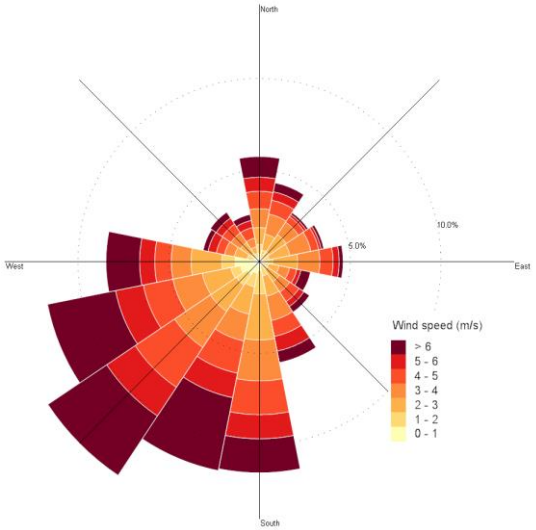
WindRose PRO User's Guide

Version 3.1.x

By Roberto Bellasio



Enviroware
Air quality consulting

WindRose PRO is a software for analysing and drawing directional data

SUMMARY

1. DOCUMENT COPYRIGHT

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2. INTRODUCTION

WindRose PRO is a Windows application for representing directional variables starting from raw data or from their frequencies.
It can be used to represent wind roses, but it is also possible to represent roses of any other variable of interest. A **wind rose** is a chart which gives a view of how wind speed and wind direction are distributed at a particular location over a specific period of time. It is a very useful representation because a large quantity of data can be summarised in a single plot.

WindRose PRO is capable to load different file formats:

- Microsoft Excel files (XLS and XLSX)
- ASCII files with fields separated by specific symbols
- EnergyPlus Weather files
- Typical Meteorological Year (TM2 and TM3)
- Compressed WBAN hourly surface observations (TD-1440)
- CALMET 5.8 surface file
- CALMET 6 surface file
- AERMOD surface files
- ISC3ST files
- Integrated Surface Hourly (NOAA ISH)
- NMEA0183 files
- Frequencies

Date/time filtering options according to year, month, day of the week, hour of the day or day/night hours can be activated.

Beside the classical wind roses, other plots can be generated: the rose of minimum/average/maximum values, raw data and rays. Raw data plot allows to represent a third variable when data are loaded as Microsoft Excel files.

WindRose PRO allows the wind roses to be exported in **DXF** format for CAD systems, in **SHP** format for GIS environments and in **KML** format for Google Earth. Windroses can also be copied or saved in many raster formats (JPG, PNG, etc.).

Numerical results can be exported in Microsoft Excel format, and charts are automatically created within such files.

Wind turbines power curves can be imported in WindRose PRO (or directly defined in it) and used to define the wind power potential of a specific location.

A **batch processing procedure** allows the automatic creation of hourly, three-hourly and monthly wind roses starting from a single input file.

Other features of the software are:

- Typical day is calculated when date and time are loaded
- Calculates the theoretical wind power distribution
- Calculates crosswind, headwind and tailwind, and evaluates the correct orientation of a runway
- Calculates the exceeding frequencies
- Calculates the wind erosion emission factors for PM30, PM15, PM10 and PM2.5
- Automatically produces a text summary of the data
- User's logo can be added on the plot

3. SYSTEM REQUIREMENTS

WindRose PRO is a Windows application that can be used both on 32 bit and 64 platforms. It is based on the **.NET framework 4**, which must be present on the PCs where it is installed (the installation package checks if they are present). WindRose PRO has been tested by the developers under Windows XP, Windows Vista and Windows 7. It has not been tested under older versions of Windows.
It might not function correctly under any Windows emulator of Mac, Linux or Unix systems.

3.1 Installation

To install WindRose PRO from the distribution setup package, simply double click over the setup file. The Setup program will issue a number of prompts. Unless you have a reason to override the defaults it is strongly recommended that you accept the installation default settings (just press OK, Yes, or Next, as appropriate). WindRose PRO requires the .NET framework 4, and the installation package checks for their presence. If they are not present, the setup package will automatically install them on your PC. The Microsoft C++ redistributable will be also installed if needed.

3.2 Uninstallation

There are two ways to uninstall WindRose PRO, should you wish to do so.

3.2.1 Control Panel

Activate the Control Panel, double click Add/Remove Programs, and double click on the WindRose PRO list box entry.

3.2.2 Start Menu

From the Start menu, click Programs, then WindRose PRO, and then Uninstall WindRose PRO.

4. WINDROSE PRO ORDERING INFORMATION

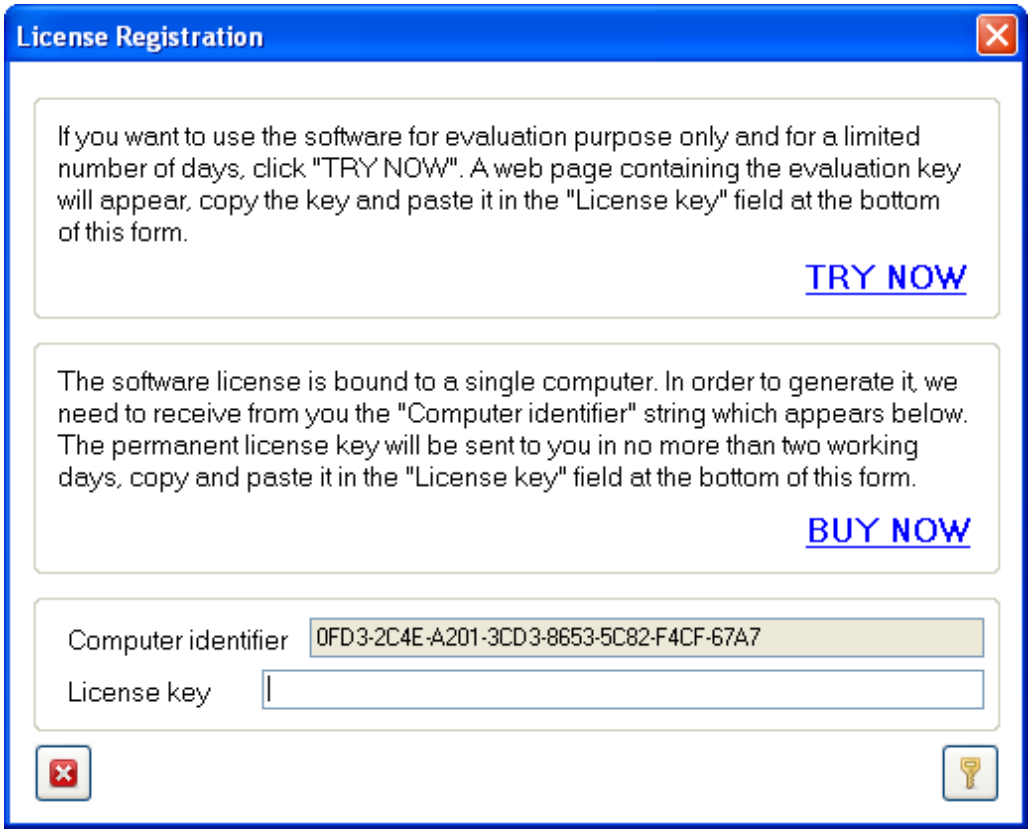
All orders are subject to the **WindRose PRO License agreement**. Enviroware srl is willing to license the WindRose PRO software only if you accept all of the terms in the license agreement. Please read the terms carefully before you install the software, because by installing the software you are agreeing to be bound by the terms of the agreement. If you do not agree to the terms, Enviroware srl will not license the WindRose PRO software to you, and in that case you should immediately delete all copies of the software you have in any form.

4.1 Permanent Software Key Delivery

The permanent software key will be sent by email in no more than 2 working days after the purchase. If the order is received during working days from 9 a.m to 6 p.m Italian time, the permanent software key is typically sent in less than one hour.

4.2 Credit Card Orders

You can place secure credit card orders on the Internet using the order link on the Enviroware web site (http://www.enviroware.com/portfolio/windrose-pro3/).
Alternatively, you can use the `BUY NOW` link on the `License Registration` form which automatically transmit your computer identification code needed to generate your license.



4.3 Other types of Orders

Please contact Enviroware srl (info@enviroware.com) to know about the possibility of other order types.

4.4 WindRose PRO Pricing

Current price is indicated on the WindRose PRO web page:
http://www.enviroware.com/portfolio/windrose-pro3/.
The software purchase price includes:

- the software package and the unlimited-time license;
- one year of free software updates;
- one year of free technical assistance.

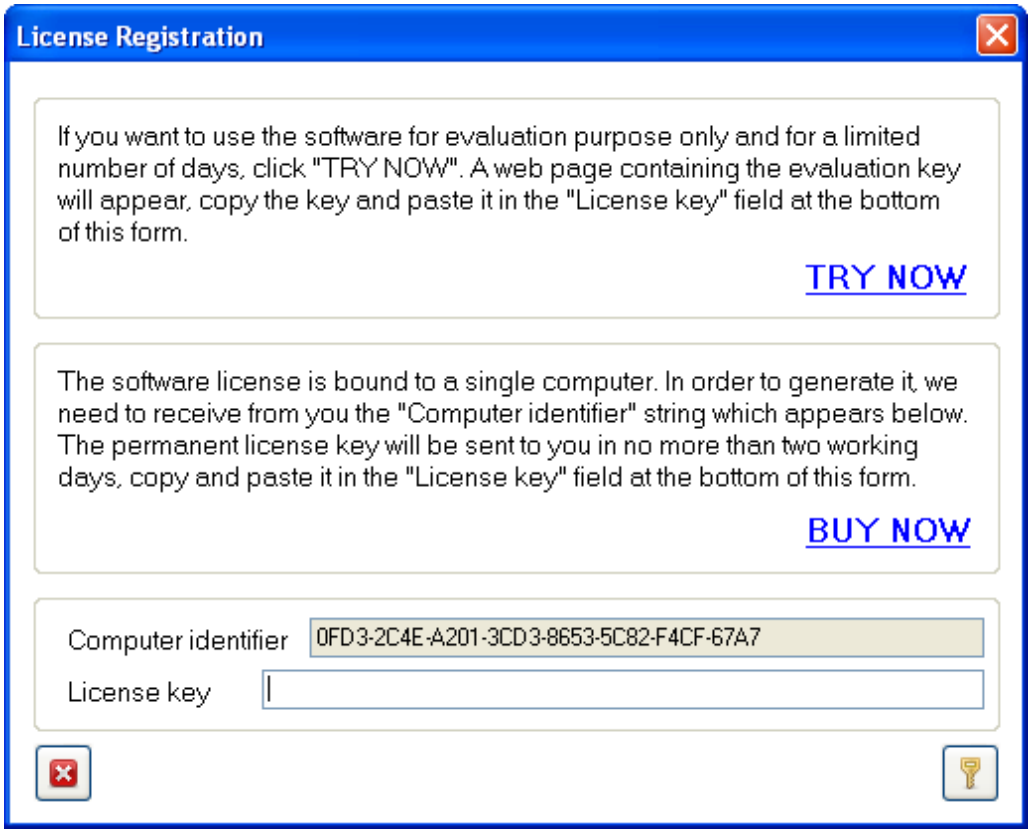
After the first year software updates, technical assistance and license transfer will be available only to the users which will purchase the yearly, or multi year, maintenance plan.

5. REGISTRATION

WindRose PRO must be activated with an evaluation key or with a permanent key.

5.1 Evaluation key

If you want to evaluate WindRose PRO click on the `TRY NOW` link on the `License Registration` form represented in the following figure (you need an active internet connection during this phase).



A web page of the Enviroware's internet site will appear, asking to insert optional information (country and town) which will be used only for statistical purposes. You may insert your email address if you want to be informed about new Enviroware products, otherwise click the Proceed button and you will see a page containing an evaluation license key. Copy the key, paste it in the `License key` field shown in the previous figure, then click the registration button  at the lower right corner of the form. At this point you will be able to evaluate WindRose PRO for **a limited number of days**.

The evaluation version has some limitations with respect to the full one:

- watermarks or notes are written on each plot,
- images cannot be copied,
- images cannot be saved,
- check for updates does not work.

5.2 Permanent key

You obtain a permanent key only after purchasing WindRose PRO. The permanent key is bound to a single computer by means of the computer identifier that you must write exactly during the payment procedure (if you use the BUY NOW link shown on the previous image, the computer identifier is automatically communicated to the internet site for the payment). The computer identifier is a code automatically generated by the software to uniquely identify the PC where it is installed.
After receiving the payment we will send to the buyer:

- an email containing the instructions to download the full version of the software and the permanent license;
- an email containing the invoice in PDF format.

Please note that:

- the **software is not physically delivered** on any type of support, it will be downloaded from an internet address;
- the permanent license alone will not enable all the features of the software, the buyer must download and install the full version of the software.

6. SUPPORT, QUESTIONS AND WARRANTY

To check whether you have the most recent version of WindRose PRO, please use the `Check for Updates` menu item.

Please see the WindRose PRO web page (http://www.enviroware.com/portfolio/windrose-pro3/) for answers to common questions.

The best way to report problems is to send an email to info@enviroware.com (you can also use the feedback button on the software, which is represented by an envelope).

When reporting problems, please include at least the following information:

1. Is the problem reproducible? If so, how? (Please include the input data).
2. What version of Windows are you using?
3. What version of WindRose PRO are you running? (To see what version of WindRose PRO you have, choose the About button). Please include version number and date in your problem report.
4. If a dialogue box with an error message was displayed, please include the full text of the dialogue box, including the text in the title bar.

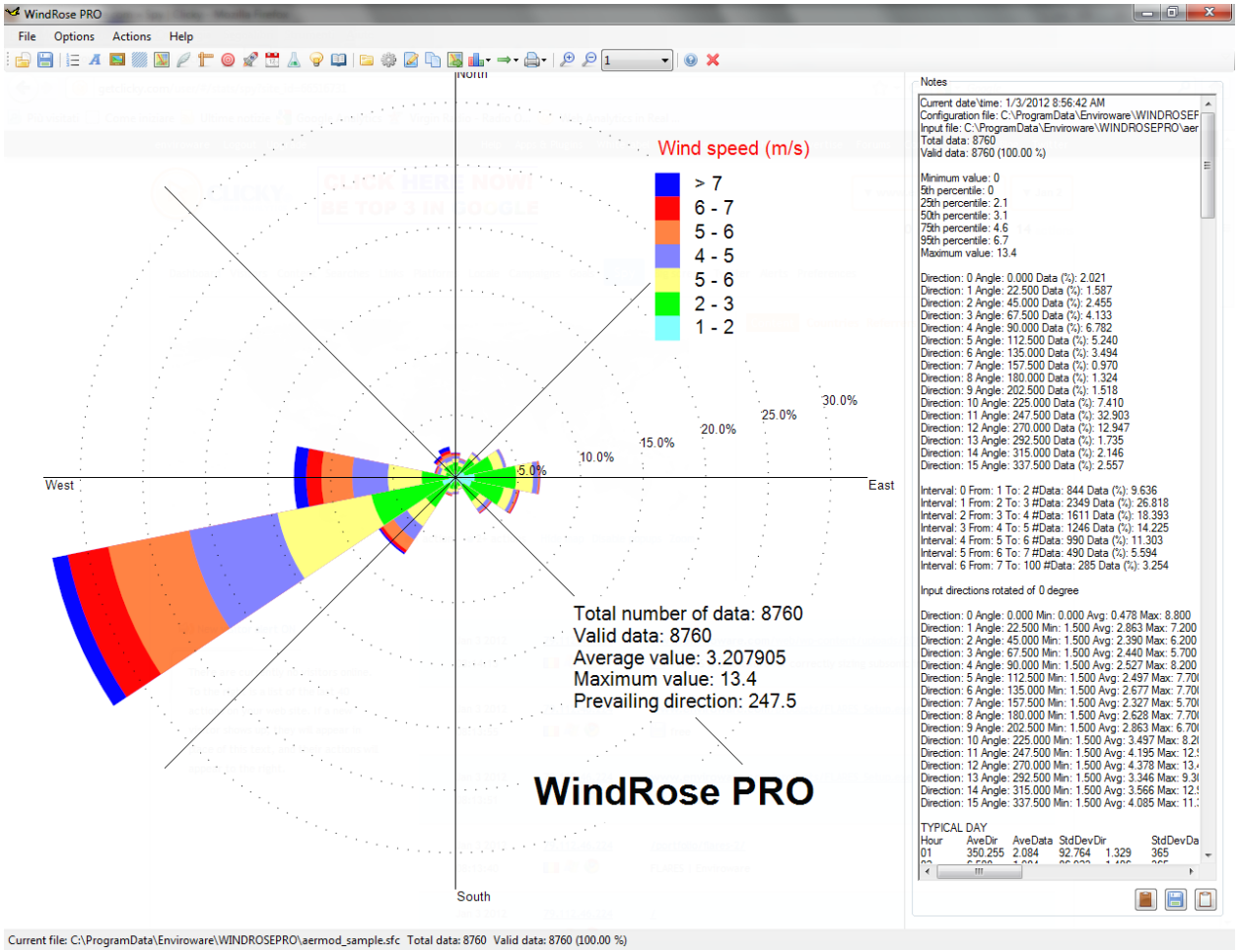
6.1 Technical warranty

WindRose PRO is covered by a technical warranty for a period of 6 (six) months after the purchase date. During this period Enviroware will fix all the bugs that should arise.

7. TUTORIAL

7.1 Menu and buttons

The main form of the WindRose PRO software is represented in the next figure.



There are four menu topics:

- **File:** allows to save a new configuration file (i.e. a set of options used for representing the directional data) and to load an existing configuration file.
- **Options:** allows to specify all the options that will be used for representing the directional data: data intervals, plot title, user's logo, legend, calms, plot types, plot scale, percentage circles, runways calculation, filtering of data according to their values or to date/time, wind power options and others.

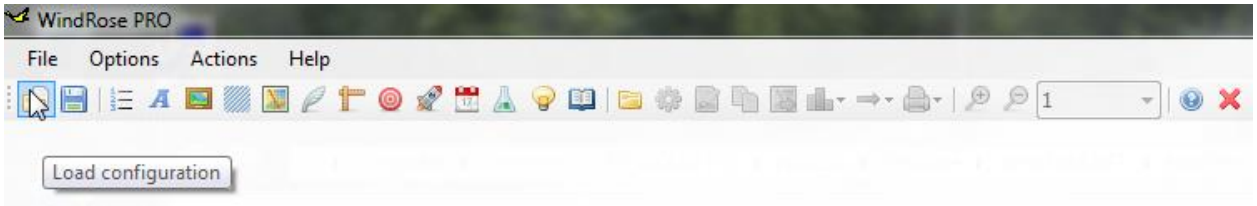
- **Actions:** used to load the directional data, to analyse them, to draw the plot, export, save, print or copy it, view the charts, and to insert wind turbine features.
- **Help:** allows to access the User's Guide (this document), to send feedbacks and to carry out other operations.

The main operations can also be done by means of the buttons placed within the toolstrip just below the main menu, as represented in the previous figure.

7.2 File

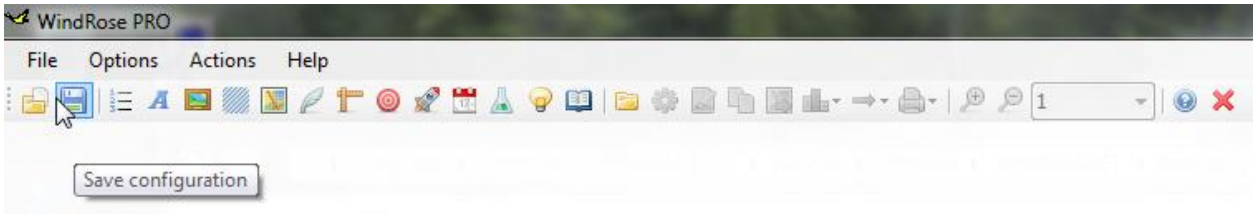
7.2.1 File > Load configuration

The *File > Load configuration* menu item allows to load WindRose PRO configuration files previously saved. The same result is obtained by clicking the button shown in the next figure. The configuration files are XML files with the extension *.wro3*.



7.2.2 File > Save configuration

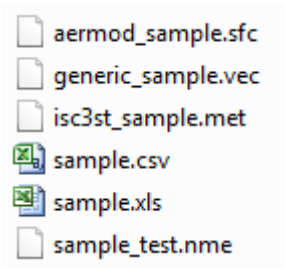
The *File > Save configuration* menu item allows to save WindRose PRO configuration files. The same result is obtained by clicking the button indicated in the next figure.



7.2.3 File > Load data

The `Actions > Load data` menu item allows to look for an input file of directional data within the user's PC. The same result is obtained by clicking the button shown in the next figure.

Some input files are distributed with the WindRose PRO setup package (see next figure for example), and are located within the sample folder. The WindRose PRO sample folder is `\Enviroware\WINDROSEPRO\` under the *common application data folder,* which depends on the Windows version installed on the user's PC. For example, in Windows 7 the common application data folder is `C:\ProgramData\`, while in Windows XP it is in `C:\Documents and Settings\All Users\Application data\`.



The data can be loaded in two forms: as data organised in records or as frequencies. When data are loaded as frequencies, not all the analyses can be carried out (for example it will be not possible to plot roses of average speeds, or of maximum speeds).

IMPORTANT: For real numbers the decimal separator must be a dot (.), not a comma (,). If this is not the case, WindRose PRO will not work correctly.

When data are organised in records, they can be loaded as ASCII files with fields separated by tabs, commas, semicolon or spaces, as Microsoft Excel files, as AERMOD surface meteorological file, as ISC3ST meteorological file, as EnergyPlus Weather files, and others.

Wind direction must always be in degrees (do not use radians), while the units of the directional variable are not important for the software (wind speed for example can be in m/s or in knots). After loading the data, the file name, the total number of data and the total number of valid data, appear at the bottom of the main software mask. The number of valid data is determined using the information that the user inserts in the value filtering mask.

7.2.3.1 Microsoft Excel files (.XLS and *.XLSX)*

The data organised in records can be read from Microsoft Excel files, both Excel 97-2003 (*.XLS) and Excel 2010 (*.XLSX). The file must have a sheet containing, at least, directions and corresponding values in two different columns. Each column must have a header record. The user first selects the worksheet containing the data, then the columns containing the direction and the directional data (for example wind speed).
The user may also select a column containing date and time of each measurement. This feature allows to filter the data to be analysed according to year, month, hour of the day, or day/night hours. Moreover WindRose PRO will automatically calculate the typical day (i.e. the average of the variable for each hour of the day).
Since dates are written in different formats around the World, the user must also select the date/time format of the Excel file. The possible formats are:

- DD/MM/YYYY hh:mm:ss
- MM/DD/YYYY hh:mm:ss
- YYYY/MM/DD hh:mm:ss
- YYYYMMDDhhmmss

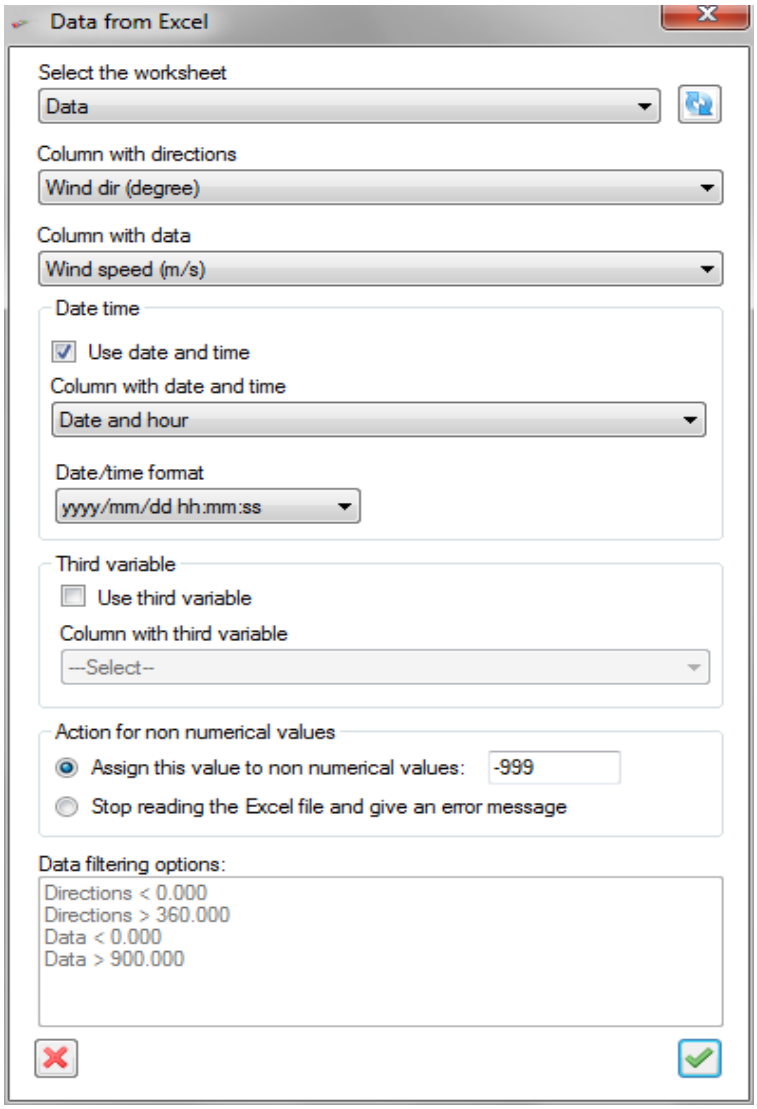
Minutes (mm) and seconds (ss) are not mandatory. This means that you will select DD/MM/YYYY hh:mm:ss even if your dates are in the format DD/MM/YYYY hh.
The user may also select a column containing a third variable (e.g. pollutant concentration, temperature, etc.) which might be used to generate the raw data plot.
The user may also specify the action to carry out when cells with non-numerical values (for example empty cells) are found. The two possible options are to stop reading the Excel file with an error message, or to substitute non numerical values with a specified value. In this last case, the same value is used for direction, data and third variable, if

used. Be aware that the value used for substitutions must not alter your data. For example, if you filter values smaller than 0, use a negative value for substitutions.

