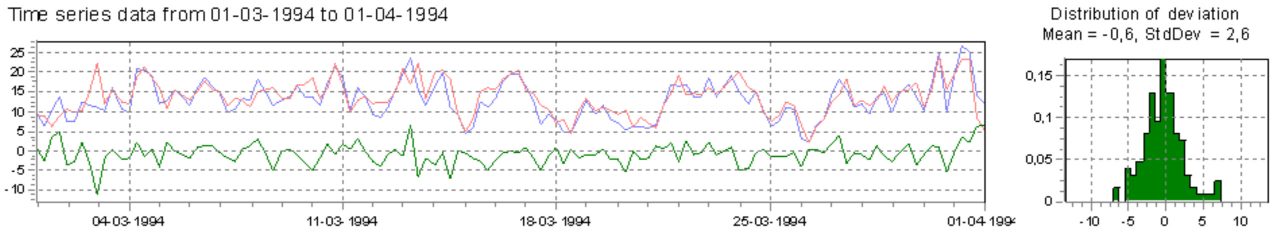

Wind speeds: Site data as function of reference data for each sector with calculated correlation.

This is the correlation typically referred to. If there is no good correlation it could be due to a change in wind direction. This issue some of the prediction methods handles, so even with a poor correlation here, the final results might come out quite well.




*Wind veer for each sector as function of wind speed.*

What is interesting here is not so much the correlation value, since the direction change should be independent from the wind speed. Actually, the veer should be constant with the wind speed. At low wind speed the veer varies significantly, but at higher wind speeds where the transformation function must perform well the veer must be well defined and not changing with wind speed.




*Time series sections with wind speed differences.*

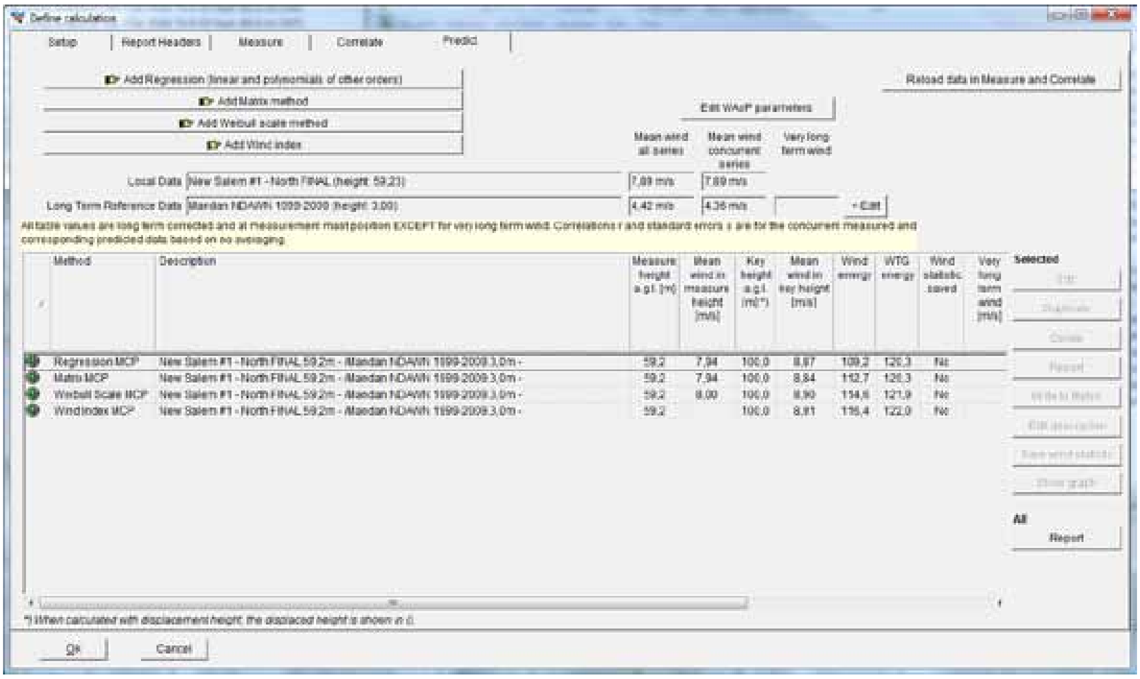
Extracted sections of the time series with the wind speeds of the reference and of the local data, and the deviation of the wind speeds. For each section the deviations are plotted in histograms and will most often resemble normal distributions, which confirms or refute whether the Matrix assumption is valid (see later).

## 11.2.4 Predict

Go to the Predict tab to perform the actual corrections and predictions.

Here four different methods can be applied on the data sets chosen in Measure and for the concurrent part extracted and fine tuned in Correlate. When a method has been applied the result will appear as a row in the lower part of the form and another method can be applied resulting in a second row. In this way a number of different methods can be tested with different parameter settings. Another reference can also be selected in the Measure tab and loaded through correlate to compare with the first selection.

When a preferred setting has been found the relevant calculation can be selected and either saved as a wind statistic with the “Save wind statistic” button or written to a Meteo object at the location and height of the local data with the “write to Meteo” button.



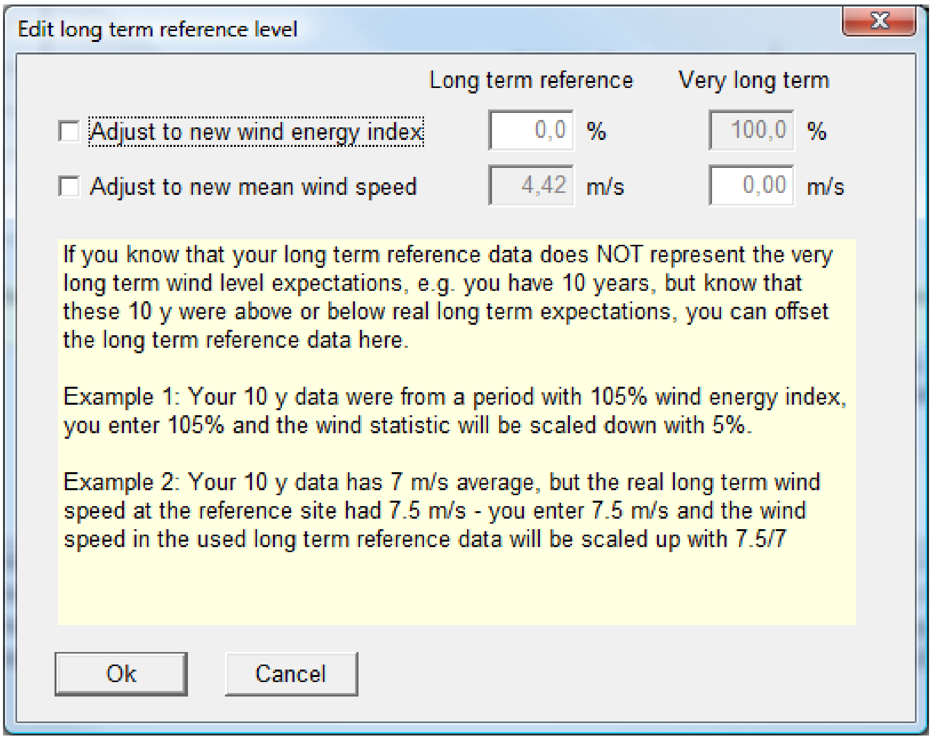

*At the "predict" form different prediction methods can be started and the results evaluated, compared, reported and saved as results, either in a Meteo object or as a wind statistic.*

Data basis

The data resource for the prediction is listed in the two rows in the top; Local data and Long-term reference data. These rows give the mean wind speed of the entire length of the data set and the concurrent part.

WindPRO will retain information on which time series were used the last time the MCP calculation was run, but it will need to reload the data series every time you restart the MCP calculation. Pressing the “Reload data in Measure and Correlate” is a one-touch way to do that.

If it is known that the correct long-term level (here called the very long term level) is different from that of the long-term reference it is possible to change this with the Edit button.




The adjustment of wind energy index level makes a correction to the resulting wind statistic, which is applied when it is used to calculate production output.
The adjustment to a particular new mean wind speed adjusts all the wind speeds in the resulting time series so the new average becomes this value.

#### 11.2.4.1 Long-term correction methodologies

The long-term correction methods are described in detail in the theoretical section. The following text only deals with the practical application and gives a short guide to best practice.

**Regression** and the **Matrix** methods are both classical MCP methods. They build a transformation function based on the concurrent data, which is used to convert the reference data to the conditions on the site of the local measurement. The success on this conversion is largely based on the ability to successfully transfer the reference data to the site and, secondly, consistency in reference data outside the concurrent period with the local data.

The first requirement is covered by the correlation coefficients, but this should include a well-defined relation between the wind directions at the two sites and a sufficient frequency of measurements, particularly for the reference data. Well correlating ground stations will usually be predicted well with these methods, while reanalysis data will often be too infrequent and with too poor directional correlation to give an adequate prediction. If the relation is linear of nature the Linear regression method will often be a good choice, while non-linear relations are often best handled by the Matrix method.