Note that Microsoft Excel must be installed on the user's PC.

Examples of Microsoft Excel input files (both XLS and XLSX) are contained in the sample directory.

The worksheet with the data is expected to be in a table-like format with column headings in the first row and rows of data beneath.



If you see the warning message "*Some headers cells in the selected Excel worksheet have no titles*", the software is unable to find a title to put in the drop down boxes in order to allow to select the variables. It is a warning message, therefore you can continue to load the data. However, if you don't like such messages try one of these solutions:

1) Verify if all the columns with the data in your file have a title, if not add one or more titles as needed.
2) Excel has a sort of memory of the cells that were filled in. If you simply delete the contents of some columns they still appear as used, and WindRose PRO3 tries to load them. Since they do not have a title, the warning message is issued. The solution is to select the **whole columns** (clicking on the letters identifying the columns) and delete them. It is important to delete the columns, not only their contents.

If you get a message after loading your data saying that N substitutions have been done for empty cells, the reason may be similar to point 2 above. Select the whole rows at the bottom of your data and delete them.

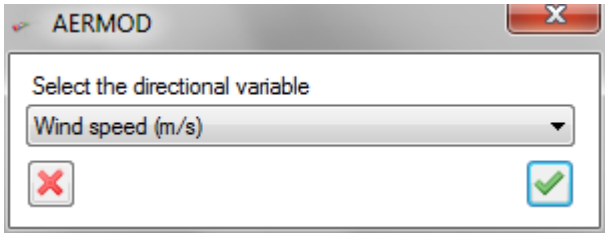
Another issue concerns the date format. If the columns containing dates are actually formatted exactly as dates in Excel the selection between the two formats *"DD/MM/YYYY hh:mm:ss"* or *"MM/DD/YYYY hh:mm:ss"* works without problems. Sometimes dates in Excel appear as *"DD/MM/YYYY hh:mm:ss"* even if they are not formatted as dates, but as "Custom". In these cases, if the user specifies the format that seems correct (*"DD/MM/YYYY hh:mm:ss"*) WindRose PRO3 gives an error because the day and month fields are misplaced. The solution in these situations is to specify the *"MM/DD/YYYY hh:mm:ss"* even if it is not the format seen within the Excel cells.

Finally, charts must be at the end of the worksheets. If the first worksheet is a chart the software gives an error message.

7.2.3.2 AERMOD surface meteorological file

AERMOD is an atmospheric dispersion model belonging to the list of the US-EPA preferred/recommended models. In order to carry out a simulation AERMOD needs a surface meteorological file and an upper air meteorological file, both containing variables for each hour of the simulation. WindRose PRO reads directly the AERMOD surface meteorological file, which must have a SFC extension.

The default directional variable is wind speed, but the user may choose other variables contained in the surface meteorological file.



Date and time within the AERMOD surface file are also read by the software. It is then possible to filter the data to be analysed according to year, month, hour of the day, or day/night hours. Moreover WindRose PRO automatically calculates the typical day (i.e. the average of the variable for each hour of the day).

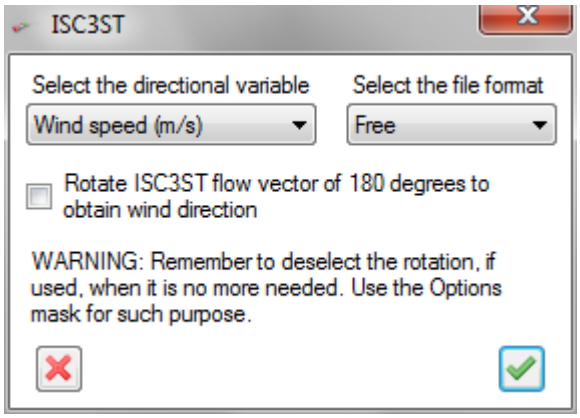
An example of AERMOD surface meteorological file is contained in the sample directory.

7.2.3.3 ISC3 Short Term meteorological file

ISC3ST (Industrial Source Complex Short Term, version 3) is an atmospheric dispersion model belonging to the list of the US-EPA alternative models. In order to carry out a simulation ISC3ST needs a meteorological file containing variables measured at surface for each hour of the simulation. WindRose PRO reads directly the ISC3ST meteorological file, which must have a MET or ISC extension.

The default directional variable is wind speed, but the user may choose other variables contained in the meteorological file. The user must also specify the file format between FREE or CARD, which are the two ASCII formats recognised by ISC3ST. Finally, since ISC3ST uses flow vector, which is the direction toward which the wind is blowing, therefore the opposite of wind direction, the user might want to rotate it by 180 degrees before analysing the data and creating the wind rose. Be aware that the rotation is stored

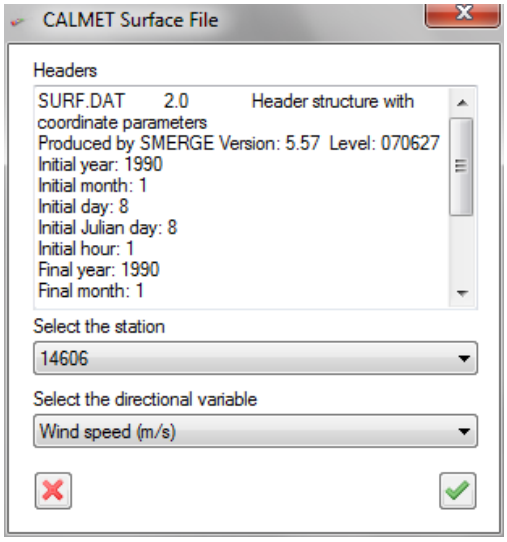
as an option, and the user must deselect it when other data, for example from an AERMOD file, are loaded.



Date and time within the ISC3ST meteorological file are also read by the software. It is then possible to filter the data to be analysed according to year, month, hour of the day, or day/night hours. Moreover WindRose PRO automatically calculates the typical day (i.e. the average of the variable for each hour of the day).
An example of ISC3ST surface meteorological file is contained in the sample directory.

7.2.3.4 CALMET 5.8 and CALMET 6 surface file

CALMET is the diagnostic meteorological model of the CALPUFF modelling system, belonging to the list of the US-EPA preferred/recommended models. The meteorological information needed in input by CALMET is contained in a surface file with the hourly observations of different stations, and in one or more vertical soundings. WindRose PRO reads the surface meteorological file of CALMET 5.8 (which is the current regulatory version) and CALMET 6. It will not work with CALMET versions having a surface file format different from the formats of version 5.8 or version 6. The CALMET file extension must be *.DAT (for example SURF.DAT).
Once the user has selected a CALMET file, the mask represented in the following figure appears. In the upper part of the mask the surface file header records are summarised. Since a surface file typically contains the observations of more stations, the user must select the station to analyse. The default directional variable is wind speed, but the user may also select opaque sky cover, air temperature, relative humidity and atmospheric pressure.



7.2.3.5 Delimited ASCII file

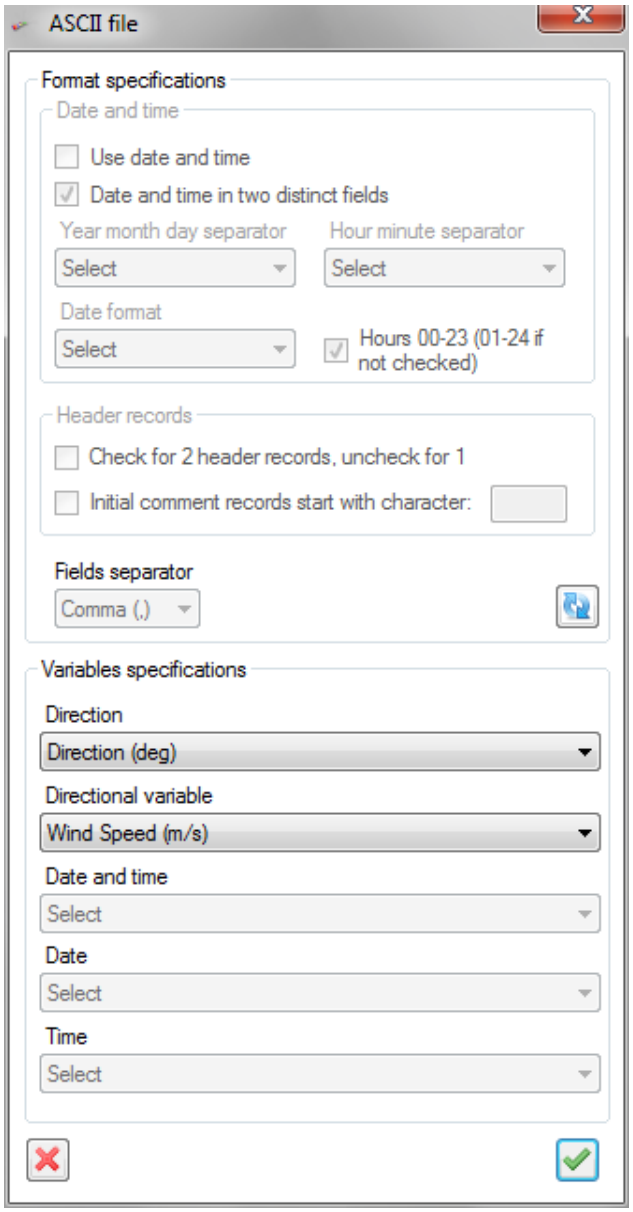
The generic ASCII file has been designed to allow the user to load data which may have a variety of formats. These files may have ASC, VEC, TXT or CSV extension. The data are loaded in two phases: first the user specifies the file format choosing some possible options, then selects the variables to analyse. Data in this format are organised in records, each one containing fields separated with a specified separator. At least one header record containing variable names is mandatory.

The user may specify:

- The field separator, which can be tab, comma, semicolon or space.
- If a second header record is present, for example with the measurements units of the corresponding variables. In this case both the header records are used to create the column names.
- If date and time are present within the file and must be used.
- If date and time are in the same field or if they are in two separate fields (when the field separator is the space, date and time can only be in two separate fields).
- The year month day separator between dash (-), slash (\) or backslash (/).
- The hour minute separator between colon (:) or dot (.).
- The date format between YYYY MM DD or DD MM YYYY or MM DD YYYY.
- The hour counting format between 00-23 and 01-24.

After the above options have been specified, click the button to continue, and select the variables to analyse in the lower part of the mask.

Date and time, if the user specifies to use them, are also read by the software. It is then possible to filter the data to be analysed according to year, month, hour of the day, or day/night hours. Moreover WindRose PRO automatically calculates the typical day (i.e. the average of the variable for each hour of the day).

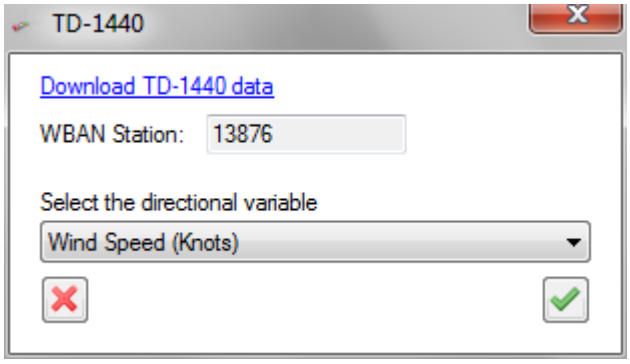


Examples of ASCII file are contained in the sample directory (sample.csv, generic_sample.vec and sample.asc). The file *sample.csv* has only two fields (direction and speed) separated by a comma, date and time are not present within the file. The file *sample.asc* is identical to sample.csv, the only difference is that fields are separated by spaces. In the contrary, in order to load the *generic_sample.vec* file, the user must select:

- Use date and time
- Date and time in two distinct fields
- Year month day separator: backslash (/)
- Hour minute separator (:)
- Date format: DD MM YYYY
- Hours: 00-23
- Header records: 2
- Fields separator: Tab

7.2.3.6 Compressed WBAN Hourly Surface Observations (TD-1440)

Another file format which WindRose PRO can read is the compressed WBAN hourly surface observations (TD-1440). These data are distributed by the US-EPA as zipped files containing years from 1984 to 1992 for many US locations. The TD-1440 files are used by the ARMOD meteorological processor (AERMET) and by other meteorological processors. Such files can be downloaded from the US-EPA internet site (http://www.epa.gov/ttn/scram/surfacemetdata.htm).



7.2.3.7 EnergyPlus Weather (EPW)

EnergyPlus (http://apps1.eere.energy.gov/buildings/energyplus/) is an energy simulation software which models heating, cooling, lighting, ventilating, and other energy flows as well as water in buildings.

EnergyPlus has its own weather file format which can be read from WindRose PRO. EnergyPlus weather files (*.EPW) are available for hundreds of points around the world, and can be downloaded from the US Department of Energy website.

WindRose PRO allows to apply date and time filtering on the wind speed and direction loaded from the EnergyPlus Weather data. Since the year of data can vary arbitrarily for each month within the EPW data, filtering on years is not allowed.

7.2.3.8 Typical Meteorological Year (TMY2)

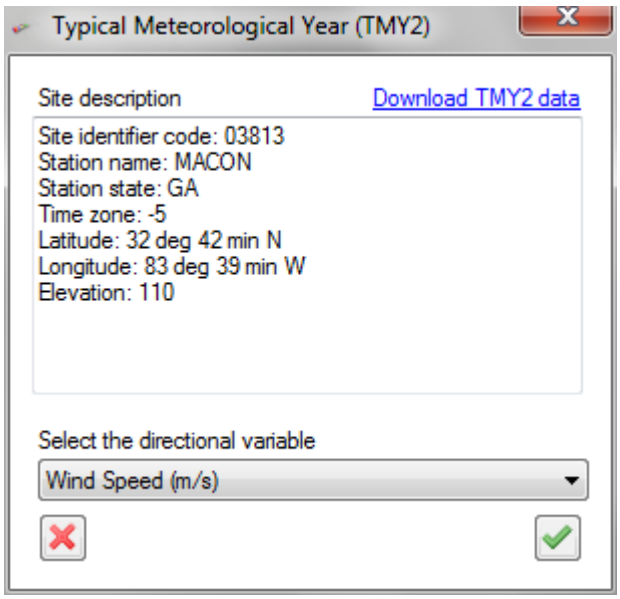
A Typical Meteorological Year (TMY) is a data set of hourly values of solar radiation and meteorological elements for a one-year period. It consists of months selected from individual years and concatenated to form a complete year. The intended use of the TMY data is for computer simulations of solar energy conversion systems and building systems. Because of the selection criteria, TMYs are not appropriate for simulations of wind energy conversion systems, nor for atmospheric dispersion simulations.

A TMY provides a standard for hourly data for solar radiation and other meteorological elements that permit performance comparisons of system types and configurations for one or more locations. A TMY represents conditions judged to be typical over a long period of time, such as 30 years. Because they represent typical rather than extreme conditions, they are not suited for designing systems and their components to meet the worst-case conditions occurring at a location.

The original TMY data were derived for the period 1952-1975. The TMY2 data refer to the period 1961-1990, and have been derived from the 1961-1990 National Solar Radiation Data Base (NSRDB). WindRose PRO reads the TMY2 data, which can be obtained from this link: http://rredc.nrel.gov/solar/old_data/nsrdb/1961-1990/tmy2/ The file extension of the TMY2 files is TM2. Once loaded a TMY2 file the following mask

appears. The upper part summarises the header records. The default directional variable is wind speed, but other variables can be selected if needed.

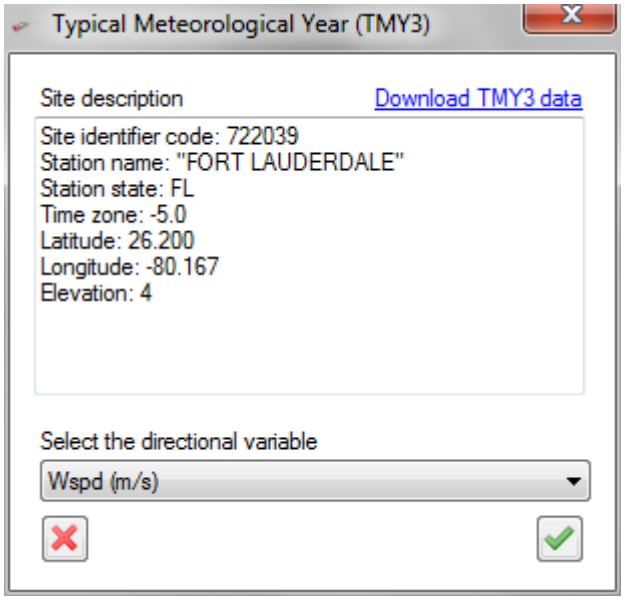
The TMY2 data are available for 239 locations in the USA.



7.2.3.9 Typical Meteorological Year (TMY3)

The TMY3 data are the most recent version of the Typical Meteorological Year. Compared with the TMY2, they are based on more recent and accurate data, and extend up to 2005. The TMY3 data are available for 1020 locations in the USA and can be downloaded from http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/.

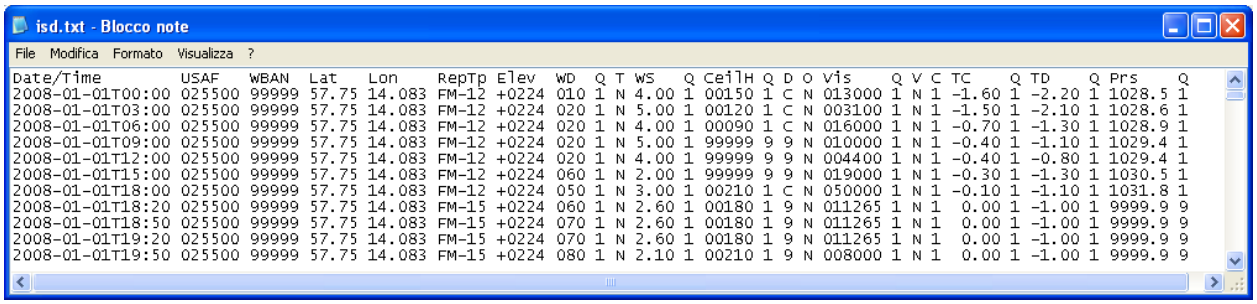
The file extension of the TMY3 files is CSV. Once loaded a TMY3 file the following mask appears. The upper part summarises the header records. The default directional variable is wind speed, but other variables can be selected if needed.



7.2.3.10 NOAA Integrated Surface Hourly

The NOAA database ISH (Integrated Surface Hourly), or ISD (Integrated Surface Data), collects all of the NCDC and Navy surface hourly data (TD3280), NCDC hourly precipitation data (TD3240), and Air Force Datsav3 surface hourly data (TD9956), into one global database. The database totals
approximately 350 gigabytes, for nearly 20000 stations, with data from as early as 1900 to present. The building of the database involved extensive research, data format conversions, time-ofobservation conversions, and development of extensive metadata to drive the processing and merging. Additional information about the ISH database can be found in http://www1.ncdc.noaa.gov/pub/data/noaa/ish-tech-report.pdf
The ISH data can be downloaded from http://www1.ncdc.noaa.gov/pub/data/noaa/
In order to be read by WindRose PRO, these files must have extension ISH or ISD (typically they do not have any extension, therefore it must be added by the user). The current version of the software reads only the non variable part of each record of data (i.e. the first 105 characters). Once the file has been read its content is automatically shown within a text editor, while wind directions, wind speeds, dates and times are stored in order to produce the wind rose. Dates and time are stored only if the year is valid, which means not equal to 9999.

An example of variables extracted from one ISH file and summarised in a text editor is shown in the next figure.



The first record is a header, while all the other records contain the data. The meaning of each column is explained in the following table (note that the order of the variables is important because some columns have the same header). For a detailed explanation about the meaning of the quality codes, missing values and other important information the user must read http://www1.ncdc.noaa.gov/pub/data/noaa/ish-format-document.pdf.

Date/time	Is the date and time of the record of data. Its format is YYYY-MM-DDThh:mm. Note that YYYY=9999 means invalid date/time.
USAF	Fixed weather station USAF master station identifier.
WBAN	Fixed weather station NCDC WBAN identifier.
Lat	Latitude coordinate of the point of observation (degrees).
Lon	Longitude coordinate of the point of observation (degrees).
RepTp	Report type: the code that denotes the type of geophysical surface observation.
Elev	Elevation of the point of observation (m) relative to mean sea level.
WD	Wind direction (degrees).
Q	Wind direction quality code.
T	Wind observation type code
WS	Wind speed (m/s)
Q	Wind speed quality code.
CeilH	Ceiling height (m)
Q	Ceiling height quality code
D	Ceiling height determination code

O	CAVOK (Ceiling and Visibility OK) code
Vis	Visibility distance (m)
Q	Visibility distance quality code
V	Visibility variability
C	Visibility variability quality code
TC	Air temperature (°C)
Q	Air temperature quality code
TD	Dew point temperature (°C)
Q	Dew point temperature quality code
Prs	Atmospheric pressure relative to mean sea level (hPa)
Q	Atmospheric pressure quality code

7.2.3.11 Frequencies (FRQ)

The frequencies data consist of ND+1 records, the first one is composed by a single field and the other ones are composed by NS fields, where ND is the number of directions in the wind rose and NS is the number of speed classes. The first record contains the number of calms (put 0 if you have no calms), while the other ones contain the number of events in each directions. The first direction is always North, and the others follow clockwise.

Be aware that:

1. you must first set the directions and the number of intervals, then load the frequencies data according to the specified values of ND and NS;
2. the numbers are integers indicating the number of events, not percentages.

Frequencies input file must have the extension .FRQ.

An example of frequencies data for 16 directions and 4 wind speed classes is shown below.

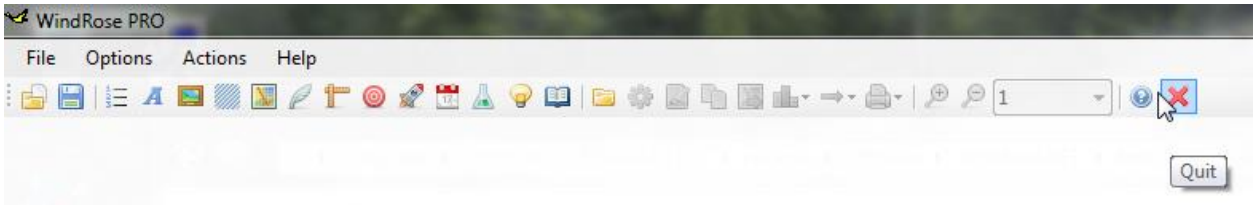
```
1036
1565,2097,627,93
2263,1247,136,8
1803,171,0,0
1433,60,0,0
3152,317,8,0
```

```
601,69,0,0
429,26,0,0
567,51,0,0
3626,651,34,0
2620,1061,68,0
1566,726,77,0
385,128,8,0
650,349,50,8
898,662,169,93
```

An example of frequencies input file is contained in the sample directory and is called *sample.frq*. Note that in order to use such sample file, you first need to load the corresponding options file named *frq_default.wro*.

7.2.4 File > Exit

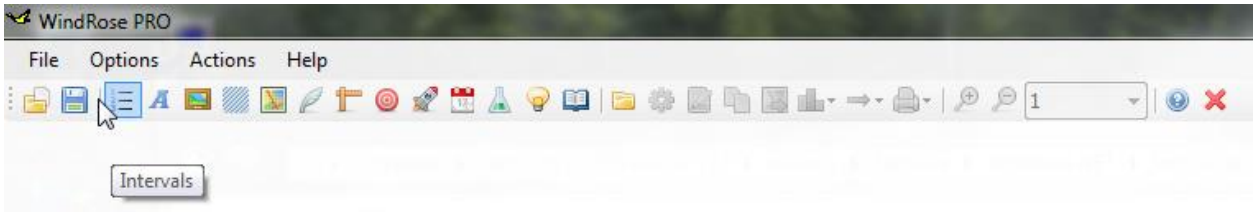
Exits the program. The same effect is obtained by using the rightmost button placed on the toolstrip just below the main menu.



7.3 Options

7.3.1 Options > Intervals

The *Options* > Intervals menu item allows to specify the data intervals to show within the chart. The intervals form can also be loaded by means of the button shown in the next figure.



The intervals allow to specify how data must be grouped for their graphical representation. For each interval, an initial and a final values must be indicated, together with its colour

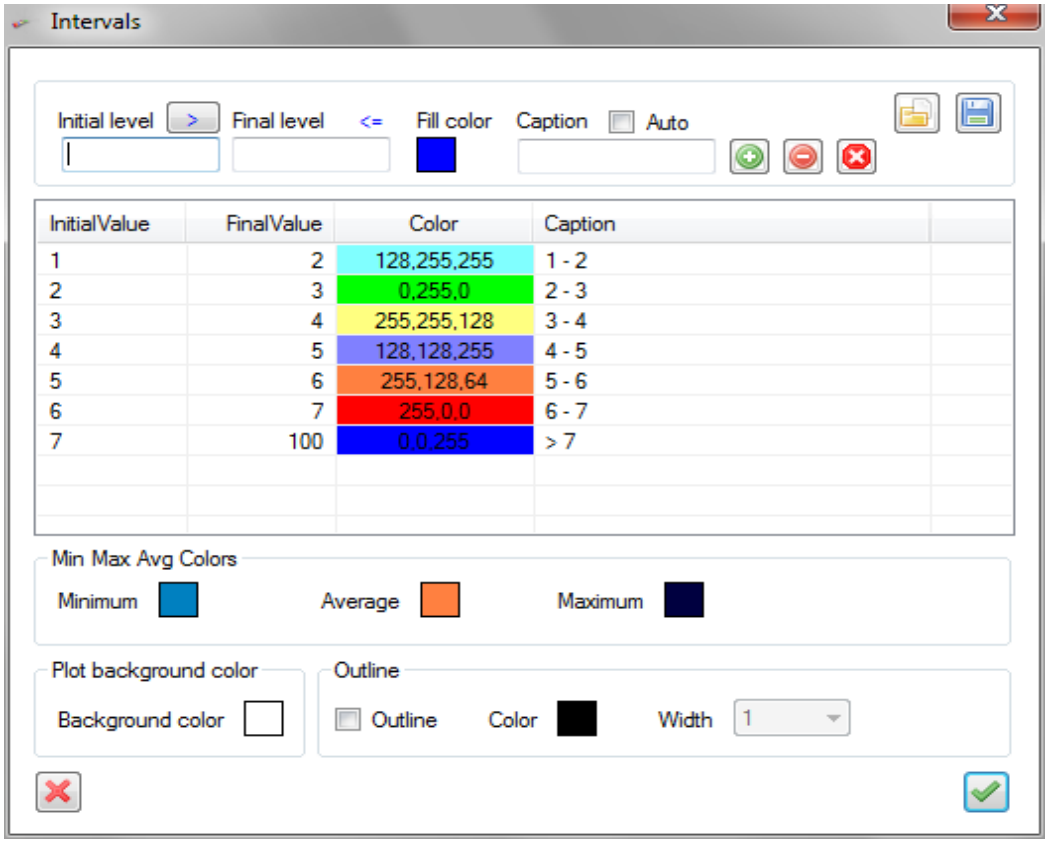
and, optionally, its caption. If the caption is not specified, it is determined using the initial and final values of the interval. Each interval can be inserted or modified by inserting the corresponding values within the text boxes and clicking the  button. A single level can be deleted by selecting it within the grid and clicking the  button, while the  button deletes all the levels within the grid.

Once the intervals have been inserted, they can be saved in a CSV file by means of the  button, and then reloaded when needed by means of the  button. Examples of CSV interval files are distributed with the software. Intervals are usually defined by the data greater than the initial value and smaller or equal to the final value, however this definition can be inverted by means of the  button.

Before loading data as frequencies (files with FRQ extension) the number of intervals specified in this mask, and the number of directions, must be equal to the directions and intervals of the frequencies table, otherwise the software shows an error message.

The `Auto` checkbox allows to create captions automatically while the user inserts the levels. Captions are created as "`IV - FV`", where IV is the initial value and FV is the final value.

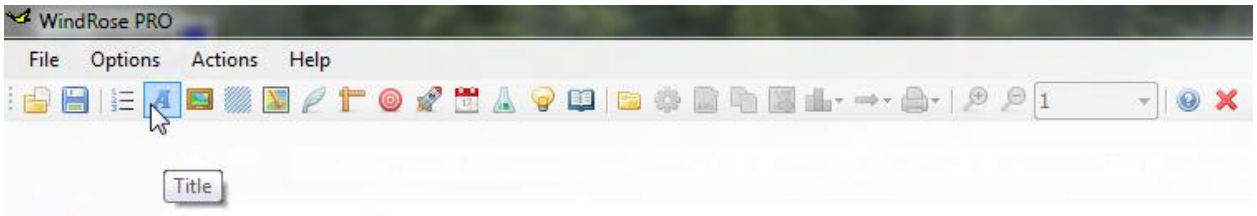
This form also allows to specify a background colour for the plot (default is white), and to specify the outline colour and width between each interval.



As in all the masks of WindRose PRO, the button exits without saving the options (or doing anything), while the saves the options (or does an action), then exits.

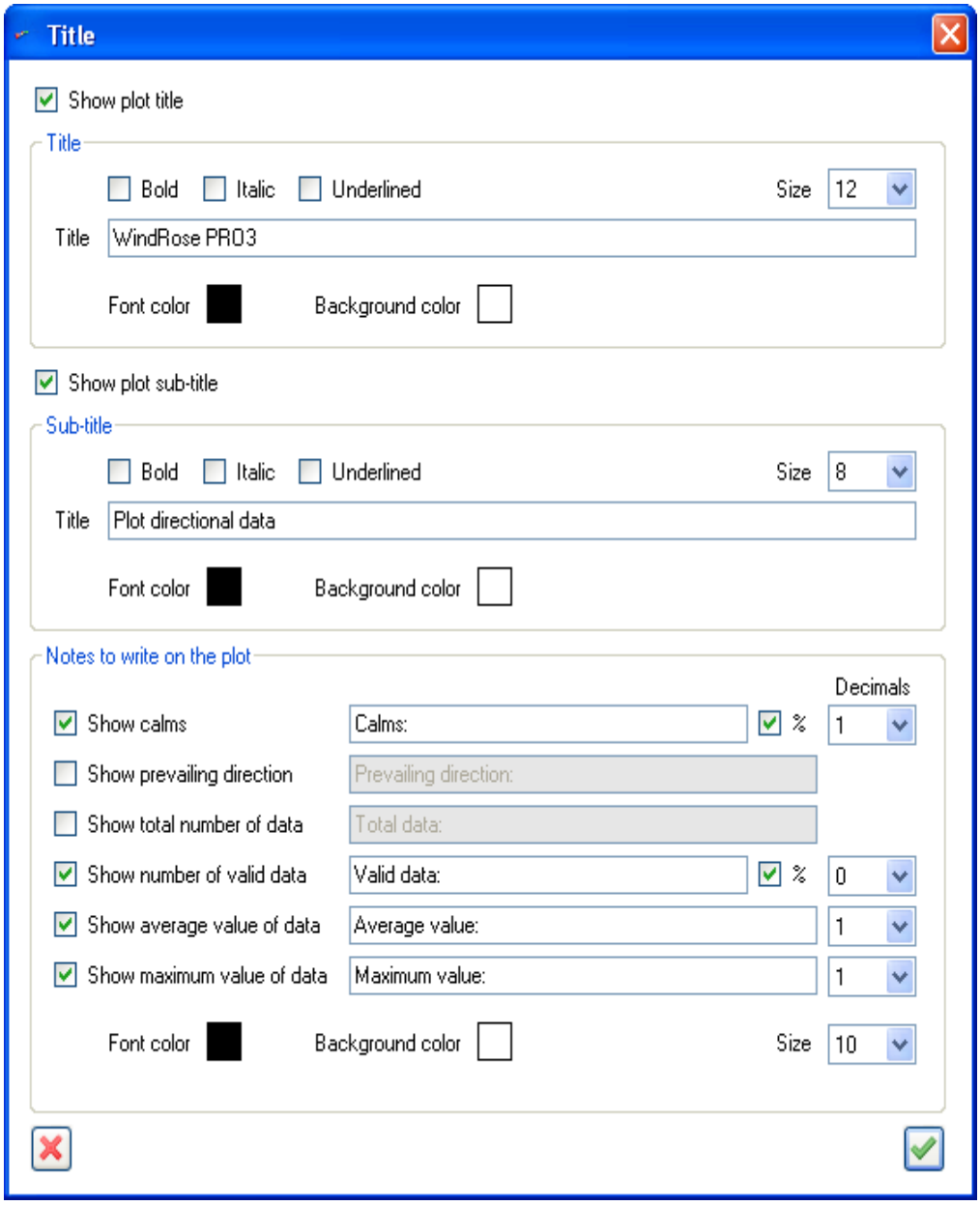
7.3.2 Options > Title

The *Options* > Title menu item allows to specify a plot title and some notes for the chart. The title mask can also be loaded by means of the button shown in the next figure.



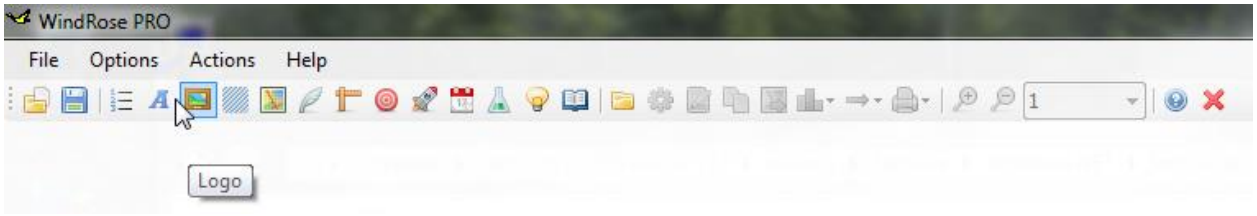
The plot title consists in a single line for which the user must specify the text, the colour, the size and other options, including background colour. The title is shown on the chart only if the Show plot title checkbox is checked. Once plotted, the title can be moved on the chart with mouse dragging operations.

A sub title with additional information can also be added if needed. Even for the sub title it is possible to specify the same parameters described for the title.
It is also possible to plot some additional information on the chart: the number of calms, the prevailing direction, the total number of data, the number of valid data, the average value and the maximum value. Each feature is plotted only if the corresponding check box is checked. The value of the feature is shown after the corresponding string inserted by the user. Once plotted, the notes block can be moved on the chart with mouse dragging operations. Calms and valid data will be expressed as a percentage if the corresponding checkbox is checked. The number of decimal points for the percentages of calms and valid data, and for the average and maximum value of the directional variable is controlled by means of four combo boxes.
The mask that allows to modify the titles can be also activated by **right clicking** over the title, sub titles and notes.



7.3.3 Options > Logo

The *Options* > Logo menu item allows to specify a logo image for the the chart. The logo mask can also be loaded by means of the button shown in the next figure.

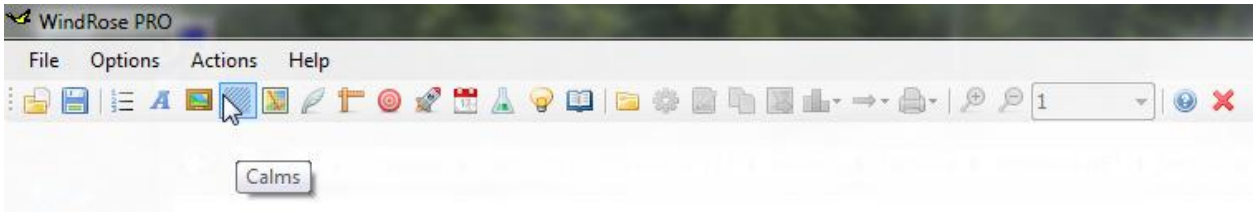


The user has the possibility to load a specific logo image and to represent it over the chart. The button allows to browse within the user's PC to select the image representing the logo. Images can be JPG, PNG or GIF.

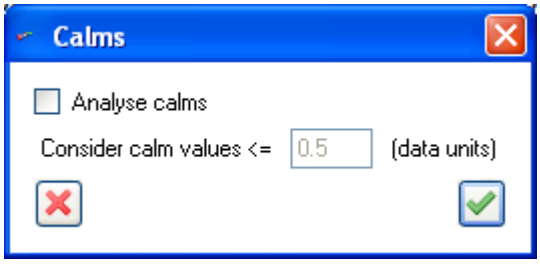
Once plotted the logo can be moved on the chart with mouse dragging operations.

7.3.4 Options > Calms

The *Options* > Calms menu item allows to specify to specify if calms must be analysed, to set a speed threshold for such calms and to choose if they must be represented in the wind rose. The calms mask can also be loaded by means of the button shown in the next figure.

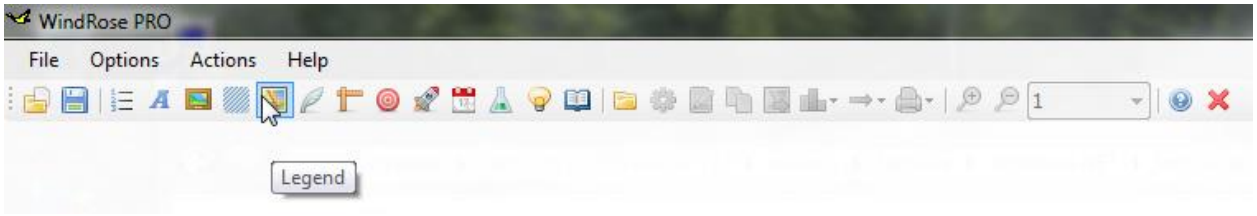


If calms must be analysed, the user must indicate a threshold for such events (0.5 in the example below).



7.3.5 Options > Legend

The *Options* > Legend menu item allows to specify a legend must be drawn on the the chart. The legend mask can also be loaded by means of the button shown in the next figure.



The legend is shown on the chart only if the Draw legend checkbox is checked. A legend title and its colour can be specified. If the Unique colour for all the labels checkbox is checked, all the labels are plotted with the colour selected in this mask, otherwise a different colour for each label is used (the same colour used for the intervals). The legend background colour can also be specified.

When the plot of minimum and/or average and/or maximum values must be done, the corresponding colours are specified in this mask.

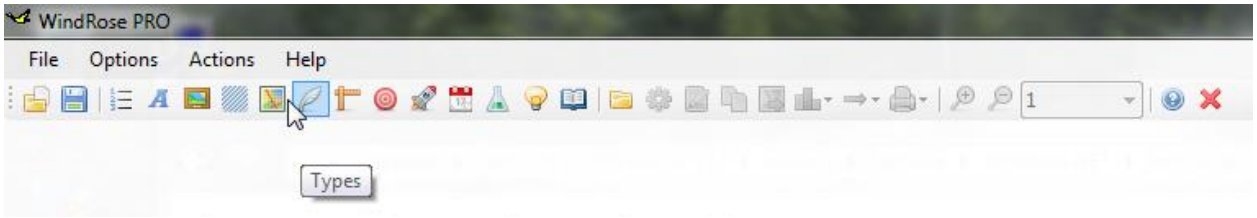
Once plotted, the legend can be moved on the chart with mouse dragging operations.

The Add percentages checkbox allows to write the percentages of each category within the legend, and the Decimals list controls the number of decimals written in the percentages. As an example, in the left hand side of the following figure is shown a legend

obtained by checking the `Add percentages` checkbox and selecting 1 decimal. If the checkbox is not checked, the same legend appears as shown on the right hand side.

7.3.6 Options > Types

The *Options* > `Types` menu item allows to specify which plot type must be produced. The plot type mask can also be loaded by means of the button shown in the next figure.



Four types of chart can be produced: wind roses, raw data, rays and minimum/average/maximum/percentile data value per direction.

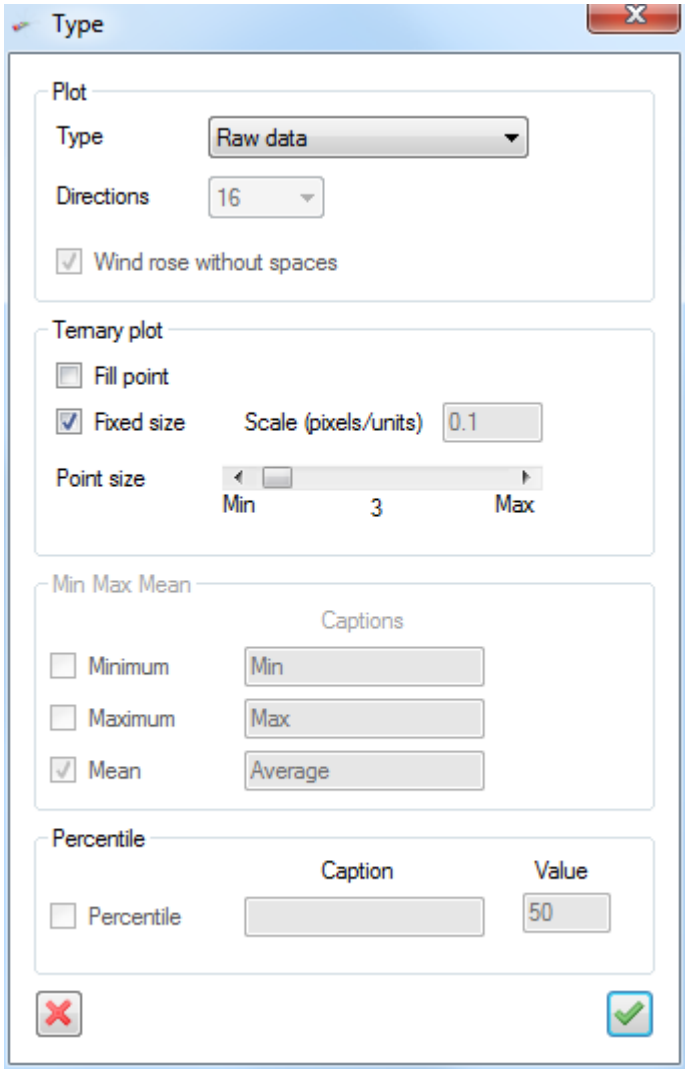
Note that if the user selects at the same time minimum, maximum and mean, such values will be represented over the same plot, and the minimum values could be not visible very well. To avoid this problem the user can choose to produce plot of minimum values only. Be aware that if the speeds are zero for all the directions, the minimum values plot will be not produced.

On the contrary, the percentiles will be always plotted alone (i.e. without minimum, mean and maximum). The **percentiles** are useful for example, for plotting pollution roses because they allow to filter possible outlier from the plot (outliers that are present when the plot of maximum values is produced). In order to create the plot of percentiles the user must specify the value of the percentile to plot, which is a number between 0 and 100, extremes excluded.

When reading a **third variable from Microsoft Excel**, it is possible to produce raw data plot depending on direction and the values of the two variables by selecting the `Raw data`

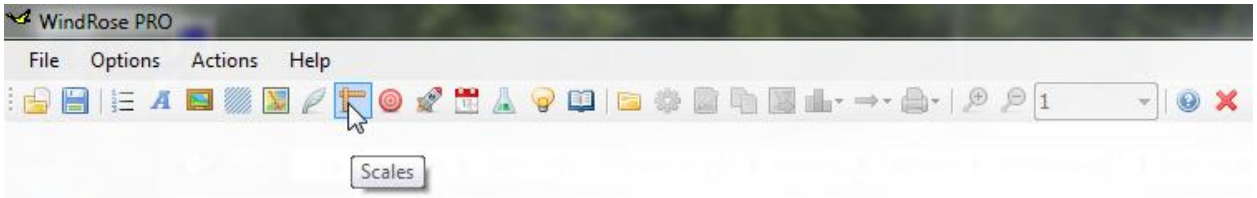
option. This is called three variables plot or ternary plot. A three variable plot can be produced for example by using wind direction, wind speed and the concentration values of a specific pollutant. A polar coordinate system is used in this kind of plots: the distance of each point from the centre (pole) is determined by the wind speed, the angle from North in clockwise direction is determined by the wind direction, and the colour and/or size of the point depends on the concentration level. The input mask allows to specify if the points must be filled or not, to select their size if they must be of fixed size, and to define a scale in pixel/units (e.g. pixels per µg/m3 of a specific pollutant) if their size depends on the value of the third variable.

The default number of directions considered for the wind rose is 16, but it is also possible to choose a different number of directions from a list. Possible numbers are: 4, 8, 10, 12, 16, 18, 20, 36, 72, 100, 120, 180, 240, 300 and 360. The user must be aware that, starting from 72 directions the chart might show strange lines, particularly for PC with low quality graphical cards.



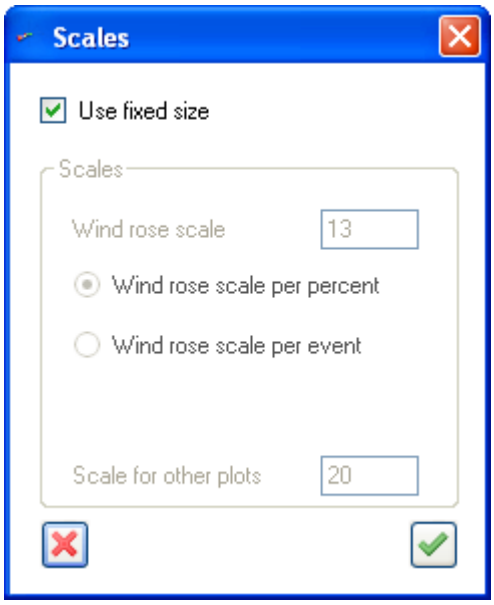
7.3.7 Options > Scales

The *Options* > Scales menu item allows to specify a scale for the plot. The plot scale mask can also be loaded by means of the button shown in the next figure.



If the Use fixed size checkbox is checked, the plot is automatically scaled to the maximum possible plotting dimension.

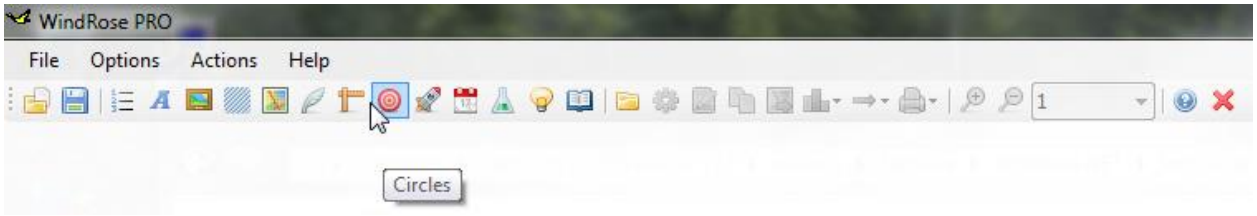
Otherwise two different plot scales can be specified, one for the wind roses and the other one for the other types of plot (average wind, raw data, etc.). The wind rose scale can be specified in terms of number of drawing points each percent of data, or by number of drawing points each event. In order to compare different wind roses, the same scale in terms of number of points per percent of data must be used. For the other types of plots the scale indicates the number of points per unit of data, for example number of points per 1 m/s when plotting the average wind speed.



The plot scale can also be controlled from the main software mask by means of the zoom in and zoom out buttons represented in the following figure. The number in the drop list indicates the zooming step, while the number within the textbox (13 in the example) represents the current scale factor. Note that the zooming buttons automatically modify the scales indicated in the previous mask. If the `Use fixed size` checkbox is checked the zooming buttons are not enabled.

7.3.8 Options > Circles

The *Options* > `Circles` menu item allows to specify if circles must be represented on the plot. The circle mask can also be loaded by means of the button shown in the next figure.