Long-term consistency is more difficult to detect from the data. Sudden jumps in data or sloping trends can indicate inconsistency. This is most easily detected when comparing two different long term data sets in the Meteo objects (or at the measure tab sheet by loading an alternative long term data series as local data). But most often the inconsistency will be detected by studying the history of the metering. The most common sources for inconsistency are:

The mast has been moved
The anemometer was changed to a different height
The anemometer was replaced with another instrument of different calibration
Houses or trees were placed or removed from the fetch of the mast
Growing trees are a particularly sneaky contamination because it happens gradually over many years. Particularly low masts are suspect to this kind of influence

It is more difficult to look at the history of reanalysis data because they consist of so many different sources of input. That makes them less vulnerable to individual contamination, but not impregnable and the sources have been changing over time.

As a rule of thumb reference data can be used as far back as the latest source of inconsistency.

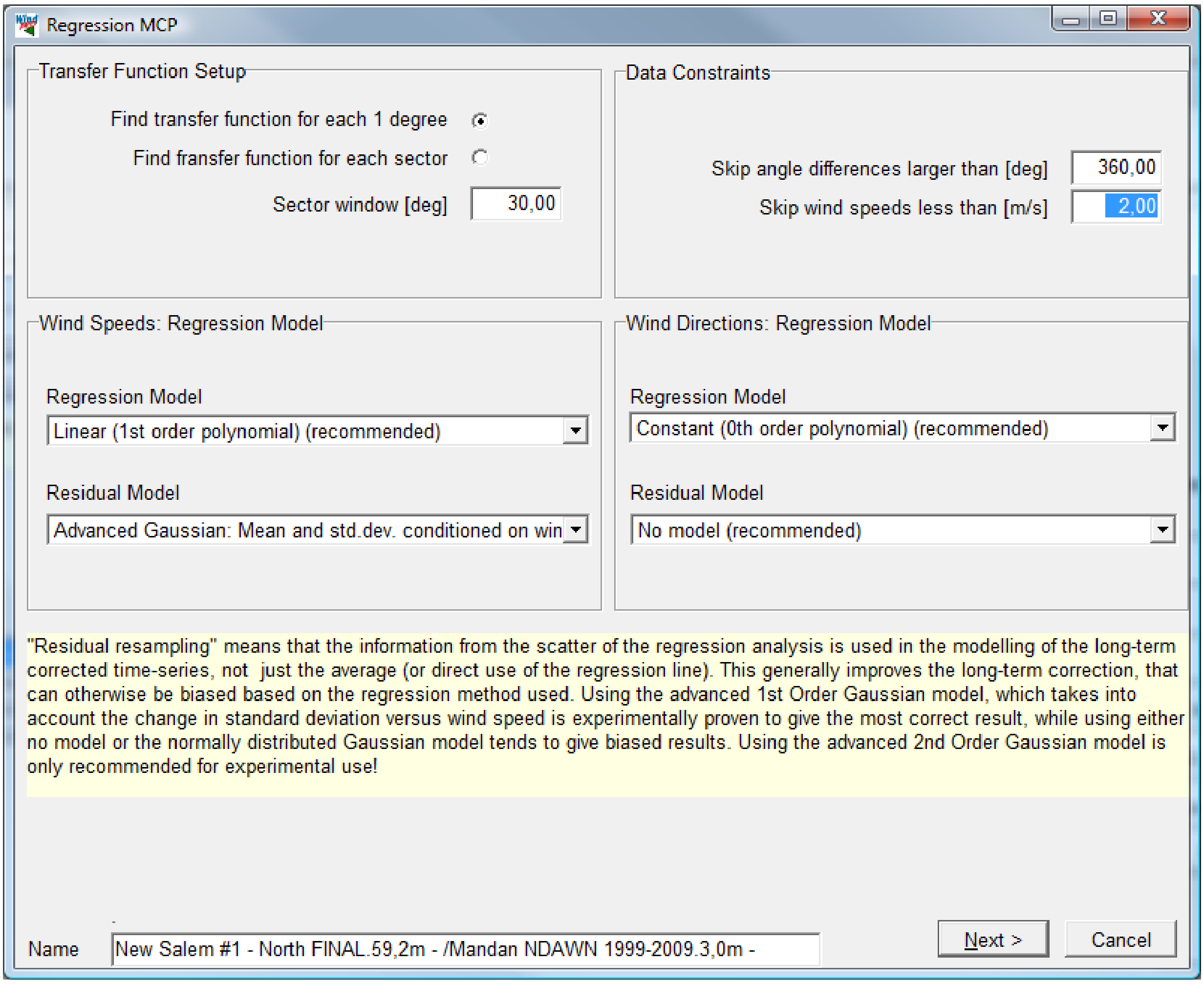
When the quality of the reference is not good enough, like with reanalysis data, the **Wind index** method is an option. With this method the energy study is performed on the actual measured data and only the final result is adjusted with a correction factor. This factor is based on the relationship between the entire reference and the concurrent part of the reference and only relates to wind speed converted to wind energy. Therefore a wind direction correlation is not so necessary and a good match on the matching concurrent data points is not so important if the correlation exists on the larger scale, like monthly basis.

The **Weibull scale** is the maverick method that does not really involve a transformation function and with a linear scaling of the Weibull parameters does not even involve good math. Nevertheless, because it scales the wind data with the distribution that best describes them, it is able to predict the long term wind regime surprisingly well. Therefore it is an excellent second opinion method that attacks the problem from another angle.

#### 11.2.4.2 Regression model

To run the Regression model press the Add Regression button.

This opens the parameter selection window. The parameters are pre-selected with settings and values, which will be suitable for most situations. Only in cases where special tests are wanted or data require special attention there will be a need for change of parameters.




*Parameters for transfer function calculations including residual resample model.*

The parameter settings are from the top down:

Transfer function type - Sector handling
The transfer functions can be made for either x sectors or for 360 directions, meaning 360 transfer functions. Division in a number of sectors (typically 12) is the typical way for “home made” Excel applications. This should be chosen for comparison with such calculations. But letting the software tool do the hard work, making 360 transfer functions based on a specific window size will be more accurate and is here chosen as default.

Sector window
Each transfer function will be made on the basis of data from a range of directions centered on the direction in question. The directions refer to the reference directions and 30 degrees is default. If 360 are chosen only one transfer function is made based on all data.

Skip angle difference larger than
Particularly at low wind speeds the angle between matching reference and local data may deviate significantly and cause a lot of noise. By rejecting point with large difference in direction this noise can be reduced. However this means discarding information that could be important. Default all data are included.

Skip wind speeds less than
As very low wind speed contribute with a lot of noise and often deviate from the linear relation seen at higher wind speeds it is useful to simply discard them from the transformation function. This does not mean that they are discarded from the full reference data set being transformed though. Depending on the amount of noise and actual wind speeds at the reference this limit can be set freely but 2 m/s is default.

Regression model (wind speed)
Here the type of regression on the wind speed is selected. Linear regression means first order and a two component linear regression will usually be preferable to a regression through origo (0,0) as this provides a better fit in the wind speed range relevant to production. This is also default. An alternative is a $2^{nd}$ order regression, which will fit a parabolic curve to data. This may create a better fit, but allow deviating extreme wind speeds to influence the fit at high wind speeds.

Regression model (wind direction)
Usually the direction change is independent from wind speed and so a $0^{th}$ order regression should be used.

Residual model
The residual resampling method from v2.5 had the limitation that the regression plot needed to have the same spread in the scatter at all reference wind speeds and that the scatter had to be centered on the regression line. Basically the transfer function became $y = ax + b + e$. Applying this method on data sets with poor correlation or oddly distributed scatter could lead to an error, often seen as an over-prediction. In such cases the advice would be to simply not do residual resampling.

In v2.6 and later it is still possible to perform the residual resampling in the same way as used in v2.5. It is now called “Gaussian resampling”. In addition we have added an “Advanced Residual Resampling” method. This method is a function of the reference wind speed so that the regression formula now is: $y = ax + b + e(x)$. The reference wind speed range is divided into a number of intervals. Within each interval the observed scatter is found as a standard deviation of the scatter together with the bias on the observations. Both are then applied when transferring the reference data to the site. The bias of the mean of data can be illustrated by switching on a LOWESS fitting to the regression curve. The observed standard deviation is modeled as either a first or a second order polynomial and is displayed in the scatter plot on the right (see Figure 52). The result is a much more dynamic fit than a standard linear regression. On well and fairly well correlating data, internal tests have shown a significant improvement on the precision of the long term prediction. The second order residual resampling do have the problem that few very scattered points at high wind speed can exaggerate the resampled scatter unreasonably. It is therefore recommended to use it carefully and if in doubt stay with the default first order advanced Gaussian residual resampling.

Press Next to calculate the regression functions.