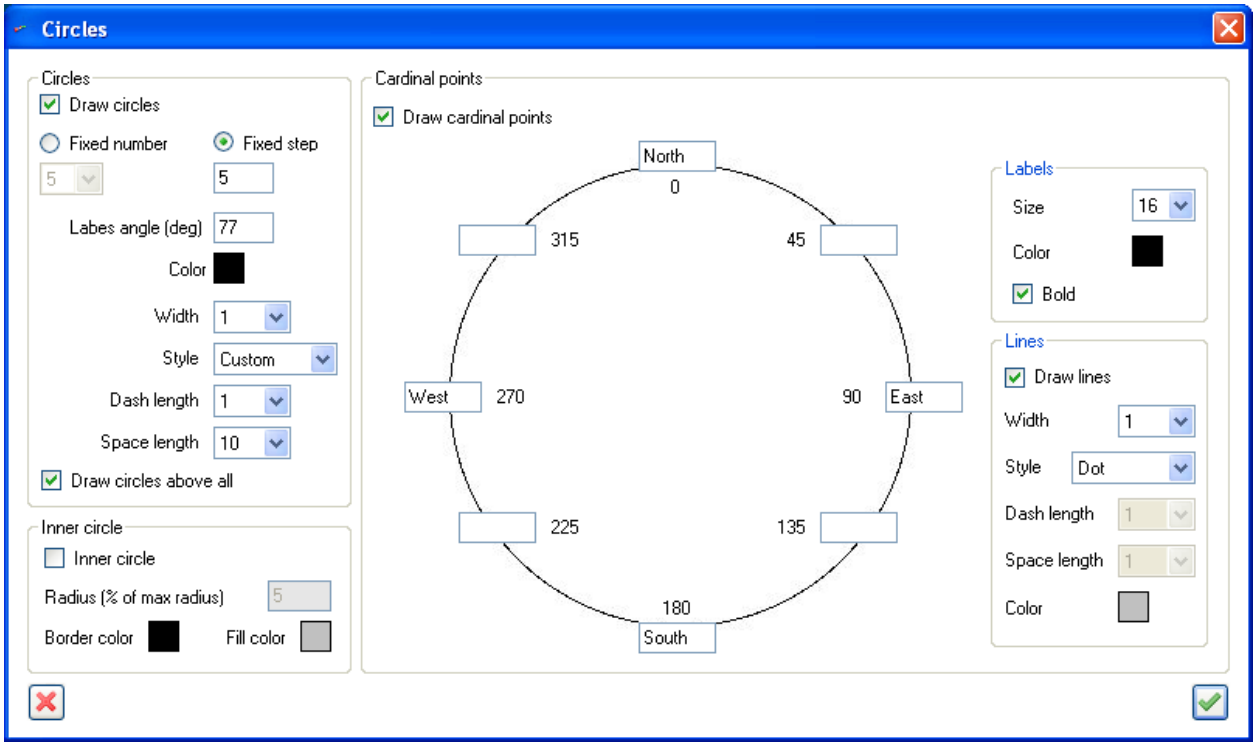


A fixed number of circles or equispaced circles can be represented over the plot. It is possible to choose their colour, width and style. The user must also specify the angle of the imaginary segment over which percentages or values are written. The angle starts from North and increases clockwise (i.e. 0 is North, 90 is East, 180 is South, ...).

It is possible to specify the number of circles to draw (if the `Fixed number` option is selected) or, alternatively, the constant distance between circles (if the `Fixed step` option is selected). In both cases the maximum number of circles that can be drawn is 10, therefore the software will issue a warning message if the value of the step is too small and too many circles would be produced. Please note that the step represents a percentage if a wind rose must be produced, while in all the other cases (raw data, rays, ...) the step represents a value (e.g. if a raw data plot of wind direction and wind speed in m/s must be produced, a value of 2 in the fixed step field means to draw a circle every 2 m/s).

It is also possible to specify if cardinal points must be printed over the wind rose plot, and the labels associated to them. Cardinal labels are written when the `Draw cardinal points` checkbox is checked. The size, colour and boldness of the labels can be defined by the user. Opposite cardinal point labels are joined by a line if the user checks the `Draw lines` checkbox. As for the circles, it is possible to specify colour, width and style of the lines.

The user can specify if an inner circle must be drawn. In that case the wind rose will start from the border of the circle, not from a single central point. Sometimes the wind rose plot could be more clear using this option. The radius of the inner circle is specified as a percentage of the maximum radius of the wind rose; the possible values of the percentage are in the range [1,30]. This means that the maximum radius of the inner circle can be equal to 30% of the maximum radius of the wind rose. The user can also specify a colour for the border of the inner circle and a colour for filling the inner circle.



7.3.9 Options > Runways

The *Options* > Runways menu item allows to specify if runways calculations must be carried out. The runways mask can also be loaded by means of the button shown in the next figure.

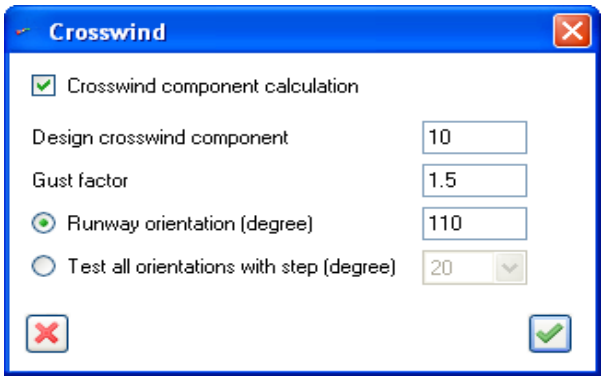
A crosswind is any wind that is blowing perpendicular to a direction.

In aviation, a crosswind is the component of wind that is blowing across the runway making a landing more difficult than if the wind were blowing straight down the runway. If a crosswind is strong enough it may exceed an aircraft's crosswind limit and an attempt to land under such conditions could cause structural damage to the aircraft.

Crosswinds can also occur when travelling on roads, especially on large bridges and highways, which can be dangerous for motorists because of possible lift force created as well as causing the vehicle to change direction of travel.

Each aircraft has a uniquely stated maximum crosswind component derived from flight test experiments. For example a Boeing 727-200 has a maximum crosswind component of 35 knots, while a Cessna 172 has a maximum crosswind component of 17 knots.

According to the Federal Aviation Administration (FAA AC 150/5300-13) a runway orientation must satisfy **95% coverage** considering yearly wind conditions. This means that for the 95% of the time, the crosswind component must be smaller than the maximum crosswind component of the aircrafts landing in such airport.



WindRose PRO can be used for calculating crosswinds and to evaluate the correct orientation of a runway. It is also possible to find the best orientation for a new runway. It is possible to specify a designed, or maximum, crosswind component, using the same units of the wind data loaded in WindRose PRO.

If you want to evaluate the correct orientation of an existing runway, check the `Runway orientation` radio button and specify the orientation in degree. Note that the orientation goes from the specified angle to it plus 180. For example an orientation of 45 degrees means a runway from NE to SW, while an orientation of 225 degrees means a runway from SW to NE.

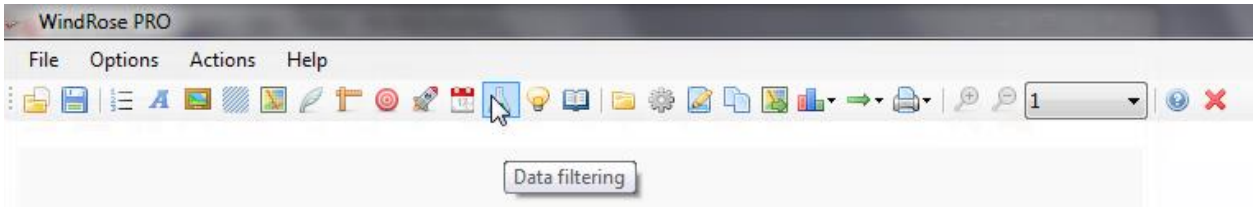
If you want to determine the best orientation of a runway, check the `Test all orientations` radio button and specify the angular step which will be applied starting from 0 degrees. For example an angular step of 10 degrees means that 36 runway orientations will be examined: 0, 10, 20, ..., 350.

The `Gust factor` is used to estimate gust values when the input data contain the wind speed averaged over a relatively long period of time (e.g. 1-hour averages), if the input data already describe the wind gusts, the gust factor must be 1.

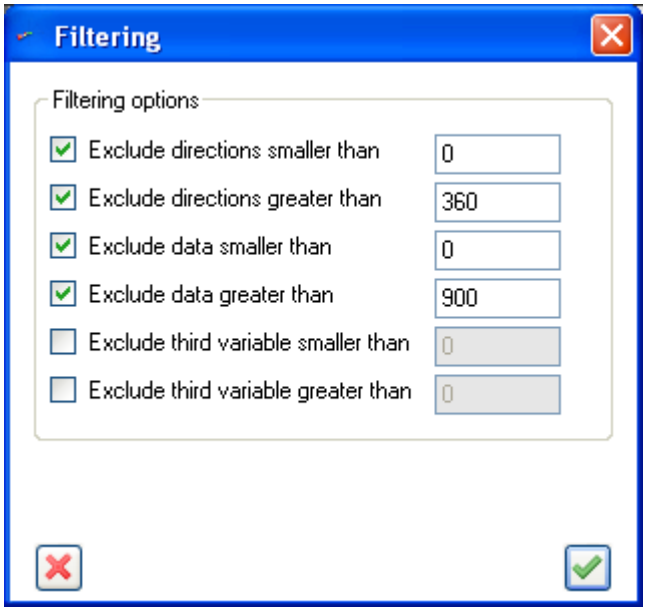
The output will contain information about the percentage of time above and below the design crosswind component, the maximum crosswind from left and right, the maximum headwind and the maximum tailwind.
Since WindRose PRO allows to filter the input data according to date and time, it is possible to evaluate the crosswind component even for airports which work only in particular seasons (for example during summer) or only during day time.
This analysis is not available when data are loaded as frequencies.

7.3.10 Options > Value filtering

The *Options* > Value filtering menu item allows to specify if particular values must be excluded from the analysis. The value filtering mask can also be loaded by means of the button shown in the next figure.

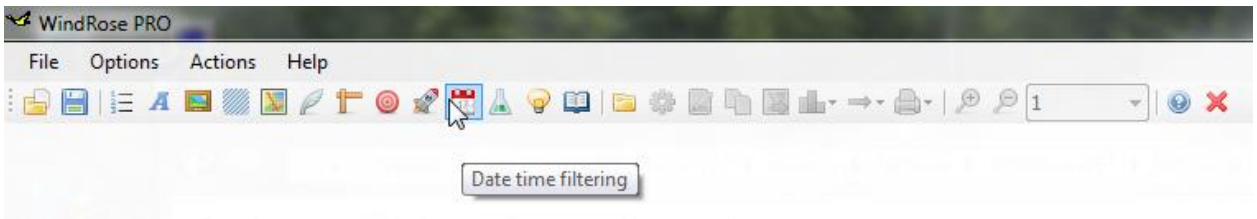


The value filtering mask allows the user to specify the values of directions and data that must be filtered (i.e. excluded) from the analysis.
Both for directions and for data, lower and upper thresholds can be indicated. Values smaller than the lower threshold or greater than the upper threshold will be excluded from the analysis. Thresholds can be specified also for the third variable, which can be loaded only with Microsoft Excel files.
When filtering options are modified, **data must be reloaded**, otherwise the filter is not applied.
The filtering options cannot be specified when data are loaded as frequencies.



7.3.11 Options > Date time filtering

The *Options* > Date time filtering menu item allows to specify if particular dates and times must be excluded from the analysis. The date time filtering mask can also be loaded by means of the button shown in the next figure.



The date time filtering mask allows the user to filter the data to be analysed according to the time and or date associated to the values. This feature can be used only if the user specifies a column containing date and time when loads data from a Microsoft Excel file or from ASCII files.

The user may filter the data according to:

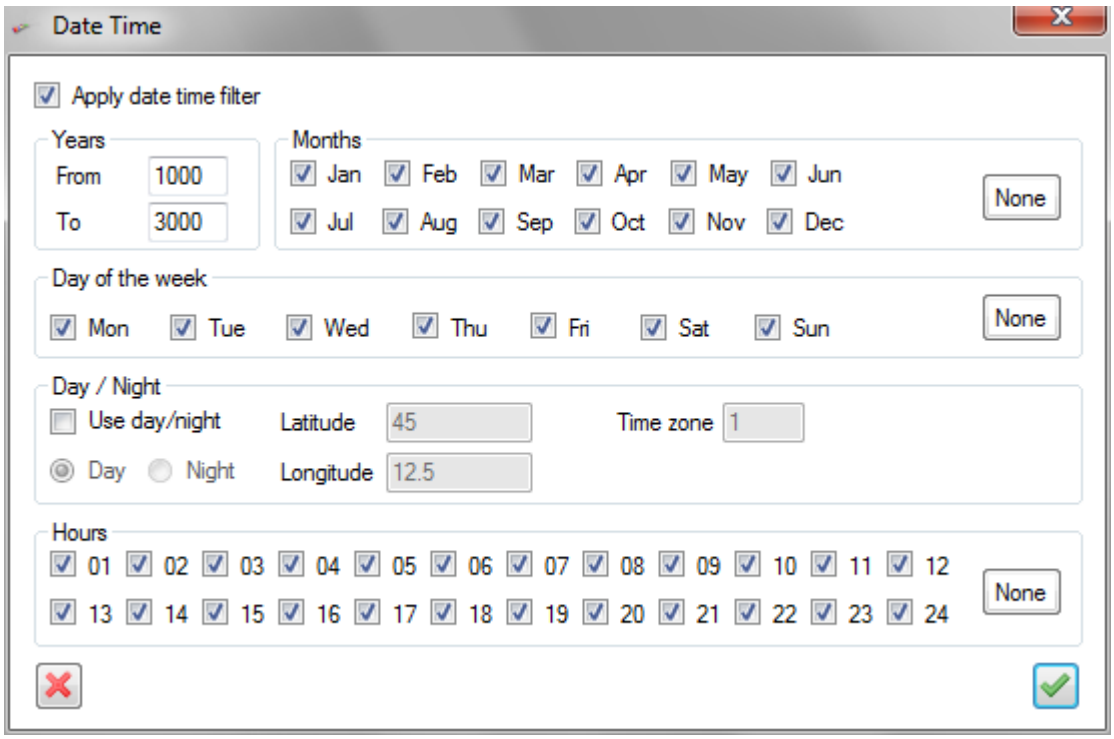
- the year;
- the month;
- the day of the week;
- the hour of the day;
- the day/night hours.

The last two options are alternative.

The day/night hours are calculated starting from longitude, latitude and time zone specified by the user. Please note that:

- Sunrise and sunset times are based on the ideal situation, where no hills or mountains obscure the view and the flat horizon is at the same altitude as the observer. Sunrise is the time when the upper part of the Sun is visible, and sunset is when the last part of the Sun is about to disappear below the horizon (in clear weather conditions).
- Daylight saving time is not considered.
- Atmospheric refraction is not considered.

When EnergyPlus Weather data are used, longitude and latitude are automatically taken from the header records of the input file.



7.3.12 Options > Wind power

The *Options* > Wind power menu item allows to specify the features of a wind turbines in order to calculate the wind power potential of a location. The wind power mask can also be loaded by means of the button shown in the next figure.

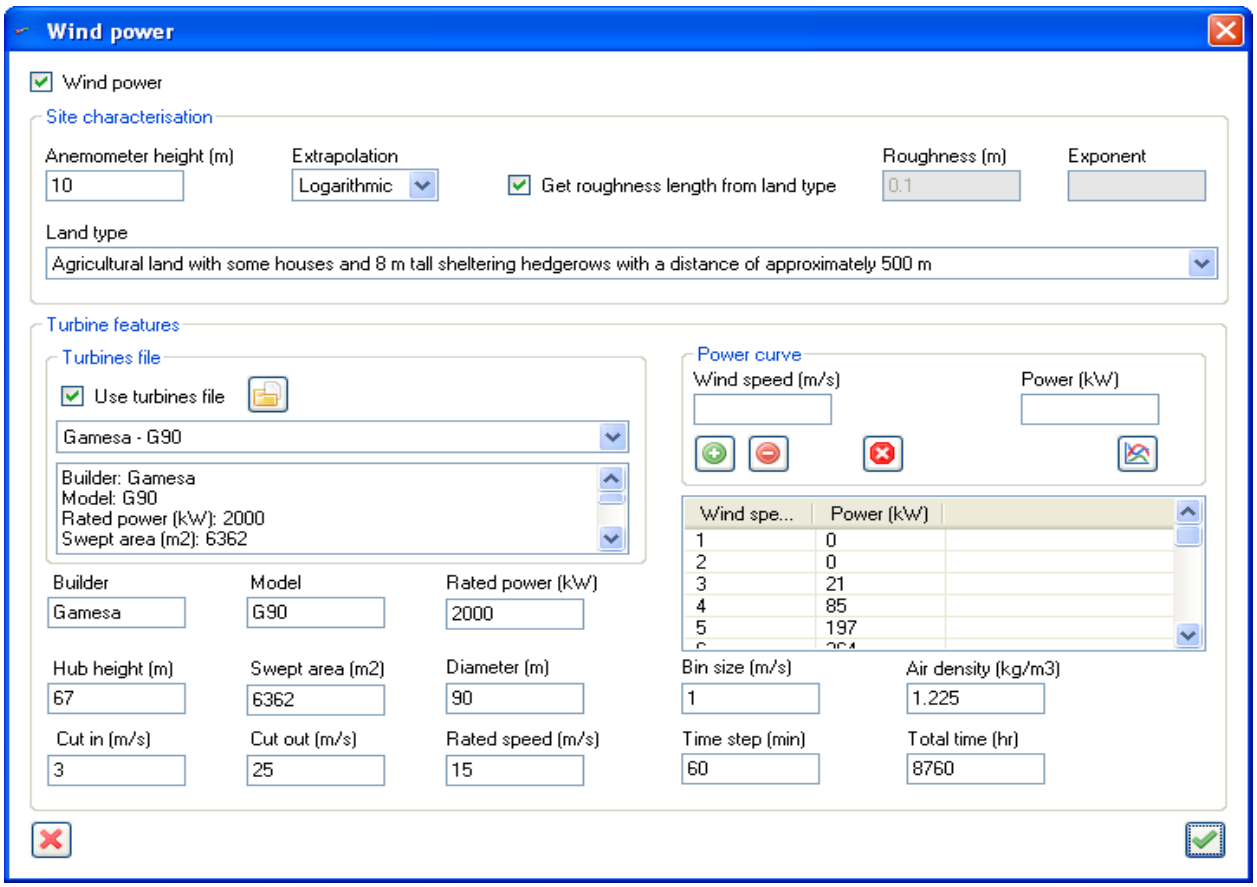
The wind power potential is calculated only if the `Wind power` checkbox is checked.

WindRose PRO assumes that the wind speed at height z can be written as

$$u(z) = \frac{u(z_0)}{k} ln\left(\frac{z}{z_0}\right)$$

where u is the wind speed, z_0 is the roughness length (m) and k is the von Karman constant. The ratio between the above equation written for the turbine hub height, and the same equation written for the anemometer height, allows to project the wind speed at the hub height by means of the ratio between two logarithms.

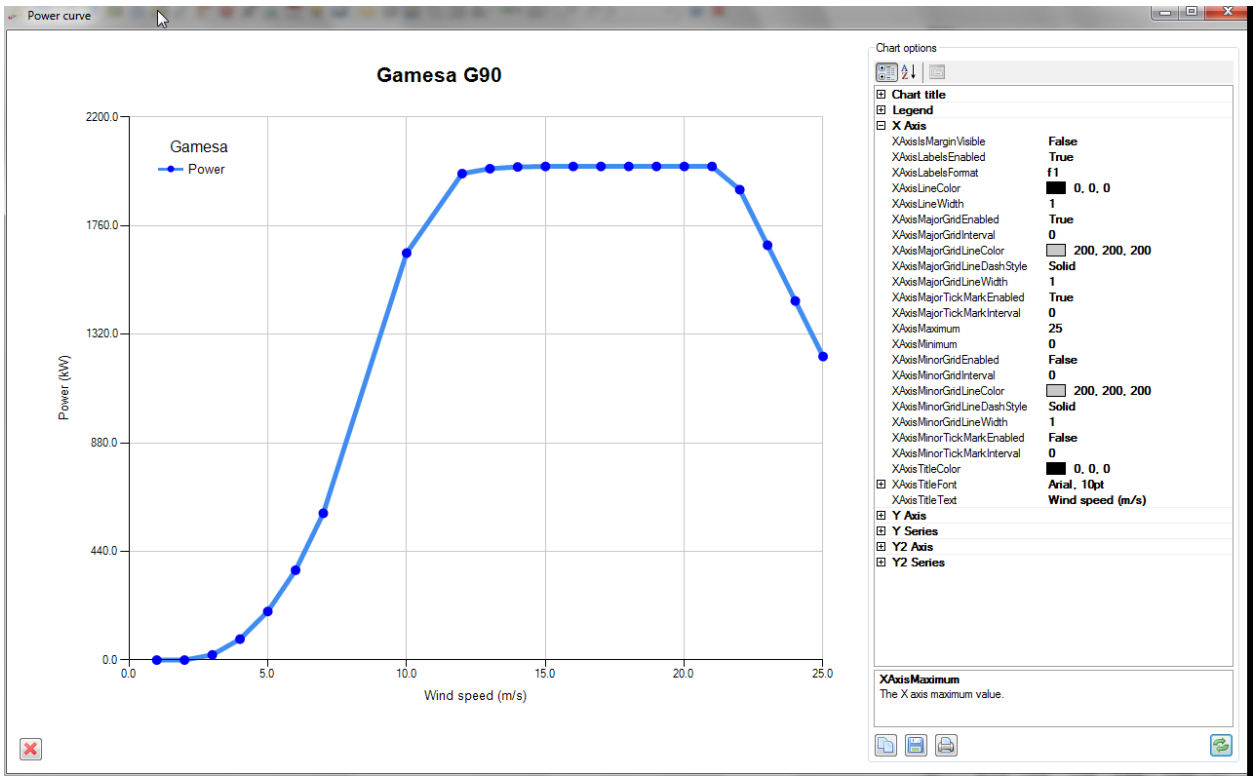
The roughness length can be determined automatically by the software by selecting the land type over which the wind turbine is located. Alternatively its value can be directly specified by the user.



The user may insert the features of a specific wind turbine, or may select a turbine among others loaded from a specific file (*.TRB), (see 7.4.7).

If the user inserts the features of a specific turbine, without using the turbine file (*.TRB), the power curve data can also be inserted. Each turbine can be added or modified by inserting the corresponding values within the text boxes and clicking the button. A single turbine can be deleted by selecting it within the grid and clicking the button, while the button deletes all the turbines within the grid.

The power curve can be graphically represented by means of the button, as shown in the next figure. The chart features can be modified by means of the right panel. Each modified option is made visible on the chart only after the button is clicked. The chart can be copied, saved and printed by means of the three buttons placed at the bottom of the chart options.



Zooming operations are also possible by clicking over the chart and moving the mouse pointer.

The **Time step** represents the time distance in minutes between two consecutive wind observations. Such a value must be constant for a correct calculation of the experimental capacity factor, that means that the time distance between two consecutive observations must be a constant through the file, for example all the observations can be spaced of 60 minutes. A wrong time step, if smaller than the correct one, will result in a underestimation capacity factor (and viceversa). The **Total time**, expressed in hours, is another important parameter for calculating the experimental capacity factor. If the available data cover one year (non-leap year), the total time must be 8760 hours, but if the data cover, for example four years, the total time must be 35064 hours. A wrong total time, if smaller than the correct one, will result in an overestimation of the capacity factor (and viceversa).

The parameters of the Weibull and Rayleigh probability density functions (PDF) are calculated by WindRose PRO.

The PDF of the Weibull distribution for a non null variable x (i.e. x ≥ 0) is described by

$$f(x) = \frac{k}{\Lambda}\left(\frac{x}{\Lambda}\right)^{(k-1)} e^{-\left(\frac{x}{\Lambda}\right)^k}$$

where k > 0 is the shape parameter and λ > 0 is the scale parameter. The Weibull distribution is related to a number of other probability distributions, for example the exponential distribution (k = 1) and the Rayleigh distribution (k = 2).

The Weibull distribution is particularly important in wind power applications for describing the wind speed distribution (i.e. x=v in the previous equation). The shape parameter and the scale parameter can be estimated starting from the average wind speed and its standard deviation σ, obtained from the measured values, as [1]

$$k = \left(\frac{\sigma}{\bar{v}}\right)^{-1.086} \qquad \lambda = \frac{\bar{v}}{\Gamma\left(1+1/k\right)}$$

Where Γ is the gamma function.

1 Jiang Q., Doyle J.D., Haack T., Dvorak M.J., Archer C.L. and Jacobson M.Z. (2008) Exploring wind energy potential off the California coast. Geophysical Research Letters, Vol. 35, L20819.