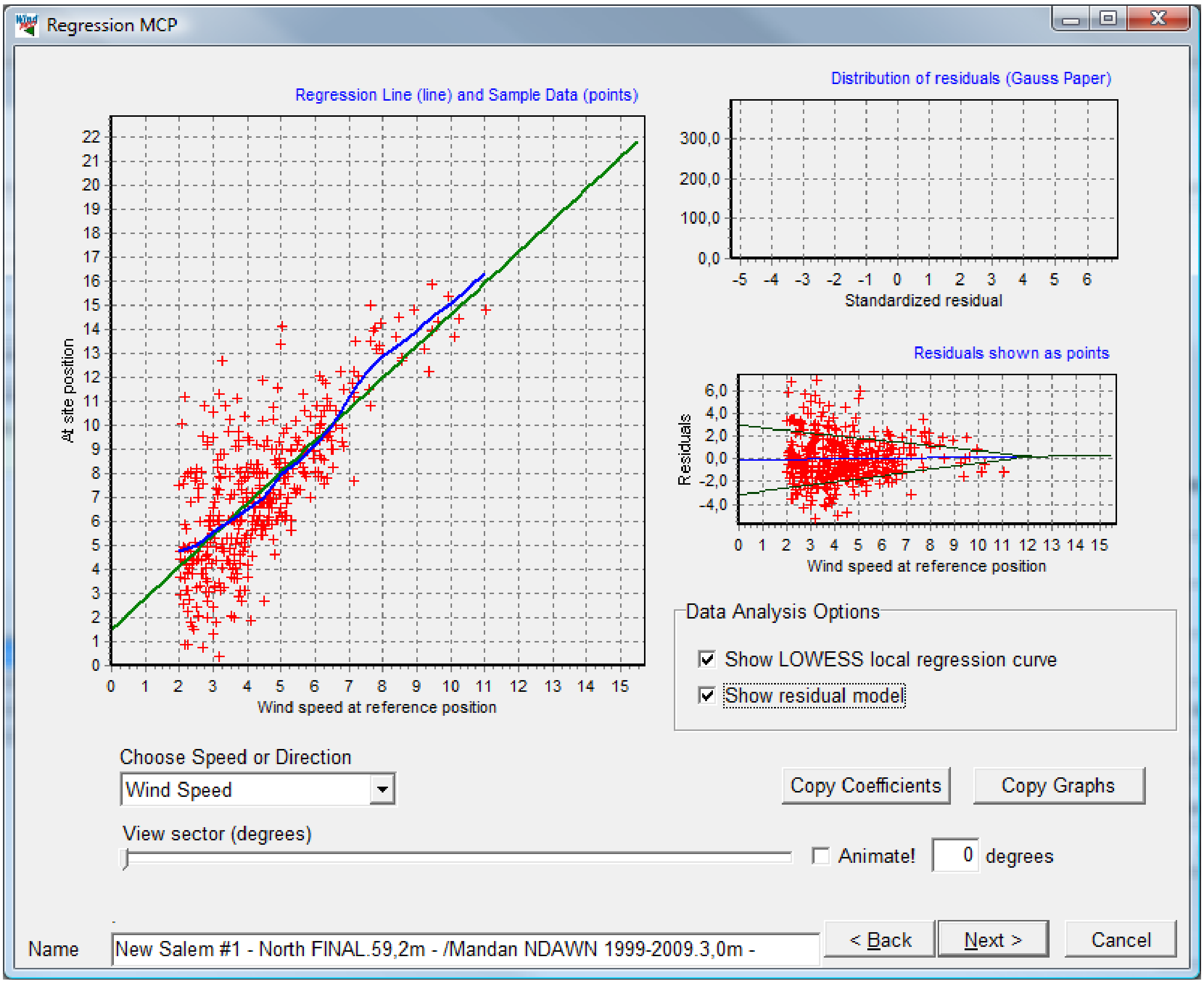
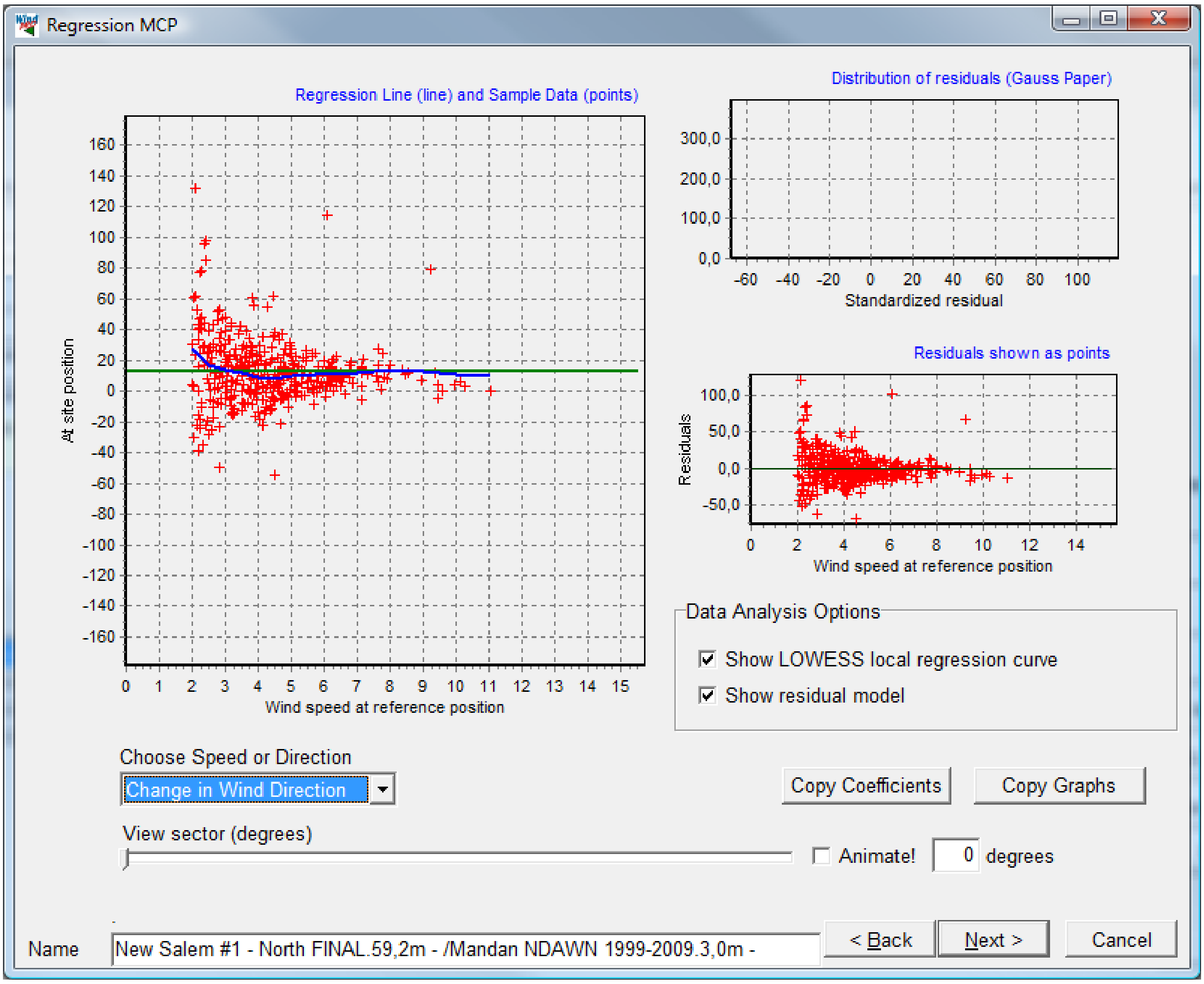



*Figure 2 Linear regression fitting illustrating the LOWESS local regression curve (blue fitting) and the advanced residual model (green curves in scatter plot).*

*Three graphs are presented as described in the theory: The site wind speed against the reference wind speed and the best fit, the residuals and the distribution of residuals.*

The presentation of the regression fits is divided into a wind speed page (above) and a wind direction page (below). The wind direction for which the regression has been made can be viewed using the bar or the selection field below the graphs. Animate will slowly scroll through the directions. The direction shown is the center angle and the points shown those within the window width specified at the previous form.

The closer the data points are to the regression fit the better prediction can be expected. How much the residuals scatter can be seen on the Residuals shown as points plot, where the modeled residual re-sampling is also shown. If this modeling of the residuals seem to fit the actual distribution of the residuals the residual model is a good choice to the transformation.