The PDF of the Rayleigh distribution for a non null variable x (i.e. x ≥ 0) is described by

$$f(x) = \frac{x}{\Sigma^2} e^{-\left(\frac{x^2}{2\Sigma^2}\right)}$$

where σ > 0 is the mode of the distribution. The maximum likelihood estimate of the parameter σ is

$$\sigma = \left(\frac{1}{2N} \sum_{i=1}^{N} x_i^2 \right)^{\frac{1}{2}}$$

where x_i is the value of the i^{th} of the N samplings of the random variable

A Rayleigh distribution is often observed when the overall magnitude of a vector is related to its directional components. One example where the Rayleigh distribution naturally arises is when wind speed is analysed into its orthogonal 2-dimensional vector components. Assuming that the magnitude of each component is uncorrelated and normally distributed with equal variance, then the overall wind speed (vector magnitude) will be characterized by a Rayleigh distribution.[2]

Integrating the Weibull PDF between two wind speeds gives the probability that the wind speed is between those two values. Therefore it is possible to define the **operating probability** of a wind turbine integrating between the cut-in wind speed v_{ci} (the minimum wind speed to operate) and the cut-out wind speed v_{co} (the maximum wind speed above which the turbine must be turned off for its protection) as (Jiang et al., 2008):

$$p_o = \exp\left[-\left(\frac{v_{ci}}{k} \right)^k \right] - \exp\left[-\left(\frac{v_{co}}{k} \right)^k \right]$$

The **energy output** can be estimated by means of an empirical equation[3]

$$P = 8760 \left(0.087 \bar{v} - \frac{P_{Rated}}{D^2} \right) P_{Rated}$$

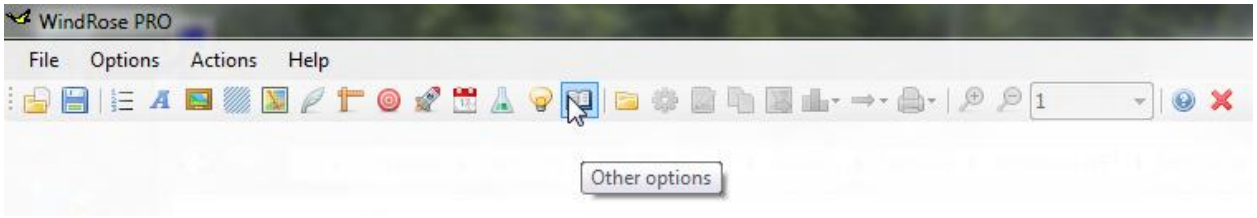
2 http://en.wikipedia.org/wiki/Rayleigh_distribution

3 Jacobson, M. Z., and G. M. Masters, 2001: Exploiting wind versus coal. Science, 293, 1438.

where 8760 are the hours in an year, P_{Rated} is the rated power (kW) of the wind turbine, D is the blade diameter (m).

7.3.13 Options > Other

The *Options* > Other menu item allows to activate other calculation options which are detailed in the following. The other options mask can also be loaded by means of the button shown in the next figure.

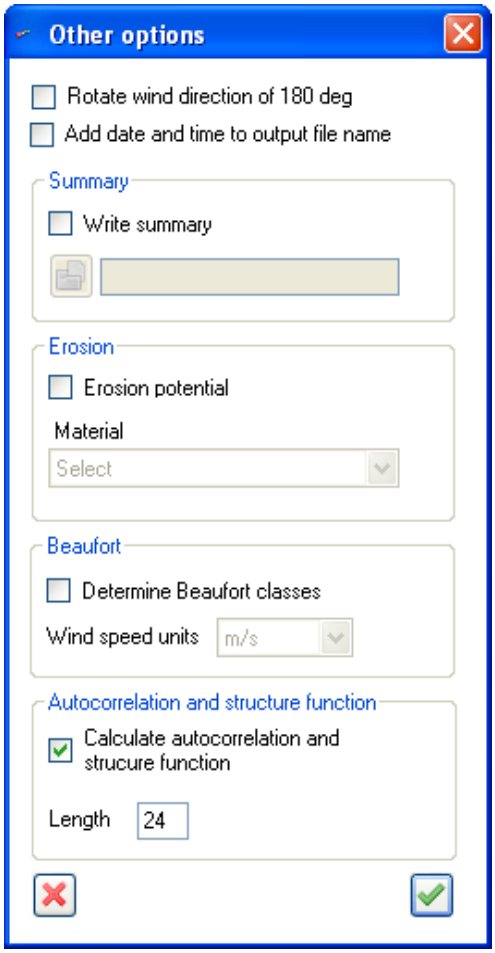


Rotate wind direction of 180 deg

Check this box if the wind direction must be rotated of 180 degrees. This option can be useful to switch from wind direction (meant as the direction from which the wind blows) to flow direction (meant as the direction towards which the wind blows), or viceversa.

Add date and time to output file name

Check this box to add date and time to the ASCII analysis output file name. Date and time are added with the format YYYYMMDDhhmmss, where YYYY is the year, MM the month, DD the day, hh the hour (00-23), mm the minute (00-59) and ss the second (00-59). By checking this box a different file will be produced at every analysis, even using the same input file. This option is useful when you do not want to overwrite the output file.



Write summary

Check this box to write a summary at the end of the output file generated during the analysis (see 7.4.1). The summary is generated starting from a template text file specified by the user containing specific TAGS. This option can be useful to write a report in short time and in the user's own language. The allowed TAGS, which must be specified in capital letters, are summarised in the following table.

An example of template summary is in the Sample directory, whose location depends on the operating system. The user can create her/his own templates. The summary can be created only when hourly data are analysed (i.e. not frequencies).

Note that the summary can be written only for 4, 8 and 16 directions.

TAG	Variable
WR_TOTDATA	Total number of data
WR_VALDATA	Number of valid data
WR_PCTDATAVAL	Percent of valid data
WR_W100	Maximum value of data
WR_W95	95 percentile of data
WR_W50	50 percentile of data
WR_DMAX01	1st prevailing direction
WR_DMAX02	2nd prevailing direction
WR_DMAX03	3rd prevailing direction
WR_DMAXPCT01	Percent of data in the 1st prevailing direction
WR_DMAXPCT02	Percent of data in the 2nd prevailing direction
WR_DMAXPCT03	Percent of data in the 3rd prevailing direction
WR_WMAX01	Data value of direction with maximum data
WR_WMAX02	Data value of direction with 2nd maximum data
WR_WMAX03	Data value of direction with 3rd maximum data
WR_WMAXDIR01	Direction with 1st maximum data
WR_WMAXDIR02	Direction with 2nd maximum data
WR_WMAXDIR03	Direction with 3rd maximum data
WR_WAVE01	Data value of direction with 1st average data
WR_WAVE02	Data value of direction with 2nd average data
WR_WAVE03	Data value of direction with 3rd average data
WR_WAVEDIR01	Direction with 1st average data
WR_WAVEDIR02	Direction with 2nd average data

WR_WAVEDIR03	Direction with 3rd average data

Erosion potential

Check this box for calculating the wind erosion emission factors for the selected material. The emission factors are calculated for PM30, PM15, PM10 and PM2.5 using the **AP42 methodology** (see chapter 13.2.5 "Industrial Wind Erosion" of AP42 for more information). The emission factors are calculated under the following assumptions:

- Input wind speed units are m/s
- Anemometer height is 10 m above ground
- Almost flat pile (height/base < 0.2)

Beaufort

Check this box for calculating the data distribution in terms of Beaufort classes.

The scale was devised in 1805 by Sir Francis Beaufort, a Royal Navy officer. In the early 19th Century, naval officers made regular weather observations, but there was no standard scale and so they could be very subjective - one man's *stiff breeze* might be another's *soft breeze*. Beaufort succeeded in standardizing the scale. For additional information see for example: http://en.wikipedia.org/wiki/Beaufort_scale.

A brief description of the 13 Beaufort classes is reported in the following table.

Class	**Wave heights (m)**	**Description**
0	0	Calm
1	0-0.2	Light air
2	0.2-0.5	Light breeze
3	0.5-1	Gentile breeze
4	1-2	Moderate breeze
5	2-3	Fresh breeze
6	3-4	Strong breeze

7	4-5.5	High wind, Moderate gale, Near gale
8	5.5-7.5	Gale, Fresh gale
9	7.5-10	Strong gale
10	10-12.5	Storm, Whole gale
11	12.5-14	Violent storm
12	>14	Hurricane force

Autocorrelation and structure function

The calculation of **autocorrelation** and **structure function** for the directional variable is activated by checking the corresponding check box and specifying the time length. The meaning of the **time length (L)** depends on the time resolution Δt of the data, for example if the data are available every hour (Δt = 1 hour), a value of 24 means to calculate the two functions up to a maximum time distance of 24 hours, while if the data are available with a time resolution of 15 minutes (Δt = 15 minutes), the same value of 24 means to calculate the two functions up to a maximum time distance of 6 hours. Each user must know her/his data in order to obtain meaningful results.

The autocorrelation is the correlation of a variable with itself at two different times. The degree of correlation of a variable x at time $t_i=i\Delta t$ with itself at a different time $t_{i+k}=(i+k)\Delta t$ is calculated as[4]

$$A(k)=\frac{\sum_{i=1}^{N-k}\left[\left(x_i-<x_i>\right)\left(x_{i+k}-<x_{i+k}>\right)\right]}{\left[\sum_{i=1}^{N-k}\left(x_i-<x_i>\right)^2\right]^{\frac{1}{2}}\left[\sum_{i=1}^{N-k}\left(x_{i+k}-<x_{i+k}>\right)^2\right]^{\frac{1}{2}}}$$

where N is the total number of data and k goes from 0 to the time length L.
The two averages indicated by < … > are calculated as:

$$<x_i>=\frac{1}{N-k}\sum_{i=1}^{N-k}x_i$$

4 Stull R.L. (1988) An introduction to boundary layer meteorology. Kluwer Academic Publishers, The Netherlands.

$$< x_{i+k} >= \frac{1}{N-k} \sum_{i=1}^{N-k} x_{i+k}$$

Approximate expressions for the autocorrelation equation also exist[5], but the exact one reported above is implemented in WindRose PRO3.

The structure function is another statistics to study possible common variations between a variable at time $t_i=i\Delta t$ and the same variable at a different time $t_{i+k}=(i+k)\Delta t$. It is defined as:

$$S(k) = \frac{1}{N} \sum_{i=1}^{N-k} (x_i - x_{i+k})^2$$

For the same time (k=0) the autocorrelation is 1 and the structure function is 0.

The maximum value which can be specified in the software for the time length is 999. If the time length exceeds the number of valid data the software will not execute the calculation of the two functions.
Autocorrelation and structure function can be calculated only if date/time filtering is not applied, otherwise a message similar to the one shown in the next figure is prompted. In such case the coefficients will be calculated only after unchecking the "*Apply date time filter*" check box (see 7.3.11).

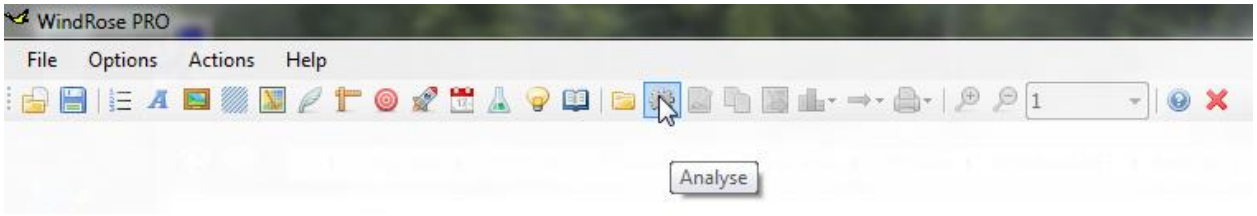
Note that autocorrelation and structure function are misleading if the data are characterized by many invalid values.
The values of the two functions are written in the Notes which can be saved in RTF format. They can be also exported in Microsoft Excel format together with the two corresponding charts.

5 Cancino-Solórzano Y., Gutiérrez-Trashorras A.J., Xiberta-Bernat J. (2010) Analytical methods for wind persistence: Their application in assessing the best site for a wind farm in the State of Veracruz, Mexico. Renewable Energy, 35, 2844-2852.

7.4 Actions

7.4.1 Actions > Analyse

The `Actions > Analyse` menu item allows to analyse the loaded data. The same action is carried out by clicking the button shown in the next figure.

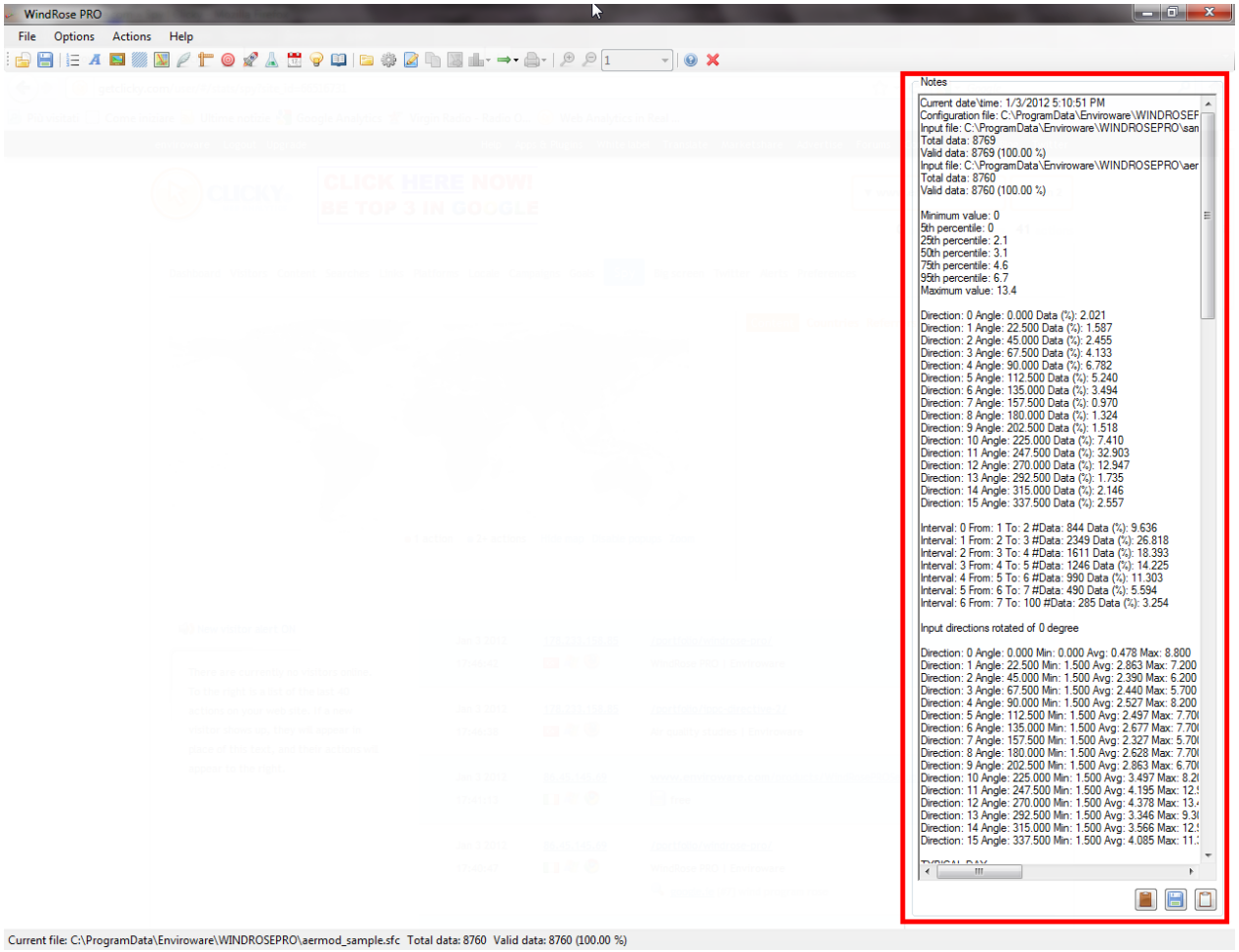


During the analysis phase many important tasks are carried out, for example the filtering of data according to their values and/or dates and times, the wind power calculations, the preparation of the joint frequency distribution of direction and values, and many other.

The analysis depends on the type of data loaded: time dependent data or frequencies (more results are produced for time dependent data than for frequencies). It also depends on the user choices (e.g. calculation of the erosion potential, calculation of wind power, etc.).

WindRose PRO produces an output file with the same name of the loaded file and extension .TXT (e.g. if the input file is sample.csv, the output file is sample.csv.txt) containing information about the data loaded. If the option to add date and time to the output file name has been selected, the output file name will also contain date and time, therefore if the input file is sample.csv, the output file is sample.csv_YYYYMMDDhhmmss.txt, where YYYY is the year, MM the month, DD the day, dd the hour, mm the minute and ss the second. In this case at every analysis a different file will be produced.

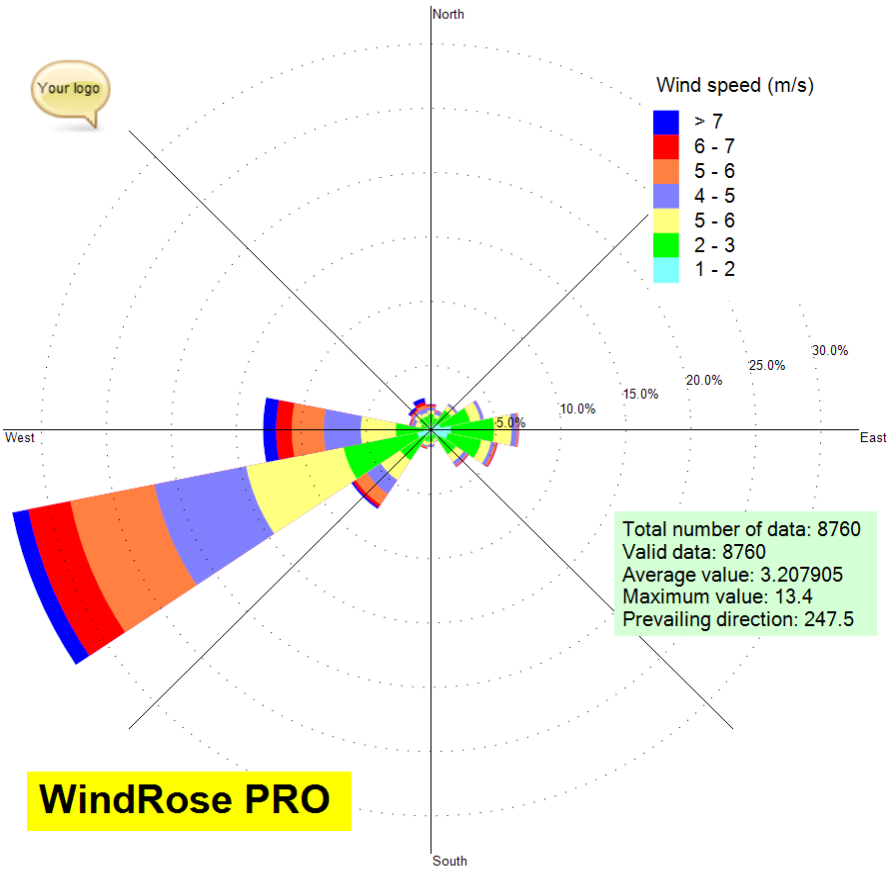
During the analysis a lot of information is written in Rich Text Format (RTF) within the notes in the rightmost part of the main mask (the red rectangle in the following image). The user can also write some text within the notes area in order to personalise the information. The notes can be saved in a RTF file () or copied within a document (). If needed, the notes can also be deleted using the  button.



7.4.2 Actions > Draw

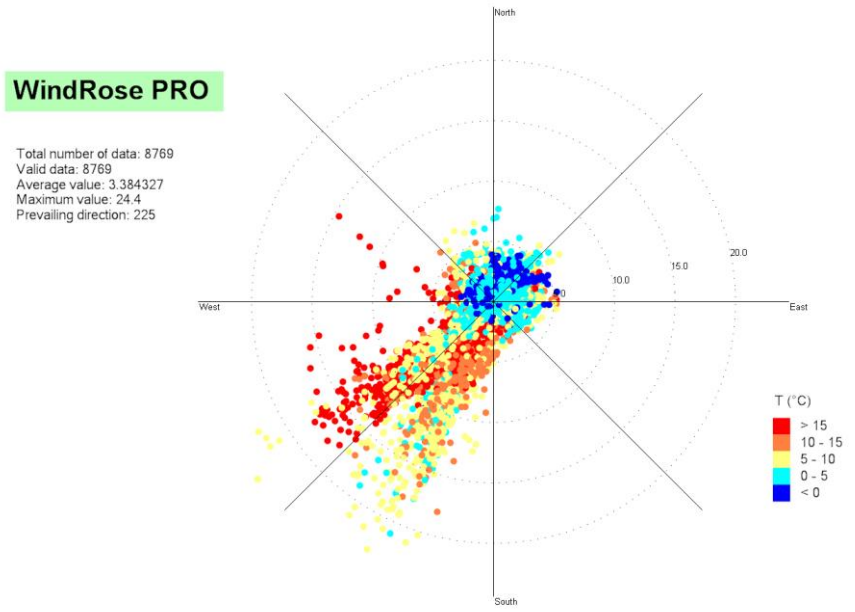
The `Actions > Draw` menu item allows to draw the plot. The same action is carried out by clicking the button shown in the next figure.

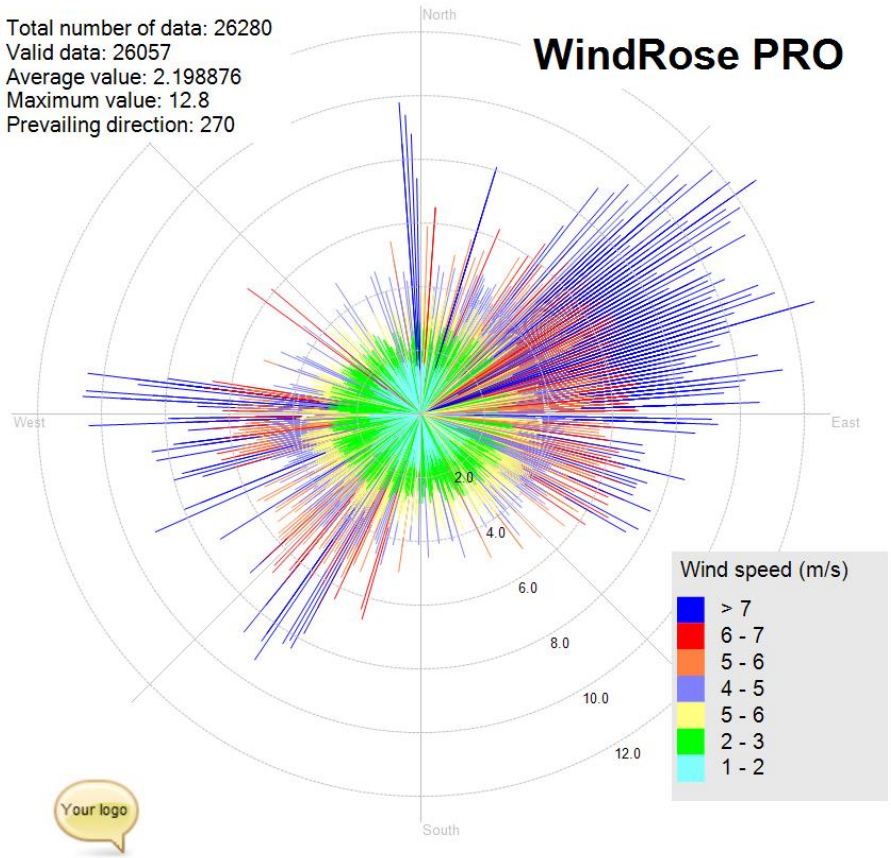
The draw button allows the user to plot the wind rose or any other selected type of plot. This button is enabled only after the data have been analysed. As a result, if you have selected to draw a wind rose, the WindRose PRO screen will appear like the following one.



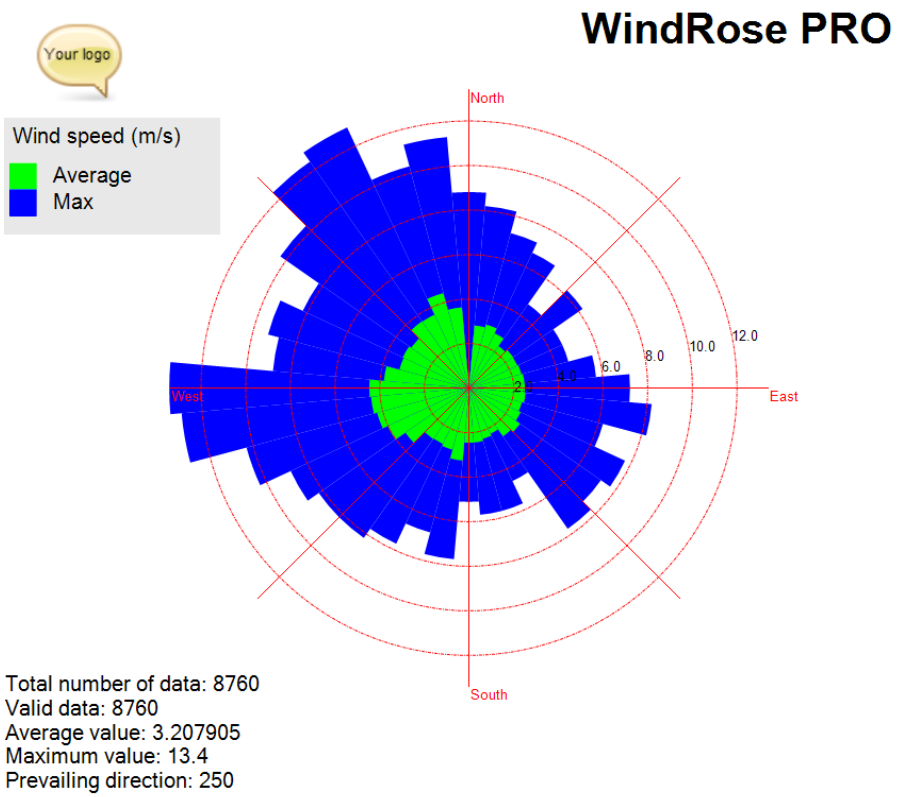
Note that the four elements on the plot (title, legend, notes and user's logo) can be placed anywhere by clicking over each of then with the mouse pointer and dragging.