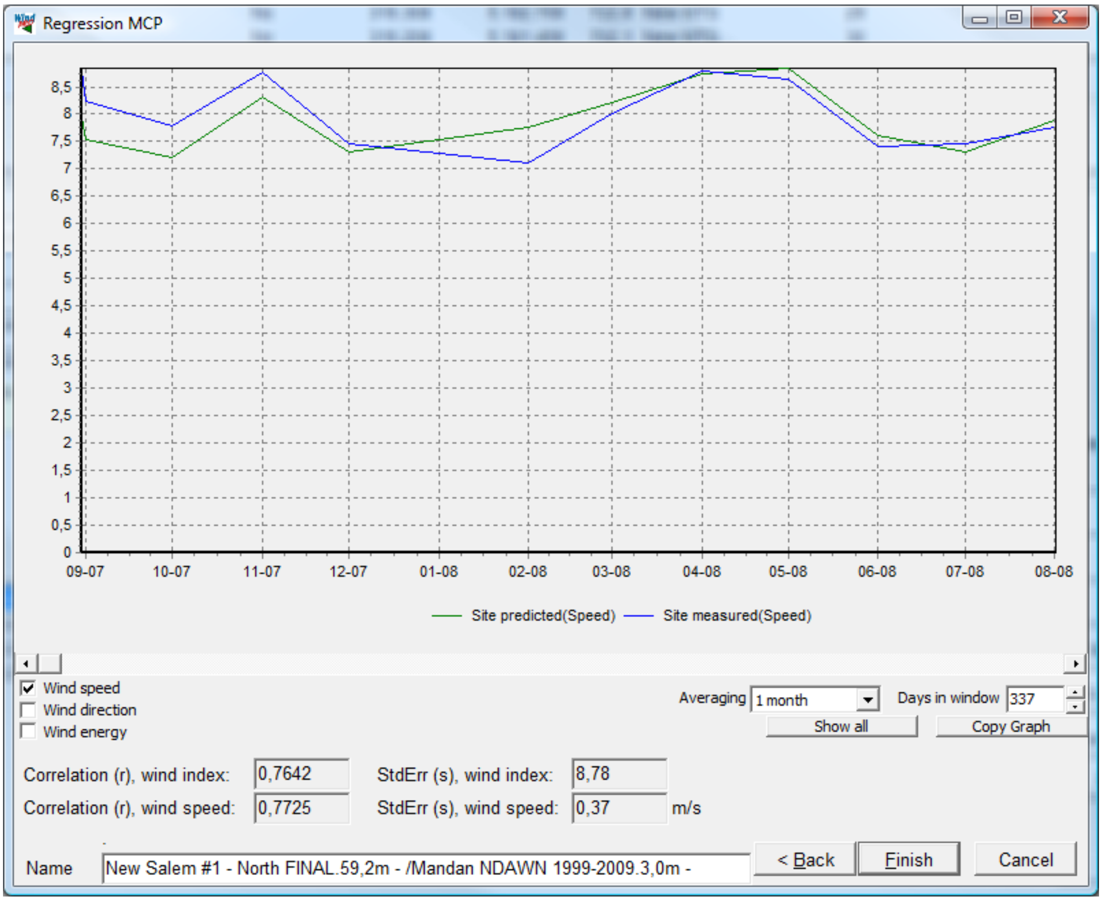



*The wind direction page is similar, though the regression fit is different. Direction changes get better defined with higher wind speed but the average value should not change.*

Copy Coefficients will copy the regression parameters to the clipboard (typically for paste into Excel) in 15 degree sectors, while Copy Graphs will copy the graphics to clipboard (typically for paste into documentation).

The wind direction page is similar, though the regression fit is different. Direction changes get better defined with higher wind speed but the average value should not change.

Press Next to perform the conversion and test how close the prediction is to the measured values.




*Comparing predictions with the measured data is the "ultimate" test of how well the prediction model performs.*

This page is similar to the Correlation graph of the Correlation tab, except for a few extra key result fields. The correlation on wind speed and wind energy tests the correlation between the predicted and the measured wind speed using the selected averaging. Because of the smoothening over the longer periods this parameter often correlates better with a longer averaging, but such a correlation is not comparable with correlation using shorter averaging periods. The standard error gives the typical difference between concurrent values in the resulting graphs.

For a transfer function to perform satisfactorily it must be able to transform the concurrent part of the reference time series into something resembling the measured time series. A good correlation on monthly energy averages is a good indication of successful prediction of production output.

When pressing finish, WindPRO asks to continue to generate a wind statistics (or just end with the meteo data). The wind statistic will be based on the entire long term corrected local data set.

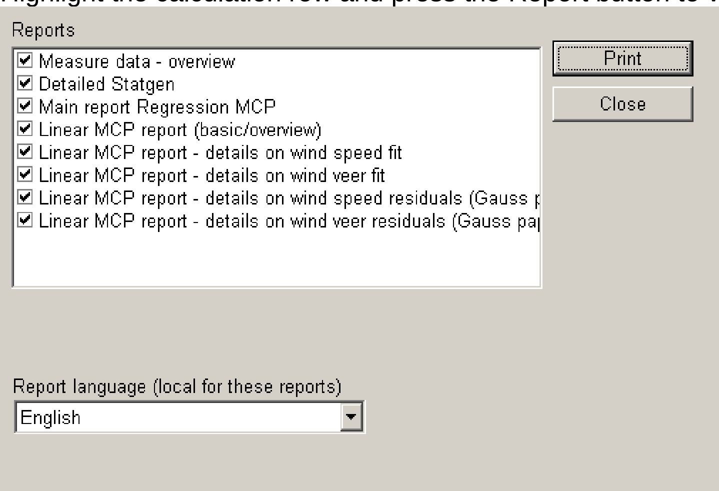
To start the calculation of a wind statistic the program will call WAsP. Two calls will actually be made: One for generating the windstatistic and one for calculating the wind speed based on the wind statistic – both based on the coordinates of measurement mast position.

A row will have appeared with key figures for the calculation. The row will contain the following parameters:

Measurement height of local data
Predicted mean wind speed at measure height (based on Weibull fit)
The key calculation height selected in the Setup tab
Predicted mean wind speed at key height based on a WAsP calculation
Relative wind energy level for using the wind statistics relative to 3300 kWh/m2/year for roughness class 1 and 50 m hub height
Relative WTG energy level for using the wind statistics relative to 1025 kWh/m2/year for roughness class 1 and hub height 50 m. This figure is directly related to the production output resulting from using these data. That makes it possible to compare the consequence of applying different models, parameters and references directly measured in relative calculated wind energy production.
A flag set if the wind statistic is saved.
The very long term wind speed level
The very long term wind index
Correlation factor r on individual measured and predicted wind speed
Standard error on individual measured and predicted wind speed
Correlation factor r on monthly mean wind energy indexes
Standard error on monthly mean wind energy indexes
Time stamp for the calculation

To the left of the row a green button will indicate that the result up to date and ready for export. A red button indicates that the result needs to be rerun to be updated as the resulting time series and wind statistics are not preserved when leaving the MCP module. A yellow button means that the raw data needs to be reloaded before updating the calculation.

Regression report
Highlight the calculation row and press the Report button to view the result printout.

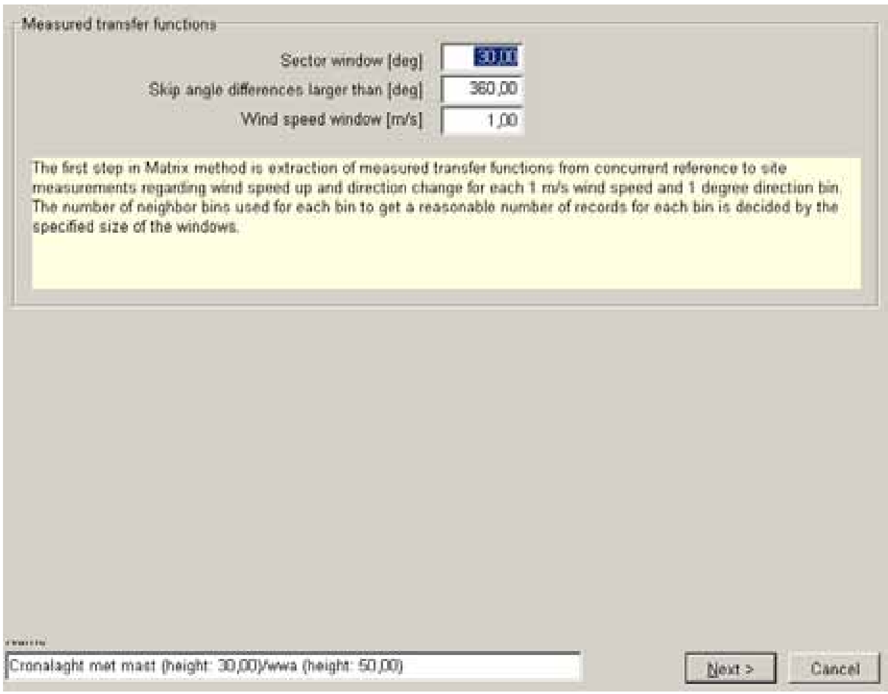



*The available reports from regression MCP.*

The reports should be self-explanatory.

### 11.2.4.3 Matrix

Press Add Matrix method to start the wizard. This opens the first parameter page.




*Parameters for transfer function calculations.*

The parameter settings are from the top down:

Sector window
Each transfer function will be made on the basis of data from a range of directions centered on the direction in question. The directions refer to the reference directions and 30 degrees is default. If 360 are chosen only one transfer function is made based on all data.