You can also select to plot the raw data or the rays plot, in such cases the WindRose PRO screen will appear like the following two images. These two plots are particularly useful when a third variable is loaded (from Microsoft Excel). For example the user can load wind direction, wind speed and the concentration of a pollutant (all the three variables measured from the same monitoring station). Then the raw data plot will show circles of different colours (representing different concentration levels) at different positions depending on wind direction and wind speed. This kind of plot will help to understand, for the specific example cited, if high levels of concentrations are often associated to a given wind direction, then facilitating the individuation of possible sources.


WindRose PRO
Total number of data: 8769
Valid data: 8769
Average value: 3.384327
Maximum value: 24.4
Prevailing direction: 225
North
West
East
South
10.0
15.0
20.0
T (°C)
> 15
10 - 15
5 - 10
0 - 5
< 0


Total number of data: 26280
Valid data: 26057
Average value: 2.198876
Maximum value: 12.8
Prevailing direction: 270
WindRose PRO
North
West
East
South
2.0
4.0
6.0
8.0
10.0
12.0
Wind speed (m/s)
> 7
6 - 7
5 - 6
4 - 5
5 - 6
2 - 3
1 - 2
Your logo

It is possible to represent in the same plot minimum, maximum and average values of data. The next figure represents, for example, the average and the maximum values of the data for each direction.



7.4.3 Actions > Copy

The `Actions > Copy` menu item allows to save the plot in the clipboard. Once in the clipboard, you can paste the plot in any document. The same action is carried out by clicking the button shown in the next figure.

7.4.4 Actions > Save

The `Actions > Save` menu item allows to save the plot in raster format. The same action is carried out by clicking the button shown in the next figure.

The possible file formats to save the plot are:

BMP Windows Bitmap

JPG JPG/JPEG Format

GIF Compuserve GIF

ICO Widows Icon

WMF Windows Metafile Format

EMF Enhanced Metafile Format

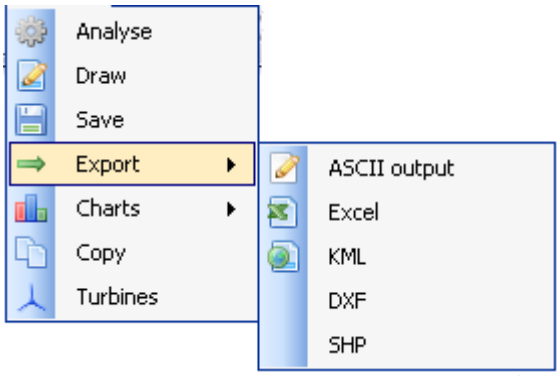
PNG Portable Network Graphics

TIFF Tagged Image File Format

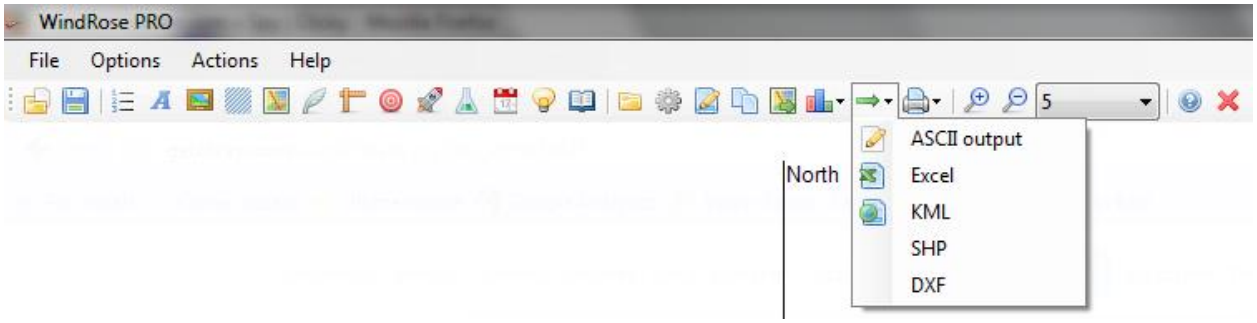
EXIF Exchangeable Image File Format

7.4.5 Actions > Export

The `Actions > Export` menu item allows to export the results in different formats, as shown in the next figure.



The same action is carried out by clicking the button shown in the next figure.



The numerical results can be exported as ASCII files or as Microsoft Excel files. The graphical results can be exported in KML format for Google Earth, SHP format for GIS systems, and DXF format for CAD systems.

7.4.5.1 Actions > Export > ASCII output

This menu item allows to view the output file (the file with .TXT extension) using the **Notepad** application installed on the user's PC.

An example of the ASCII output file is reported in the following box. This information and other, together with automatically produced charts, are also reported in a Microsoft Excel file if the user decides to export it (note that Microsoft Excel must be installed on the PC).

```
--------------------------------------------------
WindRose PRO is copyright Enviroware srl (2013)
             http://www.enviroware.com
--------------------------------------------------

File created on 1/4/2012 7:04:57 PM
WindRose PRO

Input file: C:\ProgramData\Enviroware\WINDROSEPRO\sample.xlsx
Configuration file: C:\ProgramData\Enviroware\WINDROSEPRO\sample.wro3

Total data: 8769
Valid data: 8769 (100.00% of total data)

**************************
Date/time filtering options
**************************

Years from 1000 to 3000
Months: Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Days: Mon Tue Wed Thu Fri Sat Sun
Hours: 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23

Number of data after filtering: 8768


****************
Data distribution
****************
Minimum         0
5th percentile  0.5
25th percentile 1.2
50th percentile 2.1
```

```
75th percentile 4.3
95th percentile 10.6
Maximum         24.4

**********************
Rose on 16 directions.
**********************
Dir    Angle(deg)    Percent
0     0.000       2.384
1     22.500       5.212
2     45.000       10.185
3     67.500       5.965
4     90.000       4.174
5     112.500       2.486
6     135.000       1.460
7     157.500       0.684
8     180.000       1.300
9     202.500       11.097
10     225.000       23.061
11     247.500       5.075
12     270.000       1.791
13     292.500       1.802
14     315.000       2.475
15     337.500       2.019

************************************************************
Second variable (wind speed, stability, ...) on 7 intervals.
************************************************************
Int.       From       To       Data       Percent
00         1    2  2647        30.189
01         2    3  1512        17.245
02         3    4  656         7.482
03         4    5  427         4.870
04         5    6  343         3.912
05         6    7  329         3.752
06         7    100  1203        13.720

Input directions rotated of 0 deg.

Maximum data value (units of input) 24.4

************************************
Joint frequencies (directions on rows)
************************************
92     71     34     8      0      3      1
237    166    46     7      1      0      0
581    222    65     15     8      2      0
342    132    34     15     0      0      0
197    126    32     6      5      0      0
104    99     14     1      0      0      0
76     49     3      0      0      0      0
41     13     6      0      0      0      0
49     21     13     14     8      1      8
106    93     100    93     74     93     414
228    245    216    218    217    209    689
155    95     49     23     24     16     83
91     40     16     6      1      0      3
99     39     12     1      1      1      5
143    54     9      8      2      1      0
106    47     7      12     2      3      0

************************************************************
Average data value along each direction (in units of input data)
************************************************************
Dir    Angle(deg)    #Data      Min     Mean    Max
0     0.000       434         0.000   1.264   7.700
1     22.500       588         0.300   1.809   5.700
2     45.000       1162         0.300   1.704   6.700
3     67.500       726         0.300   1.620   5.000
4     90.000       452         0.300   1.865   5.300
```

5	112.500	267	0.300	1.836	4.200
6	135.000	164	0.300	1.658	3.800
7	157.500	99	0.300	1.425	3.800
8	180.000	157	0.300	2.500	12.500
9	202.500	1064	0.300	6.470	23.000
10	225.000	2133	0.300	5.687	24.400
11	247.500	532	0.300	3.778	22.200
12	270.000	239	0.300	1.710	14.700
13	292.500	232	0.300	1.790	14.600
14	315.000	275	0.300	1.771	6.400
15	337.500	244	0.300	1.762	6.700

****
Circular statistics
****

Interval: 0 - 1
Counts: 1495
Scalar average of direction: 36.110
Scalar average of data: 0.726
Vector average of direction: 36.733
Vector average of data: 0.171
Persistence: 0.235
Standard deviation of direction: 88.240
Root mean square of data: 0.754
Variance of data: 0.042
Variance of the X component of data: 0.301
Variance of the Y component of data: 0.238
Covariance of the X and Y components of data: 0.093
Cross wind data variance: 0.189
Along wind data variance: 0.350

Interval: 1 - 2
Counts: 2648
Scalar average of direction: 40.392
Scalar average of data: 1.530
Vector average of direction: 40.278
Vector average of data: 0.450
Persistence: 0.294
Standard deviation of direction: 82.374
Root mean square of data: 1.555
Variance of data: 0.080
Variance of the X component of data: 1.263
Variance of the Y component of data: 0.953
Covariance of the X and Y components of data: 0.322
Cross wind data variance: 0.816
Along wind data variance: 1.401

Interval: 2 - 3
Counts: 1512
Scalar average of direction: 55.609
Scalar average of data: 2.481
Vector average of direction: 56.634
Vector average of data: 0.343
Persistence: 0.138
Standard deviation of direction: 93.876
Root mean square of data: 2.498
Variance of data: 0.085
Variance of the X component of data: 3.256
Variance of the Y component of data: 2.866
Covariance of the X and Y components of data: 1.195
Cross wind data variance: 1.886
Along wind data variance: 4.236

Interval: 3 - 4
Counts: 656
Scalar average of direction: 223.268
Scalar average of data: 3.510
Vector average of direction: 223.140

```
Vector average of data: 1.047
Persistence: 0.298
Standard deviation of direction: 83.341
Root mean square of data: 3.525
Variance of data: 0.104
Variance of the X component of data: 5.371
Variance of the Y component of data: 5.956
Covariance of the X and Y components of data: 3.370
Cross wind data variance: 2.281
Along wind data variance: 9.046

Interval: 4 - 5
Counts: 427
Scalar average of direction: 223.336
Scalar average of data: 4.516
Vector average of direction: 223.129
Vector average of data: 3.117
Persistence: 0.690
Standard deviation of direction: 49.897
Root mean square of data: 4.531
Variance of data: 0.132
Variance of the X component of data: 4.491
Variance of the Y component of data: 6.322
Covariance of the X and Y components of data: 2.840
Cross wind data variance: 2.513
Along wind data variance: 8.301

Interval: 5 - 6
Counts: 343
Scalar average of direction: 222.274
Scalar average of data: 5.519
Vector average of direction: 222.210
Vector average of data: 4.905
Persistence: 0.889
Standard deviation of direction: 28.459
Root mean square of data: 5.534
Variance of data: 0.167
Variance of the X component of data: 3.193
Variance of the Y component of data: 3.377
Covariance of the X and Y components of data: 1.306
Cross wind data variance: 1.976
Along wind data variance: 4.593

Interval: 6 - 100
Counts: 1532
Scalar average of direction: 220.869
Scalar average of data: 9.558
Vector average of direction: 220.417
Vector average of data: 9.212
Persistence: 0.964
Standard deviation of direction: 16.090
Root mean square of data: 10.059
Variance of data: 9.842
Variance of the X component of data: 6.390
Variance of the Y component of data: 9.935
Covariance of the X and Y components of data: 2.049
Cross wind data variance: 5.858
Along wind data variance: 10.467

Interval: All data
Counts: 8613
Scalar average of direction: 221.048
Scalar average of data: 3.445
Vector average of direction: 220.494
Vector average of data: 1.841
Persistence: 0.534
Standard deviation of direction: 96.611
Root mean square of data: 4.809
Variance of data: 11.262
Variance of the X component of data: 8.569
```

Variance of the Y component of data: 11.172
Covariance of the X and Y components of data: 7.721
Cross wind data variance: 2.041
Along wind data variance: 17.699

****
Autocorrelation and structure function
****

Distance	Autocorrelation	Structure function
0	1.000E+000	0.000E+000
1	7.156E-001	6.860E+000
2	6.212E-001	9.136E+000
3	5.450E-001	1.097E+001
4	4.661E-001	1.287E+001
5	3.996E-001	1.447E+001
6	3.366E-001	1.599E+001
7	2.750E-001	1.748E+001
8	2.259E-001	1.866E+001
9	1.862E-001	1.962E+001
10	1.670E-001	2.008E+001
11	1.443E-001	2.063E+001
12	1.301E-001	2.096E+001
13	1.197E-001	2.121E+001
14	1.089E-001	2.147E+001
15	1.114E-001	2.141E+001
16	1.205E-001	2.119E+001
17	1.357E-001	2.082E+001
18	1.627E-001	2.017E+001
19	1.906E-001	1.949E+001
20	2.259E-001	1.864E+001
21	2.627E-001	1.776E+001
22	2.926E-001	1.703E+001
23	3.178E-001	1.643E+001
24	3.222E-001	1.632E+001

****
Typical day
****

Hour	AveDir	AveData	StdDevDir	StdDevData	Events
00	226.503	3.386	84.962	3.250	366
01	233.995	3.339	85.390	3.310	366
02	230.291	3.340	85.291	3.377	366
03	231.665	3.293	83.635	3.292	366
04	236.941	3.165	84.777	3.290	365
05	239.678	3.068	86.791	3.299	365
06	238.382	3.009	86.892	3.326	365
07	248.409	2.886	87.227	3.240	365
08	258.841	2.885	92.700	3.214	365
09	291.097	2.987	96.853	3.200	365
10	332.391	3.034	96.084	3.212	365
11	5.250	3.147	92.088	3.177	365
12	15.073	3.312	90.634	3.294	365
13	28.446	3.512	90.584	3.397	365
14	44.363	3.732	89.933	3.455	365
15	53.892	3.862	92.092	3.560	365
16	64.338	3.832	94.876	3.630	365
17	96.635	3.843	97.644	3.518	365
18	141.935	3.702	96.976	3.426	365
19	163.575	3.668	91.694	3.393	365
20	181.537	3.577	86.661	3.203	366
21	199.419	3.541	82.718	3.210	366
22	212.213	3.552	83.759	3.436	366
23	216.187	3.553	83.790	3.472	366

****
Hourly direction distribution

```
*****************************

Hour    Dir00   Dir01   Dir02   Dir03   Dir04   Dir05   Dir06   Dir07   Dir08   Dir09   Dir10   Dir11
        Dir12   Dir13   Dir14   Dir15
00      6.557   4.645   5.464   5.738   4.098   6.831   1.639   1.093   1.366   14.481  28.962  7.377
        1.913   3.279   2.732   3.825
01      6.284   4.645   8.197   5.464   4.372   4.372   2.459   0.546   1.639   12.842  26.503  9.836
        3.279   3.552   4.372   1.639
02      4.918   4.098   8.470   6.011   4.645   4.372   1.366   1.366   1.639   14.481  25.683  10.656
        2.186   3.825   3.279   3.005
03      5.738   4.372   5.738   6.284   4.645   3.005   2.732   1.639   1.913   15.027  26.503  6.284
        5.738   3.279   3.279   3.825
04      6.301   5.205   7.123   4.658   6.027   2.192   2.466   1.370   0.822   13.425  26.301  9.863
        4.110   3.562   3.562   3.014
05      6.027   3.562   9.041   5.753   5.479   3.014   1.370   0.548   3.014   11.781  26.301  7.945
        4.932   4.384   2.466   4.384
06      5.479   3.836   11.233  4.658   5.205   3.014   1.370   0.822   1.644   12.055  27.123  8.493
        5.753   3.014   2.740   3.562
07      7.123   5.479   8.767   7.397   2.740   1.370   2.466   0.822   1.644   12.877  24.110  8.767
        4.110   5.479   3.562   3.288
08      7.945   6.849   12.329  5.753   4.110   2.192   1.096   0.822   1.644   13.425  21.918  7.397
        4.384   3.288   4.384   2.466
09      5.753   8.767   13.425  9.863   2.192   2.466   0.548   0.822   2.192   11.233  20.822  5.753
        4.110   3.836   4.932   3.288
10      5.753   8.219   19.452  7.123   3.288   2.466   0.274   0.548   1.918   9.863   20.274  5.753
        2.466   2.740   5.753   4.110
11      3.836   11.507  20.548  9.589   4.110   1.096   0.274   0.274   1.370   9.863   18.630  3.014
        3.288   3.014   5.479   4.110
12      4.932   13.699  22.192  9.315   2.740   0.822   1.096   0.274   0.822   8.767   20.000  3.836
        1.370   2.466   4.384   3.288
13      3.836   12.603  25.753  10.137  2.466   1.096   0.274   0.274   1.096   9.863   20.822  2.466
        1.370   1.918   3.014   3.014
14      2.466   12.055  26.027  12.329  3.562   0.822   0.274   0.822   1.096   10.137  21.370  1.918
        1.096   1.370   1.918   2.740
15      3.288   10.137  22.466  13.699  6.301   0.548   0.822   0.548   0.274   11.507  20.548  3.562
        0.822   0.822   2.192   2.466
16      4.110   7.123   21.370  12.329  7.671   1.918   0.548   0.548   1.370   12.055  20.548  3.562
        0.274   1.096   3.014   2.466
17      1.918   7.397   17.260  12.877  9.589   3.288   0.274   0.274   1.096   11.507  22.466  4.658
        2.192   1.370   2.192   1.644
18      3.288   5.479   15.342  10.411  9.041   4.658   2.192   1.096   0.822   12.329  22.192  6.575
        1.096   2.466   2.192   0.822
19      3.014   5.479   10.685  10.411  10.685  3.836   4.384   0.548   2.740   12.329  24.932  6.027
        1.918   0.548   1.644   0.822
20      4.645   3.005   9.016   7.377   8.197   6.557   3.552   3.005   3.825   11.749  28.962  3.279
        1.639   1.366   2.459   1.366
21      4.645   4.645   6.284   7.377   4.098   4.918   6.831   2.186   3.005   14.481  28.415  6.011
        2.732   1.913   1.093   1.366
22      4.918   4.918   6.284   7.104   4.918   3.005   4.098   3.279   3.005   12.842  30.055  6.011
        3.279   2.459   1.366   2.459
23      6.011   3.279   5.738   7.104   3.552   5.191   2.459   3.552   3.005   12.295  30.328  6.557
        1.366   2.459   3.279   3.825


************************
Hourly data distribution
************************

Hour    Data00  Data01  Data02  Data03  Data04  Data05  Data06
00      25.956  13.661  10.656  6.284   3.552   3.552   14.208
01      28.689  16.120  8.197   5.738   3.279   5.191   12.568
02      30.328  16.393  8.197   4.918   4.098   2.732   13.661
03      29.508  17.213  7.377   5.464   4.372   3.005   12.842
04      29.589  16.164  7.945   6.027   3.836   4.384   9.863
05      29.041  16.986  6.849   5.205   5.205   3.288   9.589
06      28.219  18.082  7.671   4.658   2.192   4.932   9.589
07      28.219  16.164  6.301   3.288   4.384   2.740   10.411
08      26.301  15.068  6.849   4.932   4.658   1.918   10.411
09      31.233  14.521  8.219   4.384   2.740   1.918   11.781
10      33.151  17.534  5.479   5.479   2.740   2.192   11.781
```

11	35.616	17.534	4.658	4.110	1.644	4.658	12.603
12	36.164	19.452	6.027	2.192	3.014	4.110	13.699
13	37.808	17.534	6.301	4.658	3.836	2.740	15.342
14	34.795	21.370	6.575	6.027	3.562	3.014	16.164
15	34.247	20.548	6.849	5.479	4.658	4.658	16.164
16	34.521	14.521	8.219	3.836	4.384	5.205	16.986
17	32.603	18.082	6.849	3.836	5.205	4.110	17.808
18	32.329	13.973	7.671	4.932	4.658	4.932	16.712
19	26.575	18.356	7.397	3.836	5.205	3.836	16.712
20	22.951	21.038	9.836	3.552	4.098	4.372	16.120
21	25.410	19.672	9.290	6.011	3.005	4.372	15.301
22	28.962	15.027	8.743	6.557	4.372	4.645	13.661
23	22.404	18.852	7.377	5.464	5.191	3.552	15.301

****
Wind power information at hub height
****

Anemometer height (m): 10
Hub height (m): 67
Air density (kg/m3): 1.225
Average wind speed (m/s): 4.782171
Wind speed standard deviation (m/s): 4.744024
Reileigh distribution parameter (m2/s2): 4.762864
Weibull shape parameter (-): 1.008736
Weibull scale parameter (-): 4.800548
Theoretical operating probability (-): 0.531597
Theoretical energy output (kWh): 2963251
Theoretical annual specific yeld (kWh/m2): 465.7936
Actual energy output (kWh): 2850361
Actual annual specific yeld (kWh/m2): 448.0484

Bin size (m/s): 1

Bin	Speed(m/s)	Actual probability	Weibull	Rayleigh	Working
0	0.500	1.036E-001	1.860E-001	2.192E-002	0
1	1.500	2.137E-001	1.527E-001	6.292E-002	0
2	2.500	1.984E-001	1.245E-001	9.602E-002	0
3	3.500	1.216E-001	1.013E-001	1.178E-001	4207
4	4.500	6.581E-002	8.229E-002	1.270E-001	3141
5	5.500	4.562E-002	6.681E-002	1.245E-001	2564
6	6.500	3.228E-002	5.420E-002	1.129E-001	2164
7	7.500	2.931E-002	4.396E-002	9.569E-002	1881
8	8.500	2.737E-002	3.563E-002	7.622E-002	1624
9	9.500	2.509E-002	2.887E-002	5.729E-002	1384
10	10.500	2.486E-002	2.339E-002	4.075E-002	1164
11	11.500	1.848E-002	1.894E-002	2.748E-002	946
12	12.500	2.110E-002	1.534E-002	1.760E-002	784
13	13.500	1.357E-002	1.242E-002	1.072E-002	599
14	14.500	1.106E-002	1.005E-002	6.209E-003	480
15	15.500	8.896E-003	8.133E-003	3.426E-003	383
16	16.500	7.641E-003	6.581E-003	1.802E-003	305
17	17.500	6.159E-003	5.324E-003	9.032E-004	238
18	18.500	4.220E-003	4.306E-003	4.318E-004	184
19	19.500	4.106E-003	3.483E-003	1.970E-004	147
20	20.500	3.422E-003	2.817E-003	8.575E-005	111
21	21.500	2.509E-003	2.278E-003	3.564E-005	81
22	22.500	2.509E-003	1.841E-003	1.414E-005	59
23	23.500	2.395E-003	1.489E-003	5.358E-006	37
24	24.500	1.825E-003	1.203E-003	1.939E-006	16
25	25.500	1.597E-003	9.727E-004	6.705E-007	0
26	26.500	7.984E-004	7.862E-004	2.215E-007	0
27	27.500	3.422E-004	6.354E-004	6.991E-008	0
28	28.500	3.422E-004	5.134E-004	2.109E-008	0
29	29.500	4.562E-004	4.149E-004	6.078E-009	0
30	30.500	3.422E-004	3.352E-004	1.675E-009	0
31	31.500	2.281E-004	2.708E-004	4.410E-010	0
32	32.500	1.141E-004	2.188E-004	1.110E-010	0
33	33.500	0.000E+000	1.767E-004	2.671E-011	0
34	34.500	2.281E-004	1.428E-004	6.146E-012	0

```
*****************************************
Wind power (W) across a 1 m2 surface of
undisturbed wind streaming (i.e. no rotor)
Assumptions:
1) Air density 1.225 kg/m3
2) No power coefficient applied (Betz law)
3) Wind speed units are m/s
*****************************************
Percentile Power(W/m2)
1       0.0
5       0.2
10      0.6
25      3.0
50      16.0
75      137.4
90      952.8
95      2000.5
99      6687.5
100     25103.6

*********************************************
Emission factor (g/m2) due to wind erosion
calculated using the AP42 methodology
(chapter 13.2.5 Industrial wind erosion).
 Multiply the emission factor and the
exposed surface to get the total emissions over
the period.
Assumptions:
1) Wind speed units are m/s
2) Anemometer height is 10 m above ground
3) Almost flat pile (height/base < 0.2)
*********************************************
Material: Overburden
Number of disturbing events: 82
Emission factor for PM30  (g/m2): 4.362e+002
Emission factor for PM15  (g/m2): 2.617e+002
Emission factor for PM10  (g/m2): 2.181e+002
Emission factor for PM2.5 (g/m2): 3.272e+001


*********************************************
Crosswind and runway orientation
*********************************************
Design crosswind component: 150 (user input units)
Runway orientation: 110 degree
Percent above design crosswind component: 0.000
Percent below design crosswind component: 100.000
Maximum crosswind from left: -7.4 m/s
Maximum crosswind from right: 22.8 m/s
Maximum headwind: 5.1 m/s
Maximum tailwind: -14.6 m/s


*******
Summary
*******

The maximum wind speed is 2.440E+001 m/s, the 95th percentile is 1.050E+001 m/s
and the median is 2.100E+000 m/s.
The prevailing wind direction is SW with 1.11E+01% of data,
while the second prevailing direction is SSW with 1.11E+01% of data.
The maximum wind speed (24.400 m/s) comes from SW, while the
maximum average speed (6.470 m/s) comes from SSW.
```