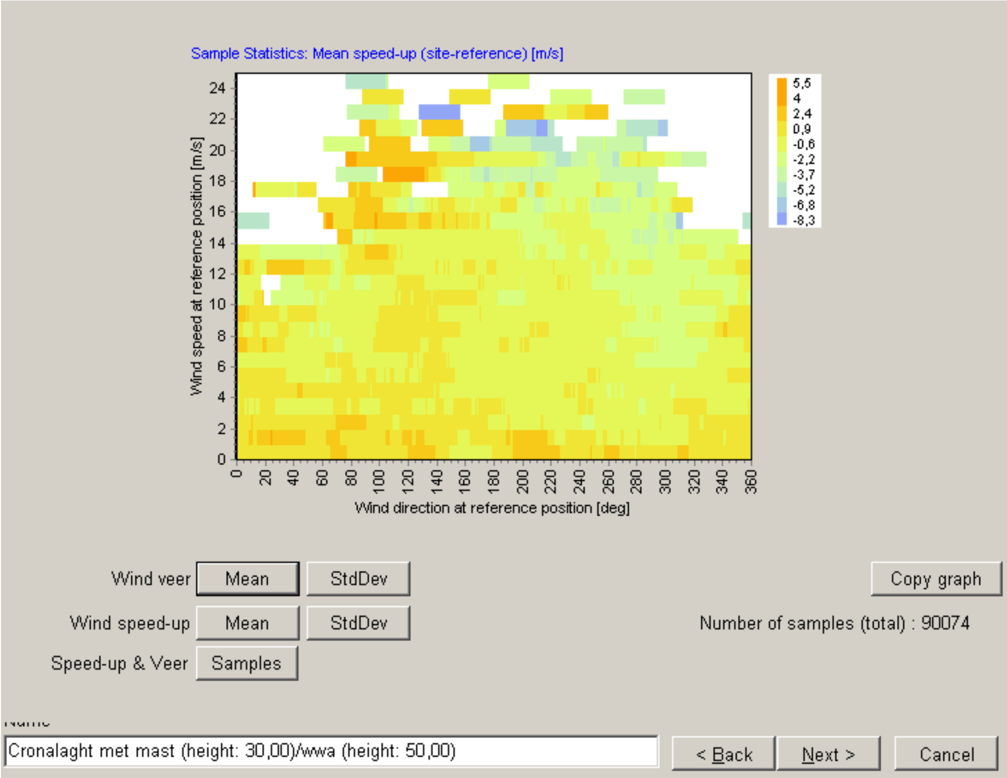
Skip angle difference larger than
Particularly at low wind speeds the angle between matching reference and local data may deviate significantly and cause a lot of noise. By rejecting points with large difference in direction, this noise can be reduced. However this means discarding information that could be important. Default all data are included.

Wind speed window
Since the Matrix builds a list of possible outcomes for the transformation for each degree and each 1 m/s wind speed bin, you can decide to include also neighbor wind speed bins for each bin in calculation. Default only the wind speeds within the bin in question is used.

Press Next to calculate the measured relations between reference and local data for concurrent data sets.

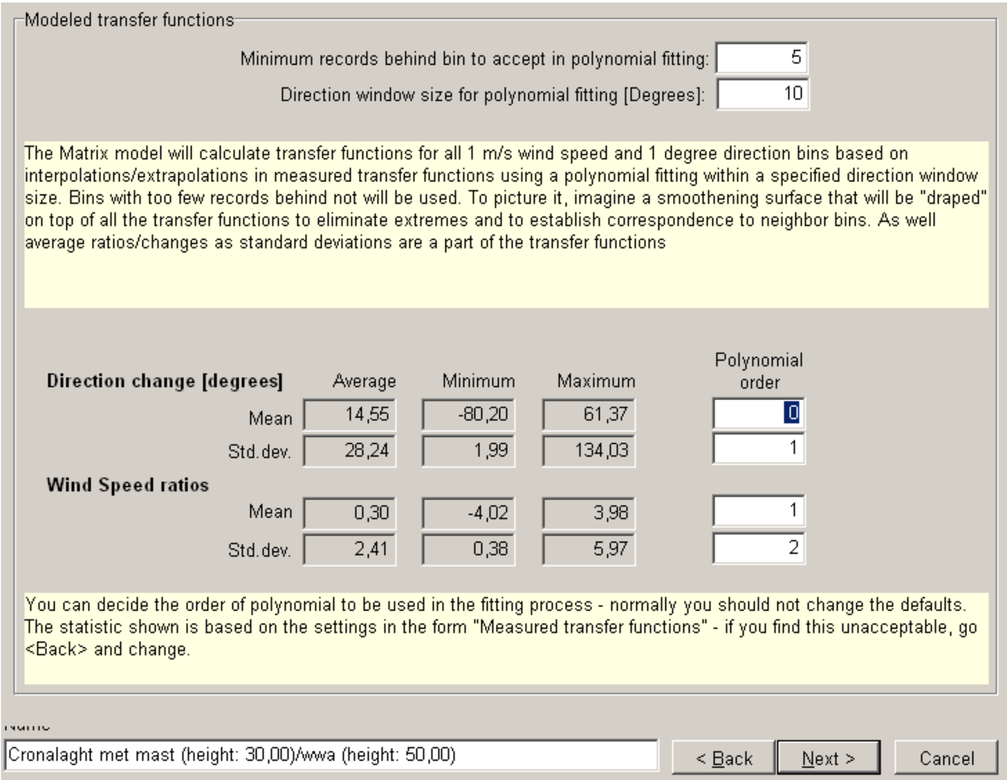
The distributions are plotted in colorful plots presenting the mean and standard deviation of the lists of wind speed and wind direction changes registered for each bin. The color-coding indicates the magnitude. The standard deviation on the wind direction change is often large at low wind speeds, but decrease with higher wind speeds. In general the lower the standard deviation the better precision on the transformation, however it is a strength of the Matrix method that it can cope with the scatter.

The samples button presents a plot of the location of the concentrations of samples. This number is much larger than the actual number of concurrent data points because each data points typically are used like 30 times if a 30 degree window were chosen.




*The measured transfer functions*

Press next to proceed to the second parameter page.




*Set up for Matrix model calculation*

Now the measured transfer functions will be converted to a “full model”, so also the direction-wind speed combinations that did not have enough data to get a measured transfer function, will get one. But also a smoothening of the calculated ones could be an improvement.

Minimum records behind…
To avoid bins based on very few data records to influence the model, these can be filtered.

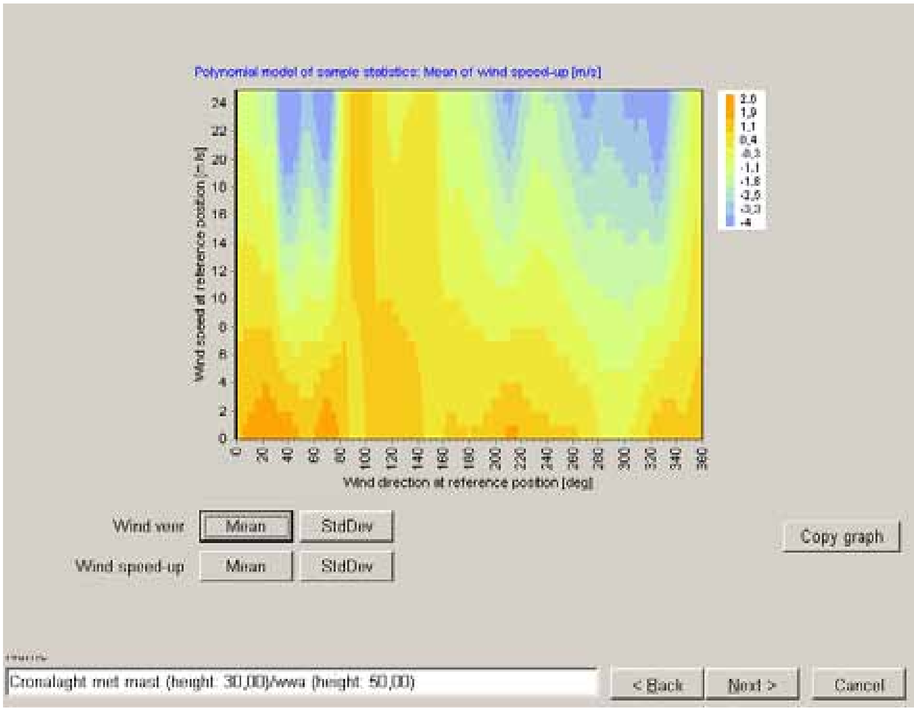
Direction window size…
Transfer function regression will be based on all transfer function within a specific window width.

The observed extreme minimum and maximum values of mean and standard deviation on direction and wind speed change are listed. Extreme values indicate highly uncertain transformations. If this shall be changed, you must go back to the setup of the parameters for calculating the transfer functions.

Polynomial order
For each of the parameters a polynomial regression can be fitted to describe the transformation function. The order can be freely chosen and can even be different from parameter to parameter. The default choice for mean wind speeds is a 1st order fit as this is less sensitive to deviating extreme values. For mean change of wind direction a 0th order polynomial is default (wind speed independent direction change). For the standard deviations, 1st order higher is recommended for wind veer and 2nd order for wind speed.