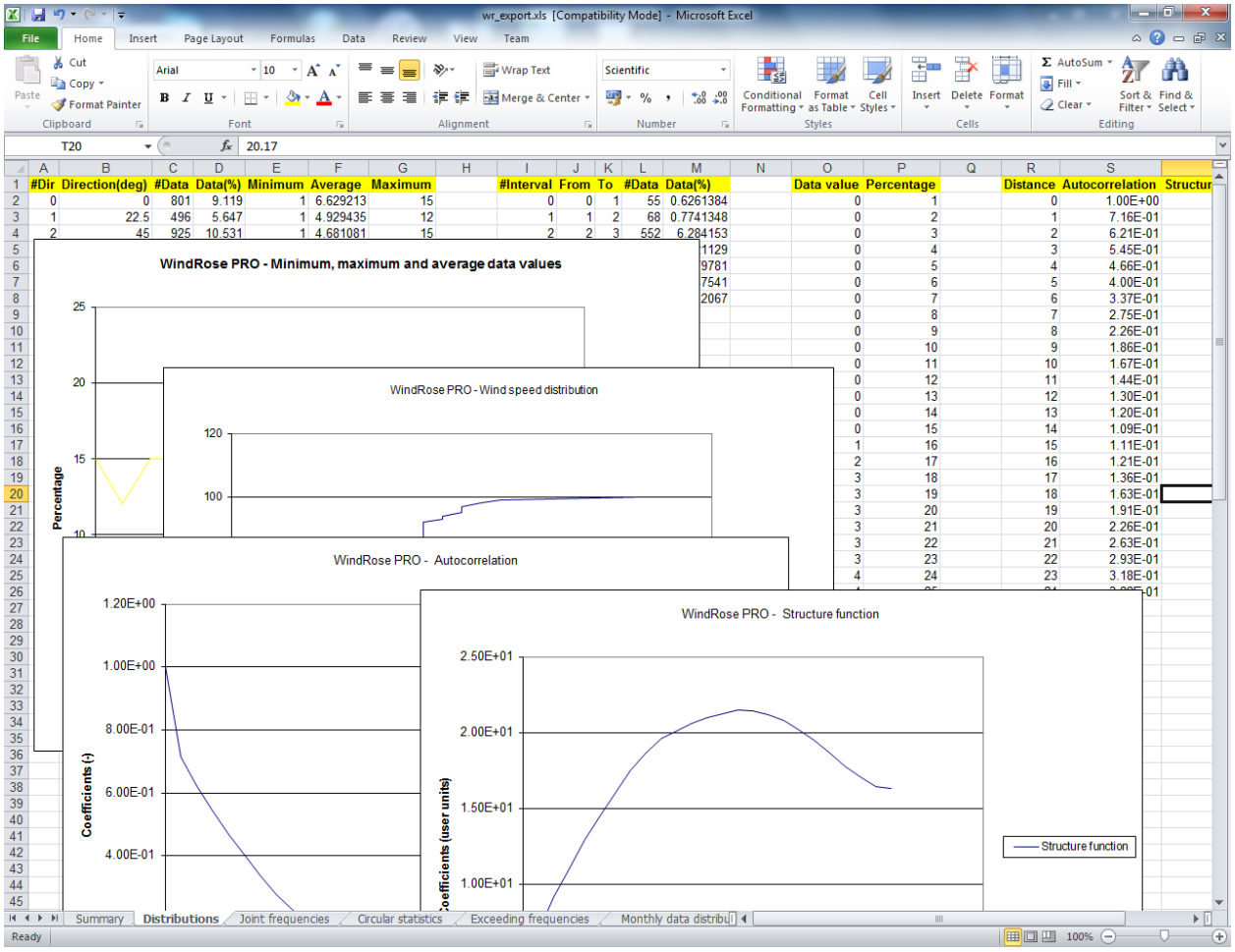
7.4.5.2 Actions > Export > Excel

This menu item allows to create an output file in Microsoft Excel format. Microsoft Excel must be installed on the user's PC. The Microsoft Excel file contains different information depending on the input data (frequencies or time-dependent records).
The output Microsoft Excel file will contain a number of worksheets which varies as function of the user's choices. Anyway, the maximum number of worksheets within the exported Excel file is eight, and their names and contents are reported in the following table.

Worksheet **Summary** contains the creation date, the name of the data file analysed, the name of the configuration file used, the number of data (total, valid, etc.), the filtering options, etc.

Worksheet **Erosion** contains information about the erosion calculation, which means the number of disturbing events and the emission factors in terms of g/m^2 for PM30, PM15, PM10 and PM2.5. This worksheet is produced only if the user selects the erosion calculation option (see 7.3.13).

Worksheet **Distributions** contains, for each direction, the number of data, the percent of data, and minimum, average and maximum values. It also contains the data distribution (number and percent) for the classes of directional variable (for example for each wind speed class). The percentiles of directional data values are also in this worksheet. Two charts are also present, one for the percentiles of directional data, and one for their minimum, average and maximum value for each direction. The autocorrelation and the structure function charts are also present if the user requested their calculation. An example of such worksheet is reported in the next figure.



Worksheet **Joint frequencies** contains the number of events for each couple of direction class and data class. An example is reported in the following table for 16 classes of directions and 7 classes of the directional variable values. For example, there are 222 events for direction 45 degrees and data values between 2 and 3.

	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 100
0	92	71	34	8	0	3	1
22.5	237	166	46	7	1	0	0
45	581	222	65	15	8	2	0
67.5	342	132	34	15	0	0	0
90	197	126	32	6	5	0	0
112.5	104	99	14	1	0	0	0
135	76	49	3	0	0	0	0
157.5	41	13	6	0	0	0	0

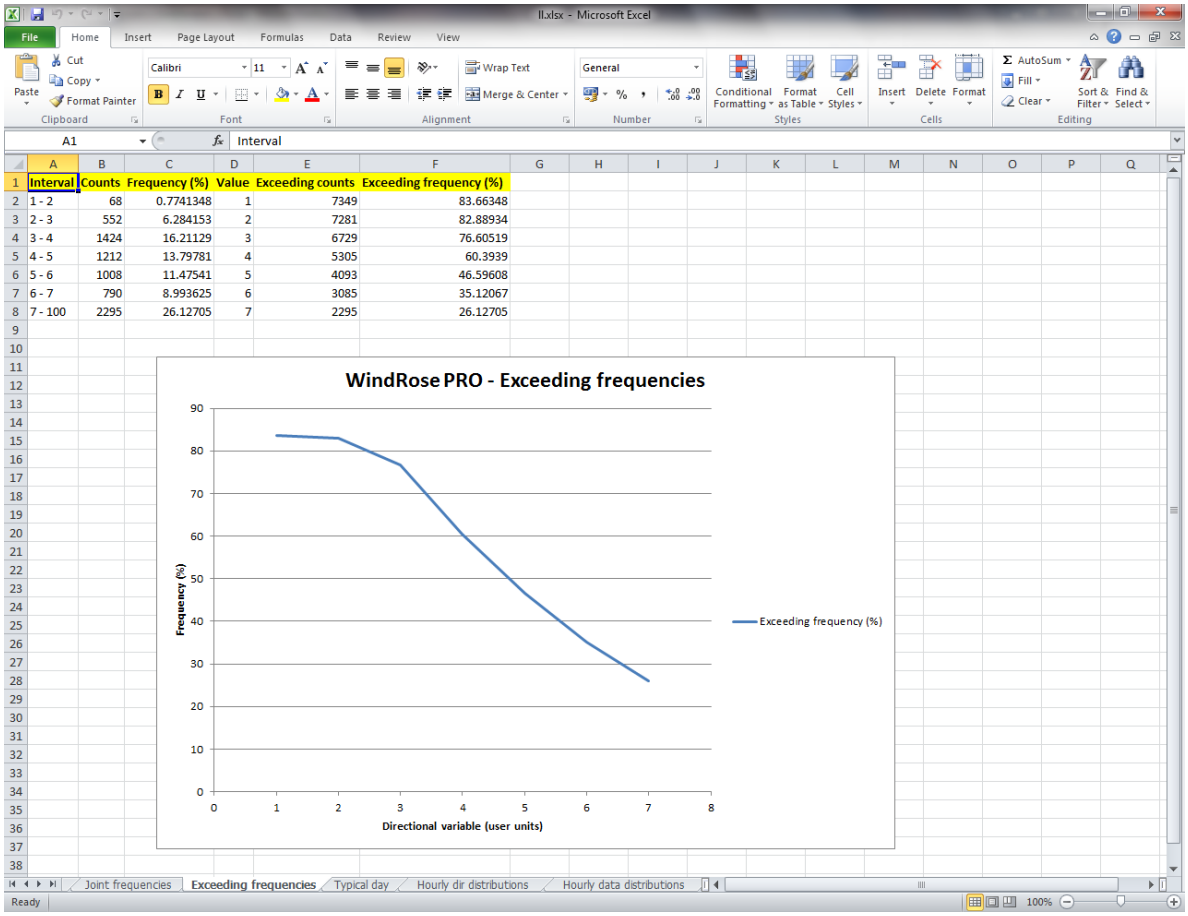
180	49	21	13	14	8	1	8
202.5	106	93	100	93	74	93	414
225	228	245	216	218	217	209	689
247.5	155	95	49	23	24	16	83
270	91	40	16	6	1	0	3
292.5	99	39	12	1	1	1	5
315	143	54	9	8	2	1	0
337.5	106	47	7	12	2	3	0

Worksheet **Circular statistics** contains such statistics for all the data used to create the wind rose, and for each single interval (for example, considering wind speed, for the intervals 0-1 m/s, 1-2 m/s, 2-3 m/s, and so on). The worksheet contains a table with the following fields for each interval and for all the data:

- counts
- scalar average of direction
- scalar average of directional data (e.g. wind speed)
- vector average of direction
- vector average of directional data
- persistence
- standard deviation of direction
- root mean square of directional data
- variance of directional data
- variance of the X component of directional data
- variance of the Y component of directional data
- covariance of the X and Y components of directional data
- crosswind data variance
- along wind data variance.

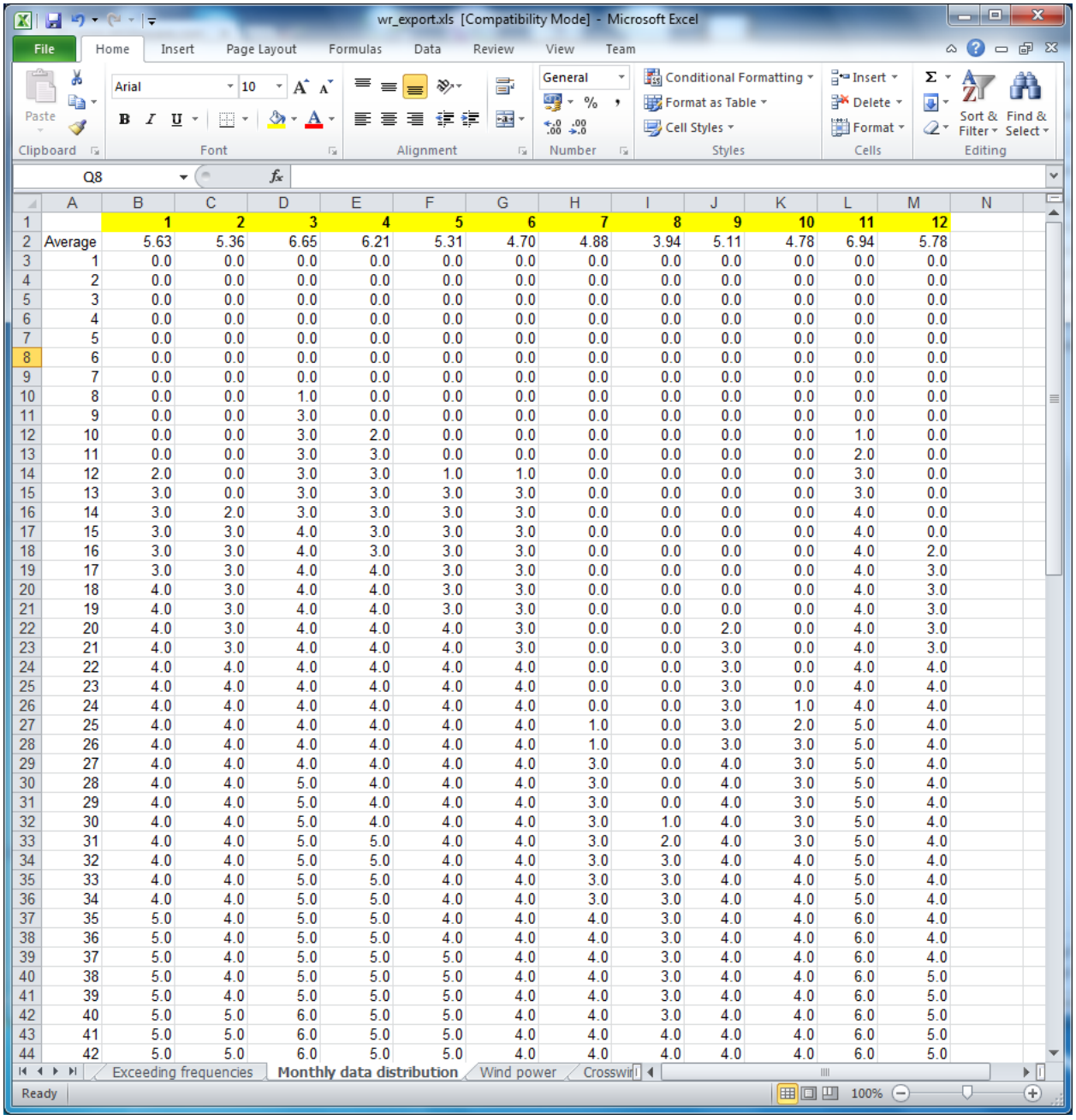
Worksheet **Exceeding frequencies** contains the number of events and the frequencies for each data interval, and the number of exceeding events and the exceeding frequencies with respect to the first value of the interval. The exceeding frequencies are calculated using **>** or ≥ according to the user specifications (see paragraph 7.3.1). An

example is reported in the following figure. The chart of the exceeding frequencies is also automatically produced.



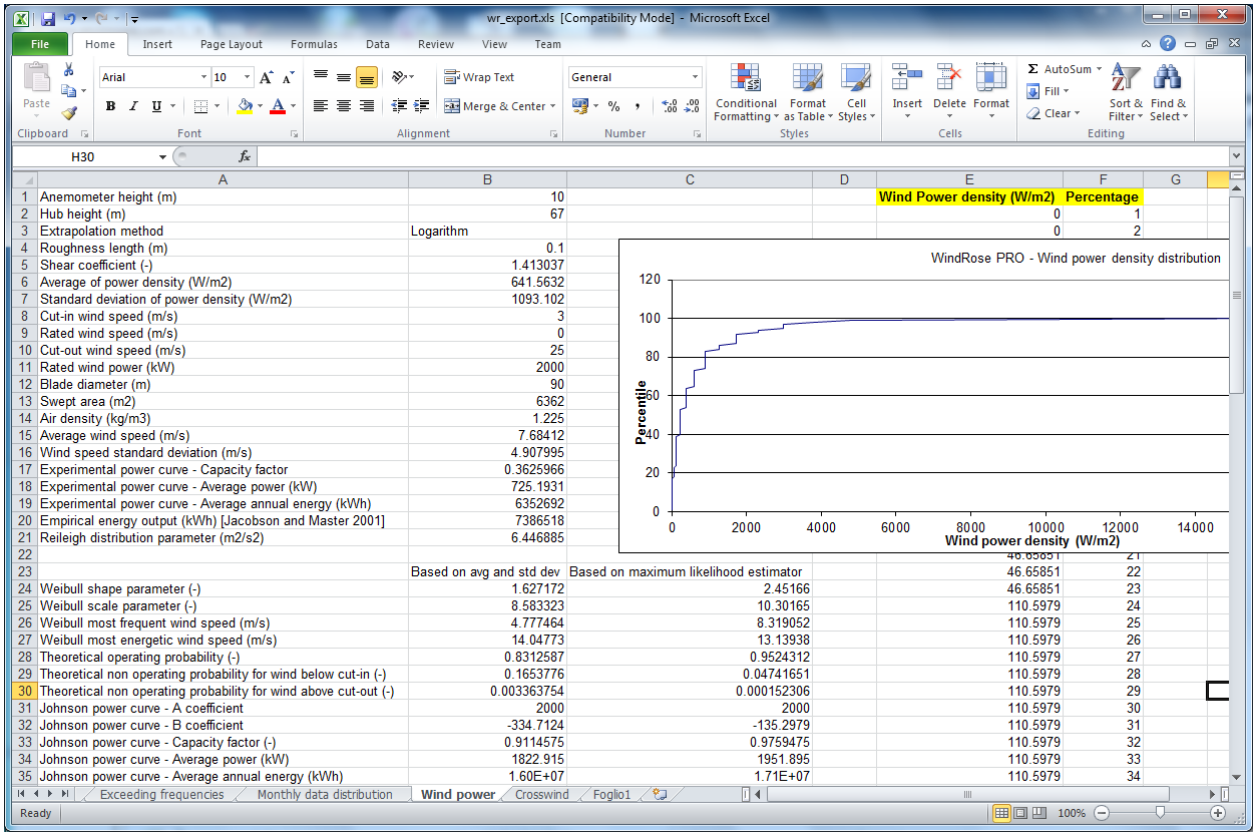
Interval	Counts	Frequency (%)	Value	Exceeding counts	Exceeding frequency (%)
1 - 2	68	0.7741348	1	7349	83.66348
2 - 3	552	6.284153	2	7281	82.88934
3 - 4	1424	16.21129	3	6729	76.60519
4 - 5	1212	13.79781	4	5305	60.3939
5 - 6	1008	11.47541	5	4093	46.59608
6 - 7	790	8.993625	6	3085	35.12067
7 - 100	2295	26.12705	7	2295	26.12705

Worksheet **Monthly data distribution** contains, for each month, the average value of the directional variable (e.g. wind speed) and the values corresponding to each percentile. Note that this worksheet is produced only if date and time are available and loaded. An example of such worksheet is reported in the next figure.



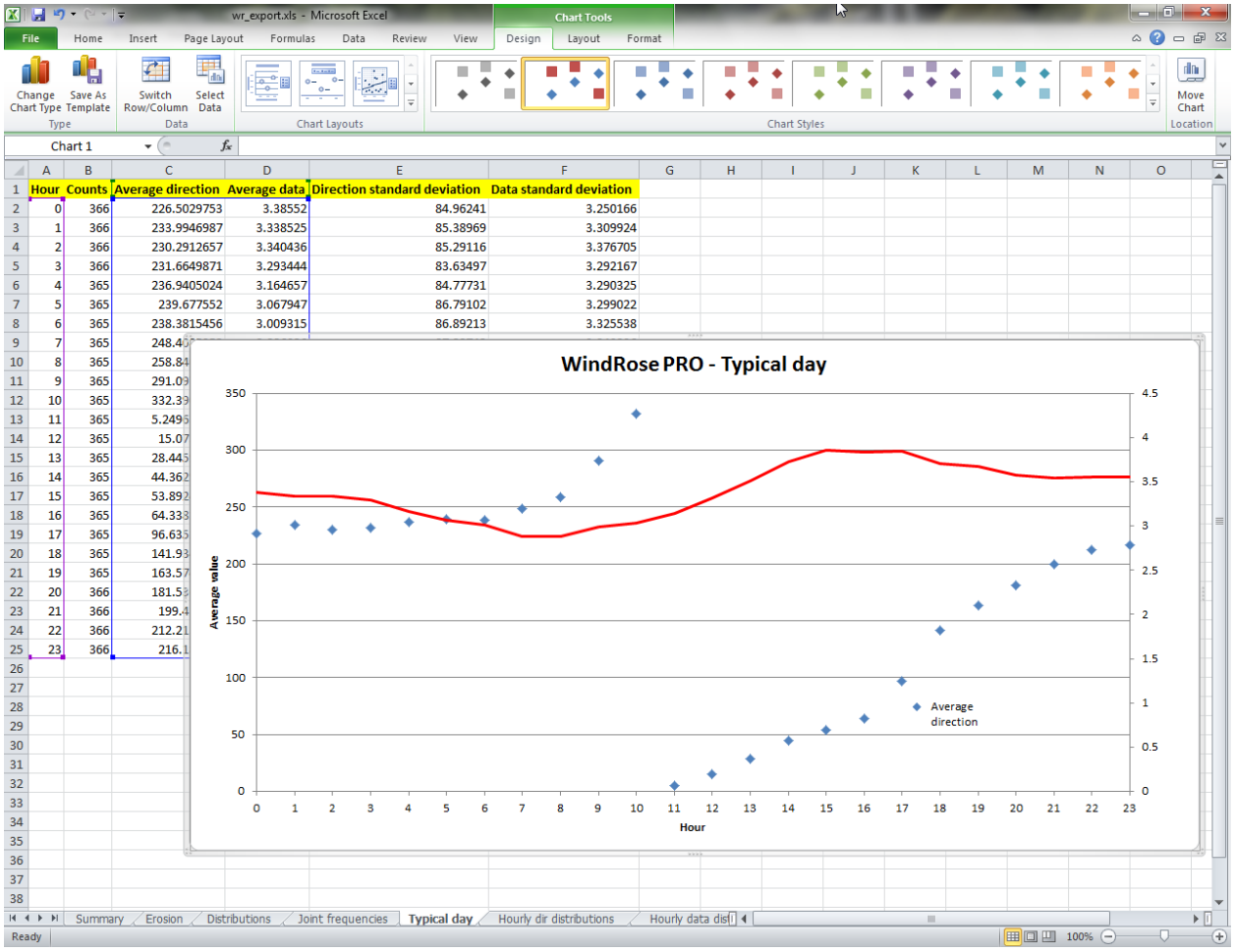
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1		1	2	3	4	5	6	7	8	9	10	11	12	
2	Average	5.63	5.36	6.65	6.21	5.31	4.70	4.88	3.94	5.11	4.78	6.94	5.78	
3	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
4	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
5	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
6	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
7	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
8	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
9	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
10	8	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
11	9	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
12	10	0.0	0.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	
13	11	0.0	0.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	
14	12	2.0	0.0	3.0	3.0	1.0	1.0	0.0	0.0	0.0	0.0	3.0	0.0	
15	13	3.0	0.0	3.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	3.0	0.0	
16	14	3.0	2.0	3.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	4.0	0.0	
17	15	3.0	3.0	4.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	4.0	0.0	
18	16	3.0	3.0	4.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	4.0	2.0	
19	17	3.0	3.0	4.0	4.0	3.0	3.0	0.0	0.0	0.0	0.0	4.0	3.0	
20	18	4.0	3.0	4.0	4.0	3.0	3.0	0.0	0.0	0.0	0.0	4.0	3.0	
21	19	4.0	3.0	4.0	4.0	3.0	3.0	0.0	0.0	0.0	0.0	4.0	3.0	
22	20	4.0	3.0	4.0	4.0	4.0	3.0	0.0	0.0	2.0	0.0	4.0	3.0	
23	21	4.0	3.0	4.0	4.0	4.0	3.0	0.0	0.0	3.0	0.0	4.0	3.0	
24	22	4.0	4.0	4.0	4.0	4.0	4.0	0.0	0.0	3.0	0.0	4.0	4.0	
25	23	4.0	4.0	4.0	4.0	4.0	4.0	0.0	0.0	3.0	0.0	4.0	4.0	
26	24	4.0	4.0	4.0	4.0	4.0	4.0	0.0	0.0	3.0	1.0	4.0	4.0	
27	25	4.0	4.0	4.0	4.0	4.0	4.0	1.0	0.0	3.0	2.0	5.0	4.0	
28	26	4.0	4.0	4.0	4.0	4.0	4.0	1.0	0.0	3.0	3.0	5.0	4.0	
29	27	4.0	4.0	4.0	4.0	4.0	4.0	3.0	0.0	4.0	3.0	5.0	4.0	
30	28	4.0	4.0	5.0	4.0	4.0	4.0	3.0	0.0	4.0	3.0	5.0	4.0	
31	29	4.0	4.0	5.0	4.0	4.0	4.0	3.0	0.0	4.0	3.0	5.0	4.0	
32	30	4.0	4.0	5.0	4.0	4.0	4.0	3.0	1.0	4.0	3.0	5.0	4.0	
33	31	4.0	4.0	5.0	5.0	4.0	4.0	3.0	2.0	4.0	3.0	5.0	4.0	
34	32	4.0	4.0	5.0	5.0	4.0	4.0	3.0	3.0	4.0	4.0	5.0	4.0	
35	33	4.0	4.0	5.0	5.0	4.0	4.0	3.0	3.0	4.0	4.0	5.0	4.0	
36	34	4.0	4.0	5.0	5.0	4.0	4.0	3.0	3.0	4.0	4.0	5.0	4.0	
37	35	5.0	4.0	5.0	5.0	4.0	4.0	4.0	3.0	4.0	4.0	6.0	4.0	
38	36	5.0	4.0	5.0	5.0	4.0	4.0	4.0	3.0	4.0	4.0	6.0	4.0	
39	37	5.0	4.0	5.0	5.0	5.0	4.0	4.0	3.0	4.0	4.0	6.0	4.0	
40	38	5.0	4.0	5.0	5.0	5.0	4.0	4.0	3.0	4.0	4.0	6.0	5.0	
41	39	5.0	4.0	5.0	5.0	5.0	4.0	4.0	3.0	4.0	4.0	6.0	5.0	
42	40	5.0	5.0	6.0	5.0	5.0	4.0	4.0	3.0	4.0	4.0	6.0	5.0	
43	41	5.0	5.0	6.0	5.0	5.0	4.0	4.0	4.0	4.0	4.0	6.0	5.0	
44	42	5.0	5.0	6.0	5.0	5.0	4.0	4.0	4.0	4.0	4.0	6.0	5.0	

Worksheet **Wind power** is produced only if the user requested the calculation of such variable. It contains a summary of the input data and many variables useful to evaluate the wind energy available, for example the capacity factor, the Weibull distribution parameters, the wind power density distributions and others. The chart of the wind power density distribution is also present. An example of such worksheet is reported in the next figure.