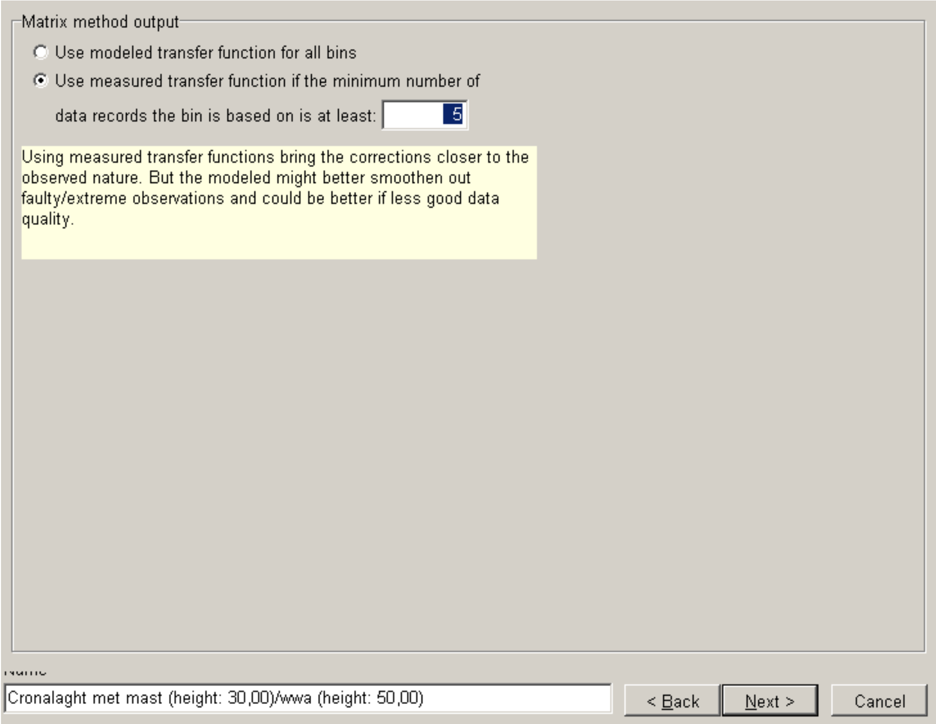
Press Next to continue

On this display page the model parameters can be viewed in the form of mean changes and standard deviation of the changes.




*The modeled transfer functions*

Press Next to continue.




*Output options for transferring long-term reference data to local site.*

Use modeled transfer function for all bins
If this is chosen only model transfer functions will be used, which give more smoothening. Alternative is to use the measured transfer functions directly, if at least x records behind the transfer function. Using measured transfer functions mean that each reference data point is transferred to the site by randomly picking a destination value among the observed values for that particular bin.

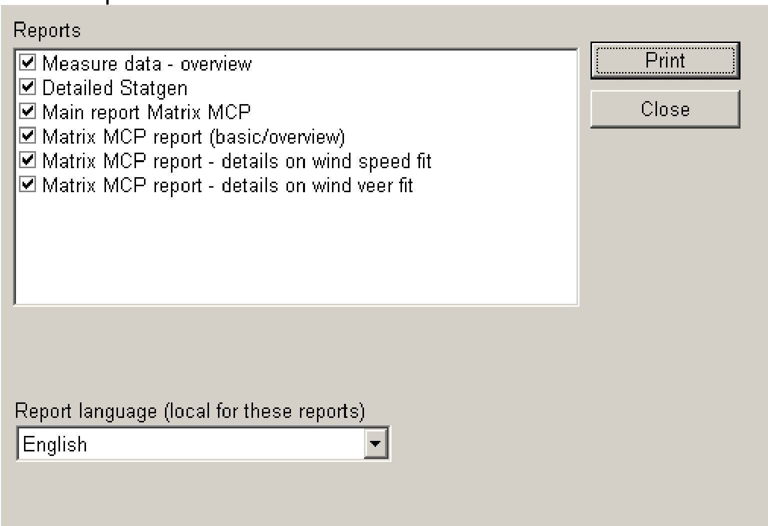
Original data
The data being converted with the transformation function will usually be taken from the time series and in that case be in sequential order rather than random order as this allows the predicted time series to be compared with the measured one. However if the full reference is only available as a directional distribution (.tab file) data must be taken from the table tab or the Weibull tab of the Meteo object and sequential transformation is not possible.

The next page is the comparison between predicted and measured data of the concurrent period. This page is described in detail for the Regression model. Note that because of the random scatter nature of the Matrix transformation the individual data records may be predicted less good than with linear regression. With longer averaging periods however this difference has been evened out.

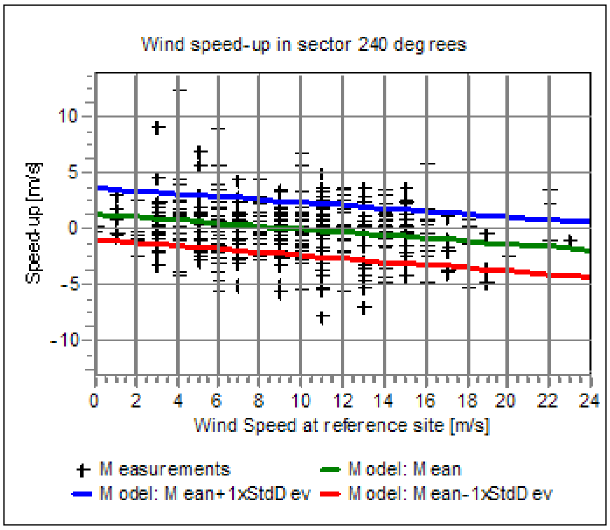
When pressing finish, WindPRO asks to continue to generate wind statistics (or just end with the meteo data). The wind statistic will be based on the entire long term corrected local data set.

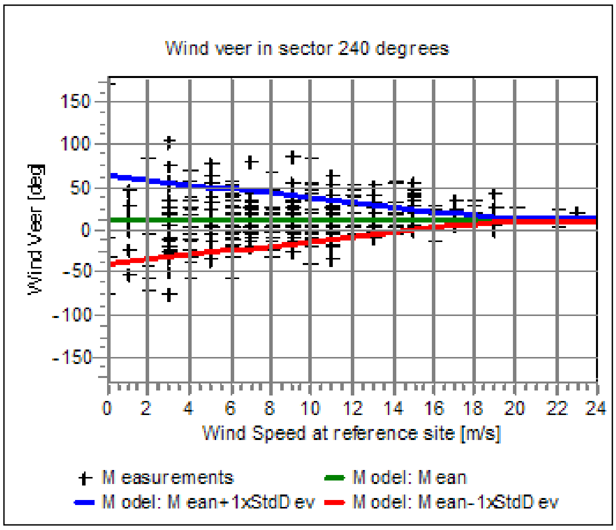
A new row is created in the history list.

Matrix report




Reports should be self-explanatory. Some examples from reports are shown below.



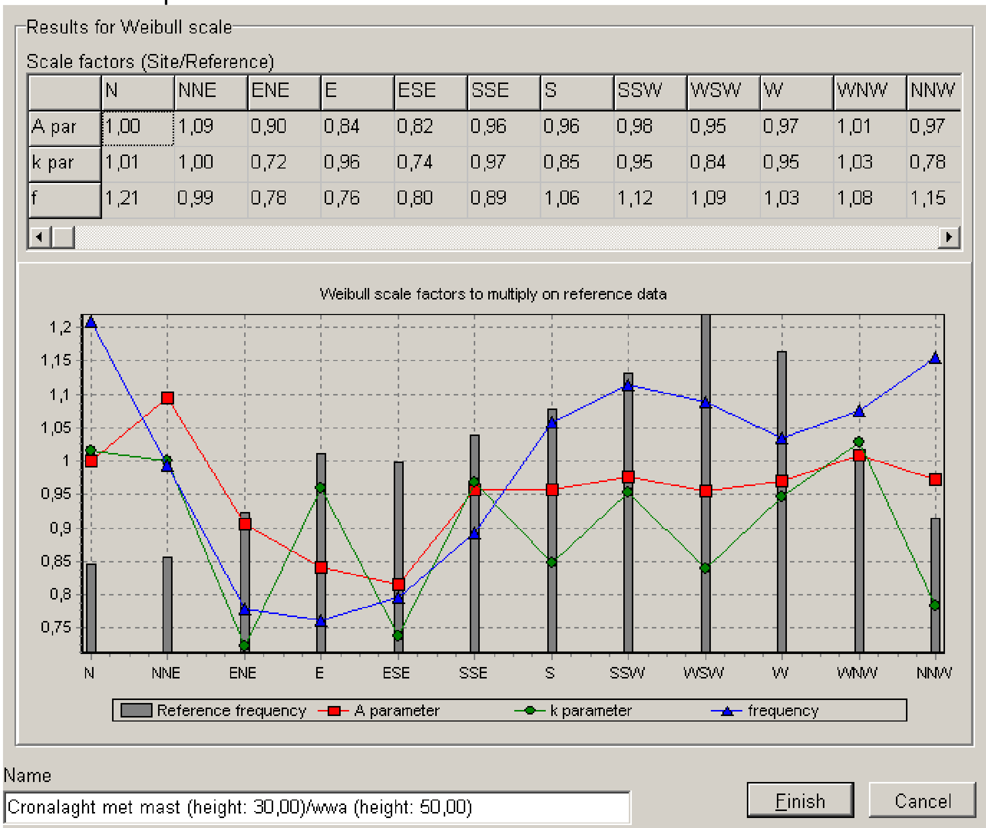




*In the report each direction sector are plotted visualizing measurements and model.*

### 11.2.4.4 Weibull scale

The Weibull scale solver is started by pressing Add Weibull scale method.

There are no parameters to be chosen.




| | N | NNE | ENE | E | ESE | SSE | S | SSW | WSW | W | WNW | NNW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A par | 1,00 | 1,09 | 0,90 | 0,84 | 0,82 | 0,96 | 0,96 | 0,98 | 0,95 | 0,97 | 1,01 | 0,97 |
| k par | 1,01 | 1,00 | 0,72 | 0,96 | 0,74 | 0,97 | 0,85 | 0,95 | 0,84 | 0,95 | 1,03 | 0,78 |
| f | 1,21 | 0,99 | 0,78 | 0,76 | 0,80 | 0,89 | 1,06 | 1,12 | 1,09 | 1,03 | 1,08 | 1,15 |

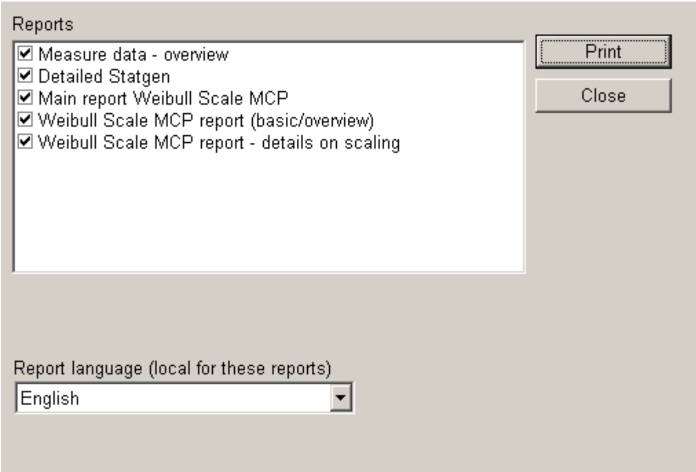


*Weibull scale shows the calculated scale factors for Weibull A, k and frequency.*

When pressing finish, WindPRO asks to continue to generate wind statistics (or just end with the meteo data, here no time series will be established, only the Weibull distribution). The wind statistic will be based on the long term corrected local data set.

A new row is formed in the history list. With this model no correlation between measured and predicted concurrent period can be calculated, as the method does not generate a transformed sequential time series. These figures are therefore missing from the result row.

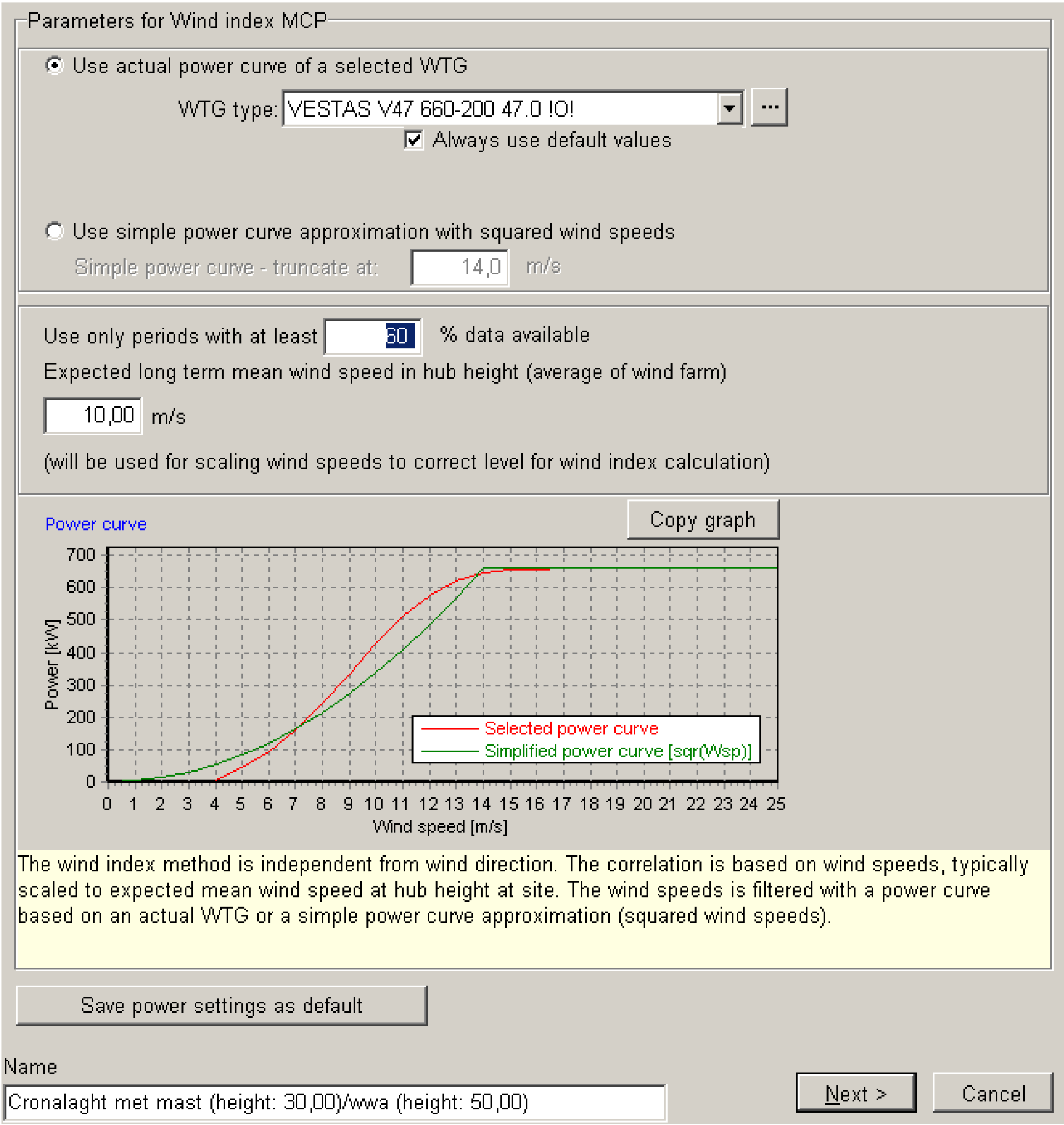
Weibull report
Page one is identical to page one of the regression model.
Page two gives the Weibull and frequency parameters for each sector for the data sets involved in the calculation. Also the resulting correction factors and the resulting long term corrected Weibull and frequency parameters are given.




*The reports of the Weibull scale MCP*

### 11.2.4.5 Wind index

The Wind index solver is started by pressing the Add Wind index button.
The settings window appears.




*Setup for wind index MCP calculation.*

The measured wind speeds must be converted to power output values. This can be done in two ways:

Actual power curve
The power curve for the turbines involved in the project can be chosen in the WTG type field. This accesses the wind turbine catalogue and the mode of selection is identical to selecting turbines in the WTG property dialog box (chapter 2.5.2).

Simple power curve
As an alternative a simple power curve can be used by checking the Use simple power curve box. The simple power curve is the squared wind speed truncated at a wind speed given in the Truncate at field. The simple power curve is useful for projects where no specific turbine type has yet been chosen.

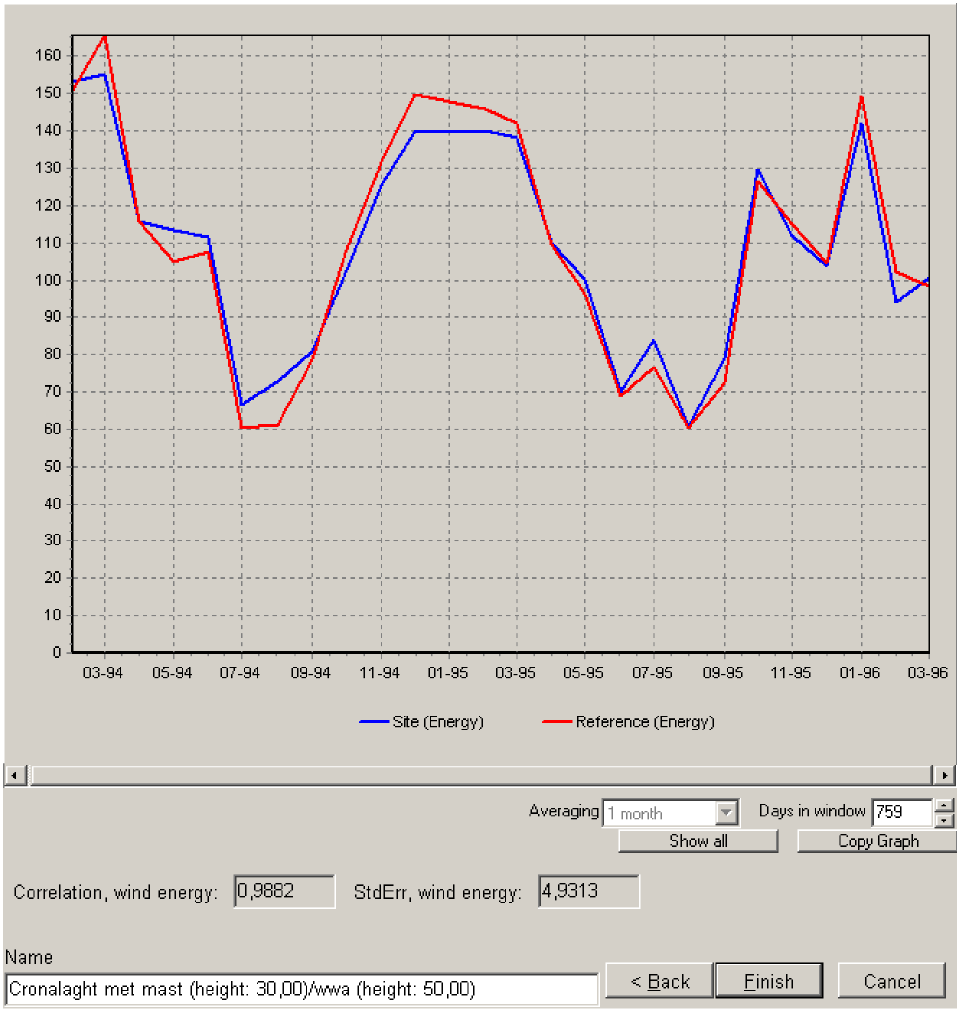
The graph compares simple and actual power curve. It can be copied or edited using the two buttons to the right.

Use only periods with at least …
This option is used to exclude months, which are poorly represented in the concurrent and/or long term reference data sets. While such months does little harm to the actual correction the correlation parameters can be badly affected by months with only few data points. The data are excluded only from the visual presentation and calculation of correlation. All data, including months with few data, are included in the actual wind index correction.

Scaling
If the mean wind speed for the local data or reference data differs a lot from the expected wind speed at hub height at site, different parts of the power curves will be used and the correction factor will be wrong. The user must therefore enter expected approximate (+/- 0.5 m/s) long term mean wind speed at hub height – which might not be known at calculation time, and there might therefore be a need for a few iterations. It works in this way: The Long term reference is first scaled to the wind speed entered. Then for the concurrent part of the reference data the average wind speed is found. This is then used to scale the concurrent local data. As scaling compares to applying a shear factor to the data this is a valid modification of data.

Pressing Next compares the energy index of the concurrent period for local and reference data. The averaging can be changed but the correlation figures relate to the monthly averages like in the Correlation tab. A difference is that the concurrent reference data are normalized with the full reference, which is set to 100. The concurrent site data are normalized with the same value as the reference concurrent.

The better the graphs match the more successful the correction has been.

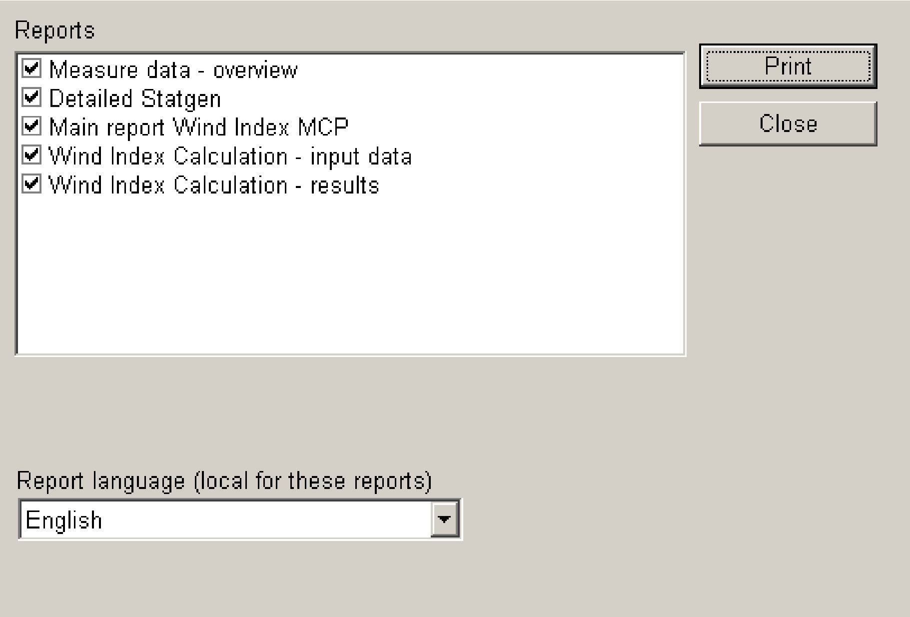



*The wind index method only compares the wind energy level of the prediction based on reference data with the measured.*

When pressing finish, WindPRO asks to continue to generate wind statistics (or just end with the meteo data). The wind statistic will be based on the entire long term corrected local data set, not just the concurrent part.

A result row is generated. Like with the Weibull scale method no correlation between measured and predicted is given. Instead the correlation and standard error is between concurrent site and reference data. A new parameter though is the Correction from Wind index. This is the correction factor, which will be applied to the production result when using the wind statistic generated from this calculation.

Wind index method Report

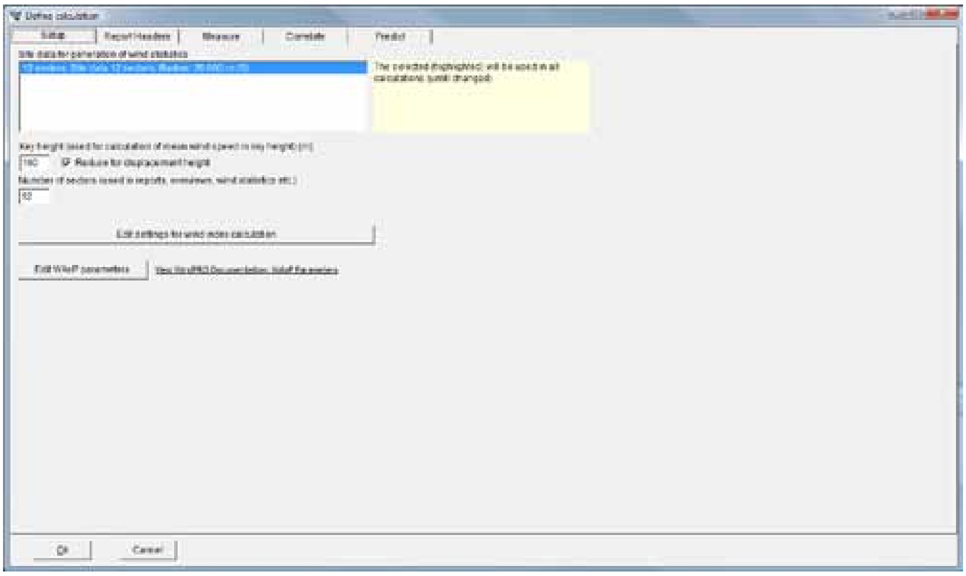



*The reports from Wind index MCP*

#### 11.2.4.6 Report All

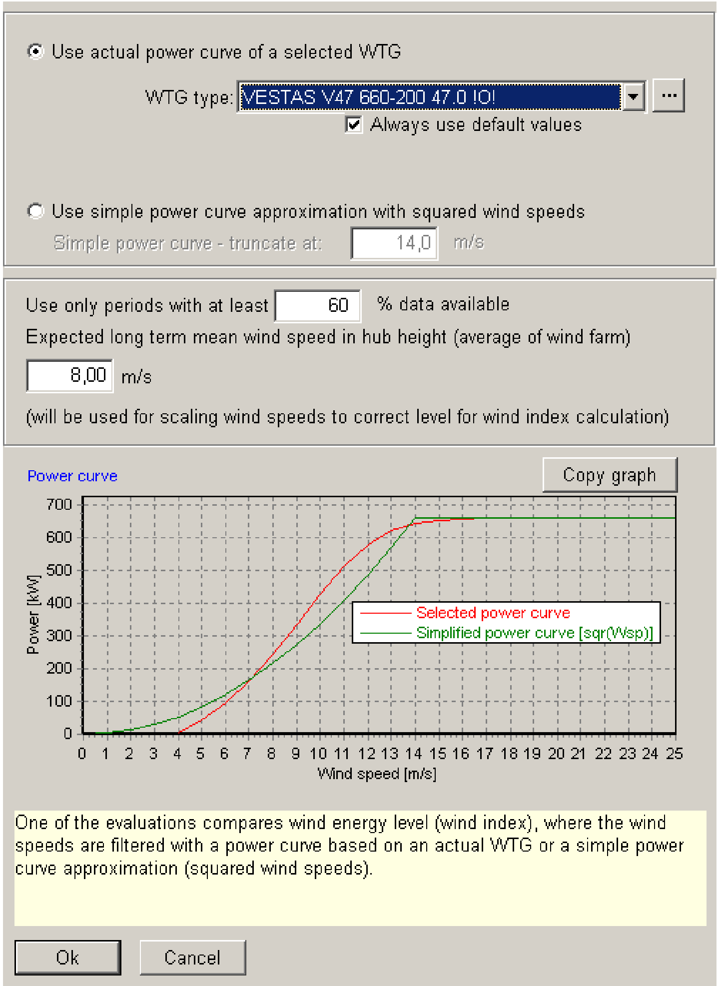
This report gives a summary of all the calculations done.

### 11.2.5 Setup




One of the important functionalities of the WindPRO MCP module is that it can generate a wind statistic from the generated long term corrected time series directly and thereby the “end result” needed for a typical WAsP PARK calculation. To generate the wind statistic a terrain description is needed. This is in WindPRO collected in a Site data object for STATGEN purpose.
The Site data object, which should be used, can be selected in this tab.

When wind index is calculated, either used in the Wind index MCP method or used as a “test option” in the other MCP methods, a few settings for wind index calculation is needed. See details described in 11.2.5.5 Wind index.



*The filter settings for calculating Wind energy index*

## 11.2.6 Report Headers

In this tab sheet the headers and calculation name, which should be used in printouts, can be selected. The feature is described in further details in chapter 2.