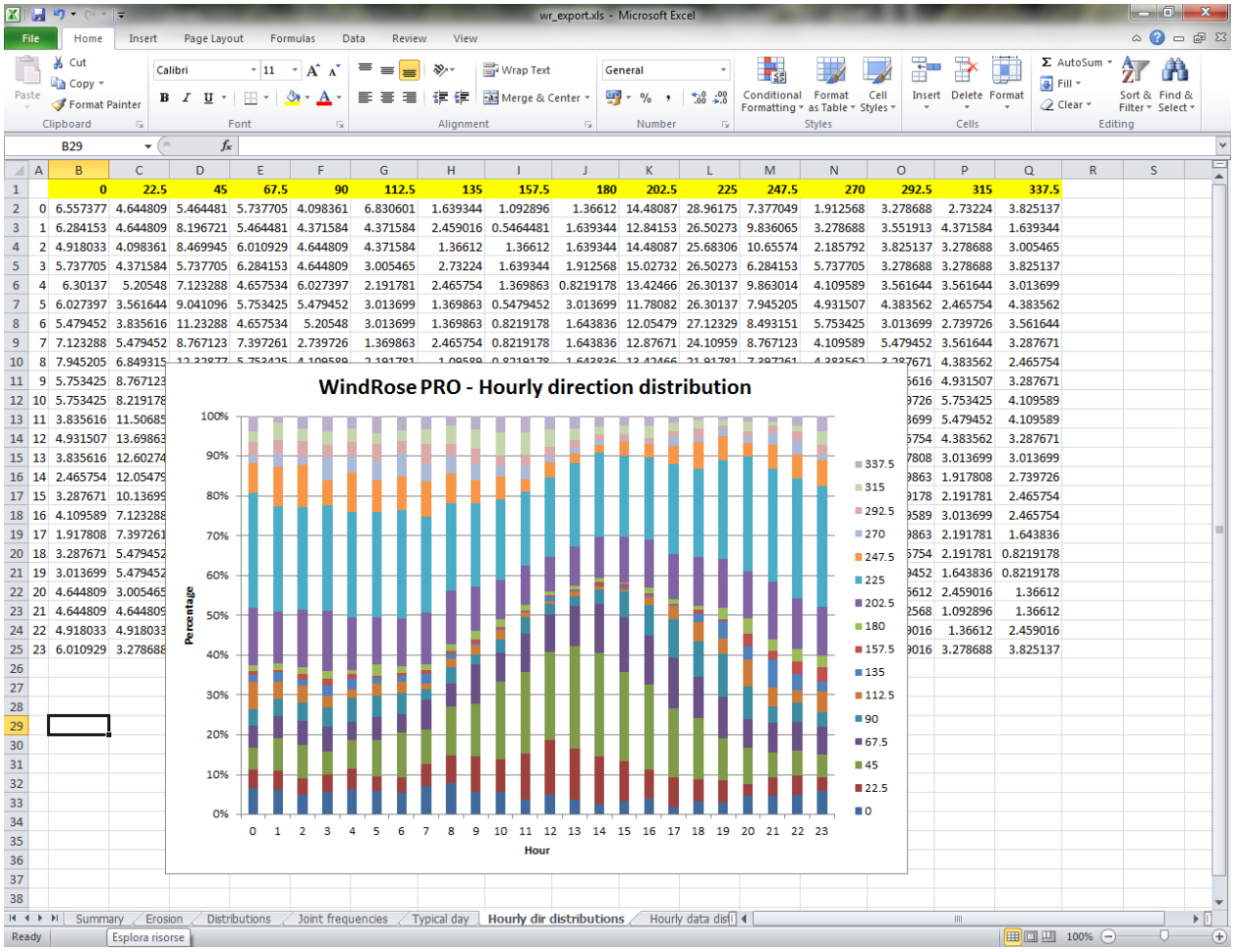
	A	B	C	D	E	F	G
1	Anemometer height (m)	10			Wind Power density (W/m2)	Percentage	
2	Hub height (m)	67			0	1	
3	Extrapolation method	Logarithm			0	2	
4	Roughness length (m)	0.1					
5	Shear coefficient (-)	1.413037					
6	Average of power density (W/m2)	641.5632					
7	Standard deviation of power density (W/m2)	1093.102					
8	Cut-in wind speed (m/s)	3					
9	Rated wind speed (m/s)	0					
10	Cut-out wind speed (m/s)	25					
11	Rated wind power (kW)	2000					
12	Blade diameter (m)	90					
13	Swept area (m2)	6362					
14	Air density (kg/m3)	1.225					
15	Average wind speed (m/s)	7.68412					
16	Wind speed standard deviation (m/s)	4.907995					
17	Experimental power curve - Capacity factor	0.3625966					
18	Experimental power curve - Average power (kW)	725.1931					
19	Experimental power curve - Average annual energy (kWh)	6352692					
20	Empirical energy output (kWh) [Jacobson and Master 2001]	7386518					
21	Reileigh distribution parameter (m2/s2)	6.446885					
22							
23		Based on avg and std dev	Based on maximum likelihood estimator				
24	Weibull shape parameter (-)	1.627172	2.45166		46.65851	23	
25	Weibull scale parameter (-)	8.583323	10.30165		110.5979	24	
26	Weibull most frequent wind speed (m/s)	4.777464	8.319052		110.5979	25	
27	Weibull most energetic wind speed (m/s)	14.04773	13.13938		110.5979	26	
28	Theoretical operating probability (-)	0.8312587	0.9524312		110.5979	27	
29	Theoretical non operating probability for wind below cut-in (-)	0.1653776	0.04741651		110.5979	28	
30	Theoretical non operating probability for wind above cut-out (-)	0.003363754	0.000152306		110.5979	29	
31	Johnson power curve - A coefficient	2000	2000		110.5979	30	
32	Johnson power curve - B coefficient	-334.7124	-135.2979		110.5979	31	
33	Johnson power curve - Capacity factor (-)	0.9114575	0.9759475		110.5979	32	
34	Johnson power curve - Average power (kW)	1822.915	1951.895		110.5979	33	
35	Johnson power curve - Average annual energy (kWh)	1.60E+07	1.71E+07		110.5979	34	

Worksheet **Typical day** contains the typical day of direction and directional variable. This means that, for each hour of the day (which is not filtered according to the user instructions), the average of direction and directional variable are calculated. The averages, together with the number of events used to calculate them and to their standard deviations are reported within the worksheet. The chart of the typical day is also present within the worksheet. Note that this worksheet is produced only if date and time are available and loaded. An example of such worksheet is reported in the next figure.

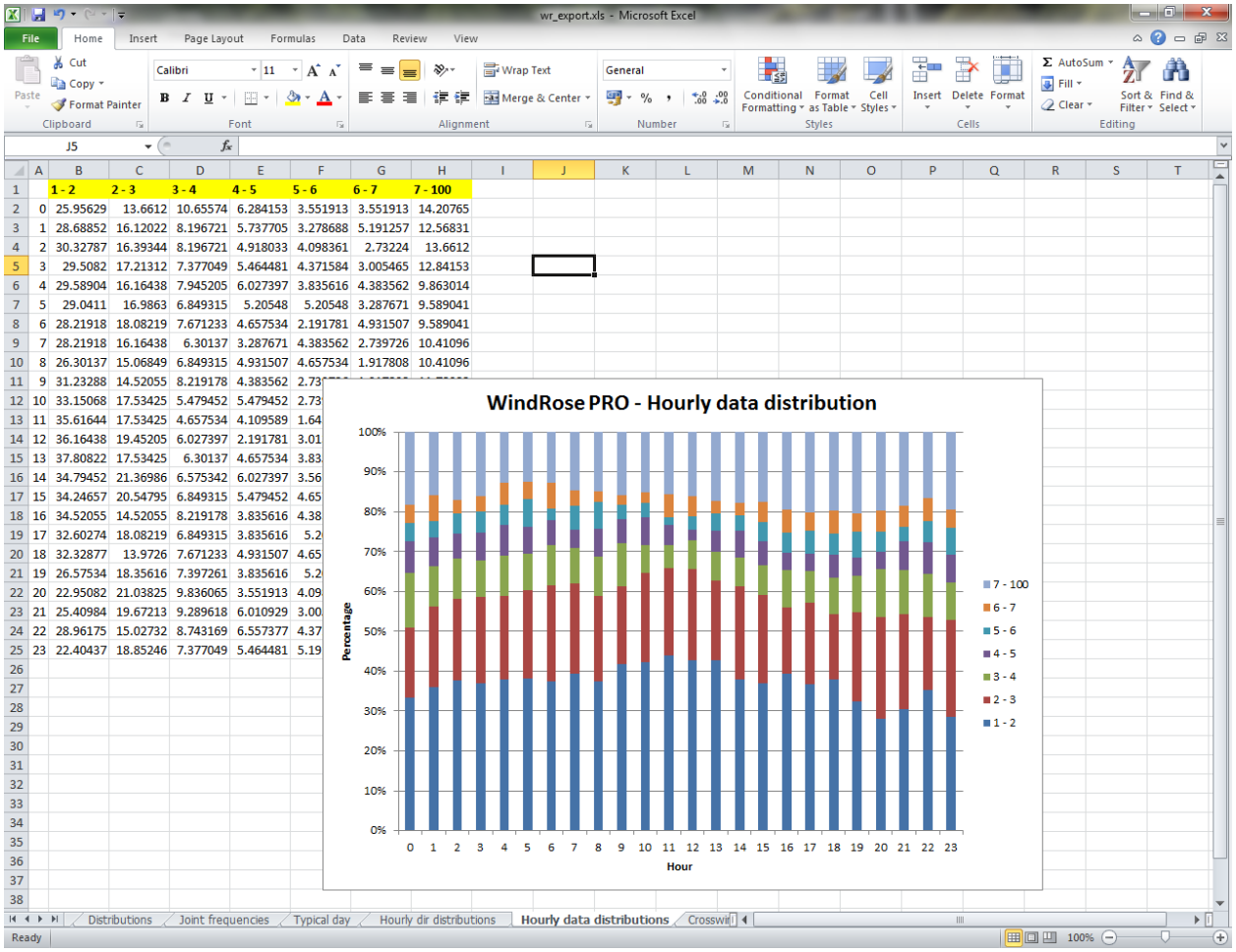


Hour	Counts	Average direction	Average data	Direction standard deviation	Data standard deviation
0	366	226.5029753	3.38552	84.96241	3.250166
1	366	233.9946987	3.338525	85.38969	3.309924
2	366	230.2912657	3.340436	85.29116	3.376705
3	366	231.6649871	3.293444	83.63497	3.292167
4	365	236.9405024	3.164657	84.77731	3.290325
5	365	239.677552	3.067947	86.79102	3.299022
6	365	238.3815456	3.009315	86.89213	3.325538
7	365	248.4			
8	365	258.84			
9	365	291.09			
10	365	332.39			
11	365	5.249			
12	365	15.07			
13	365	28.445			
14	365	44.362			
15	365	53.892			
16	365	64.333			
17	365	96.635			
18	365	141.93			
19	365	163.57			
20	366	181.53			
21	366	199.4			
22	366	212.21			
23	366	216.1			

Worksheet **Hourly dir distribution** contains the distribution of directions for each hour of the day. This information is useful to evaluate how, on average, the directions change during the day. For example, the analysis of wind directions measured close to the coast might show the sea breeze effect. The chart of the hourly direction distribution is also present within the worksheet. Note that this worksheet is produced only if date and time are available and loaded. An example of such worksheet is reported in the next figure.



Worksheet **Hourly data distribution** contains the distribution of the directional variable values for each hour of the day. This information is useful to evaluate how, on average, the directions change during the day. For example, the analysis of wind directions measured close to the coast might show the sea breeze effect. The chart of the hourly data distribution is also present within the worksheet. Note that this worksheet is produced only if date and time are available and loaded. An example of such worksheet is reported in the next figure.



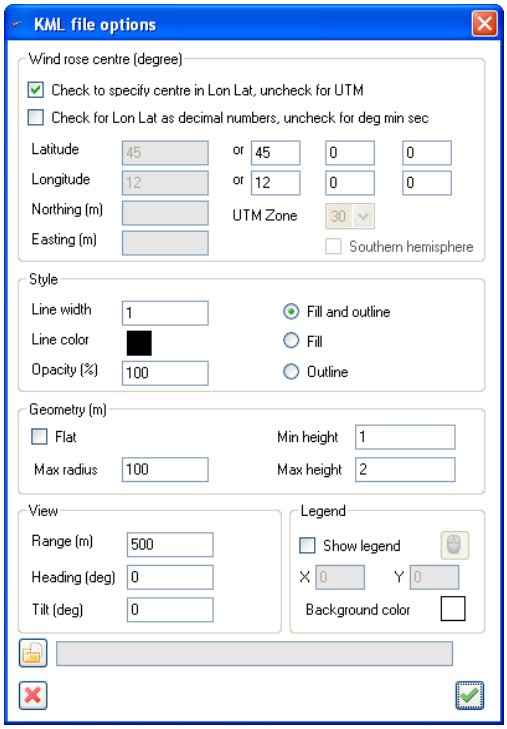
Worksheet **Crosswind** contains the information about crosswind and tailwind calculations, and the percentage of data above the design crosswind component. This information is reported for a single direction or for many directions, according to the user specifications (see 7.3.9). Note that this worksheet is produced only if the user selected such analysis.

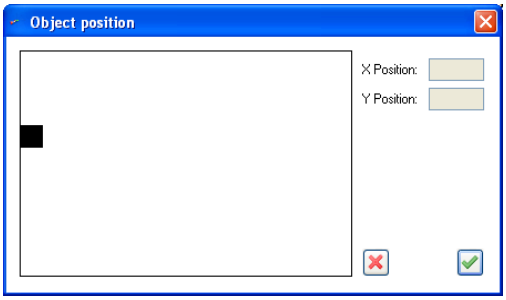
7.4.5.3 Actions > Export > KML

This menu item allows to export the wind rose in KML format, and then to import it in Google Earth (http://earth.google.com).

Note than **only wind roses can be exported in KML format**, not other types of plot.

The mask for setting the KML options is represented in the following figure (left).





The user must specify the coordinates (longitude and latitude or UTM metric) of the centre of the wind rose. Longitude is positive along East; latitude is positive in the Northern hemisphere. When EnergyPlus Weather data are used, longitude and latitude are automatically taken from the header records of the input file.

It is possible to select the style of the wind rose: the colours will be those selected for the wind rose (see 7.3.1), but is is possible to specify the colour and the width of the lines and the percentage of opacity (0 means fully transparent and 100 means fully opaque).

The wind rose can be represented as flat (i.e. with a constant height), or as a pyramid specifying a minimum height and a maximum height.

The view options can be also specified by the user:

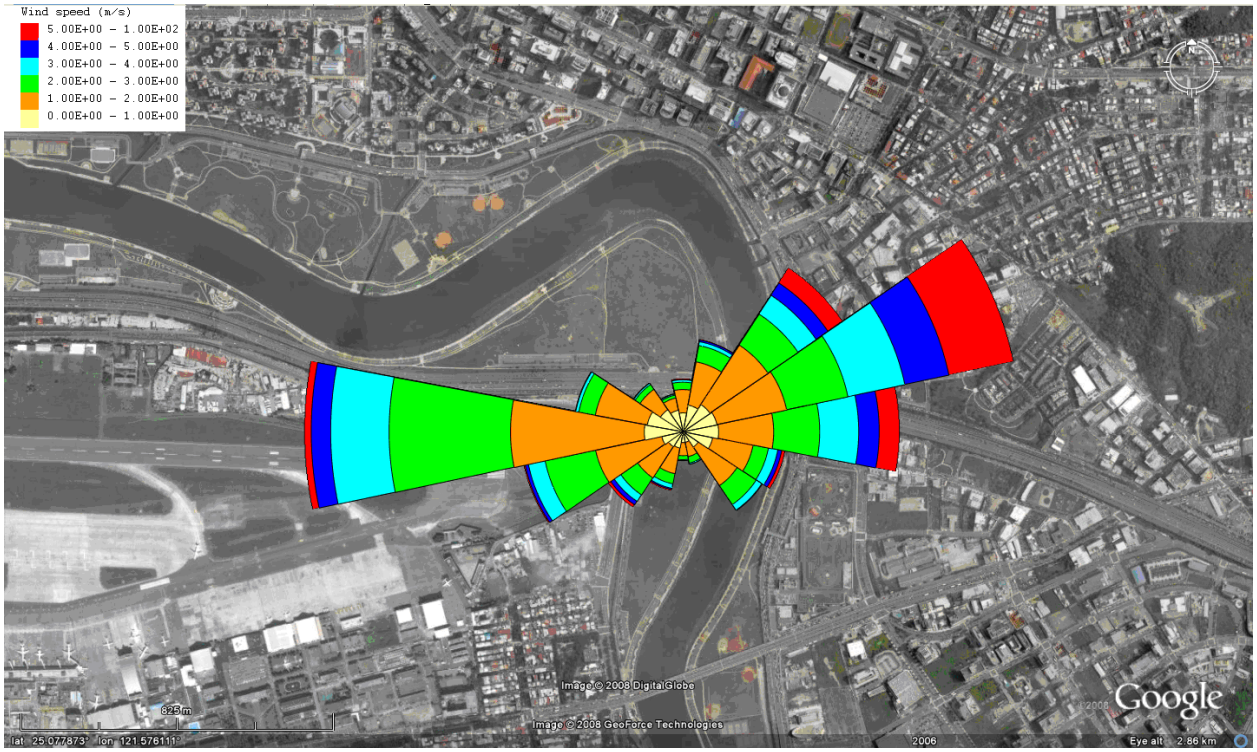
- Range determines the altitude of the eye point (m)
- Tilt indicates the angle of the eye point to the designated point (deg) [0 from the vertical; 90 laterally]
- Heading describes the angular distance along the horizon to the viewpoint; it is measured from north, 90 shows a heading due west.

The view options can be modified in Google Earth.

It is also possible to produce a legend which will be shown on Google Earth. By clicking the mouse icon within the legend frame, the mask shown in the right part of the previous figure appears. The legend position in Google Earth is determined by clicking the black square (which represents the legend) and dragging it over the white rectangle (which represents the Google Earth interface).

The KML file can be exported in any existing directory selected by the user and with any name. An example of KML file produced with WindRose PRO and imported in Google Earth is represented in the following figure.

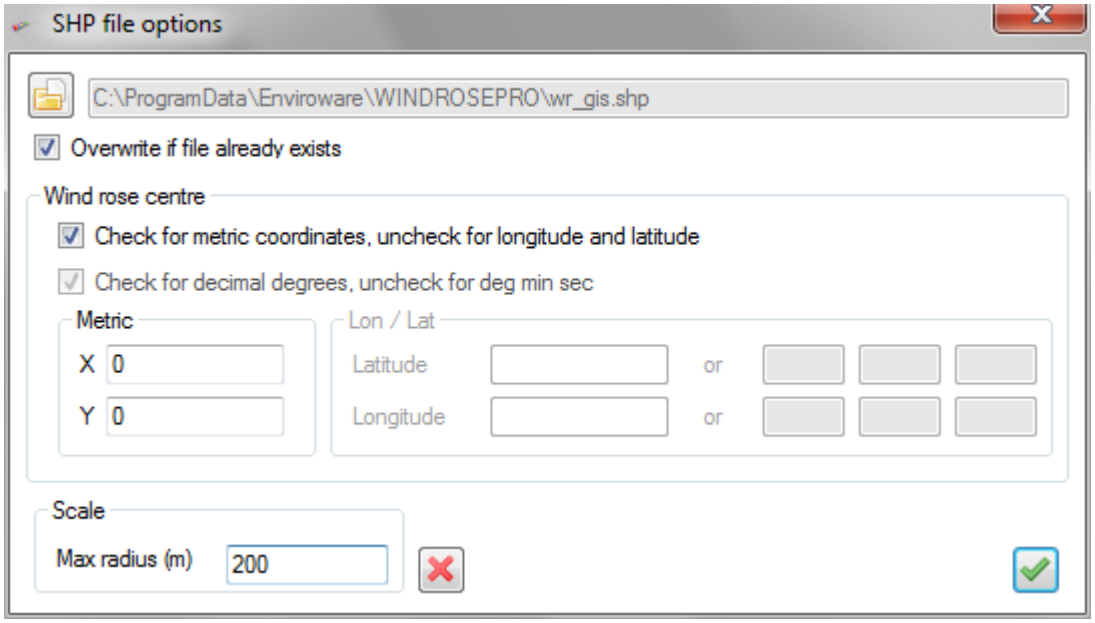
Do not use the symbols > (greater than) or < (smaller than) in the legend caption if you plan to export the wind rose in Google Earth, because that might generate a parsing error.



7.4.5.4 Actions > Export > SHP

This menu item allows to export the wind rose as a shapefile, which can be then viewed using a GIS (Geographical Information System) tool. Note than **only wind roses can be exported as shapefiles**, not other types of plot.

The following mask allows to set the shapefile options.



The user must specify the metric or geographical (longitude and latitude) coordinates of the centre of the wind rose. These coordinates will be used for positioning the plot when it is loaded as a layer in a GIS. If the centre is specified by means of its longitude and latitude, the coordinates of all the points needed to build the wind rose will be in terms of longitude and latitude. This is the reason for which the wind rose sometimes appears a bit distorted. Longitude is positive along East; latitude is positive in the Northern hemisphere.

The user also indicates the scale of the wind rose by means of its maximum size in metres.

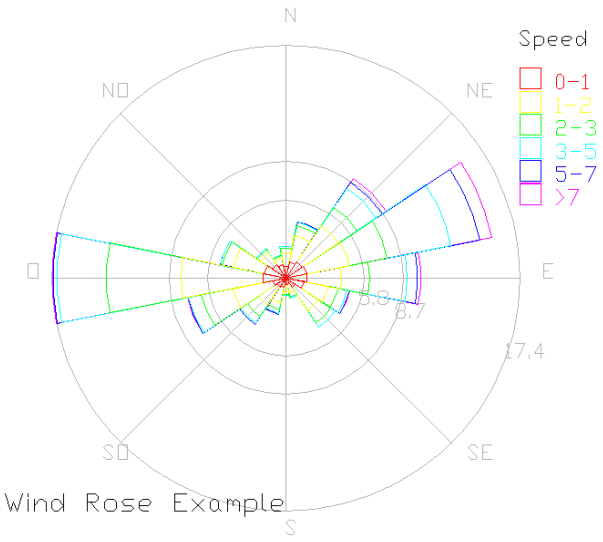
The DBF file associated to the shapefile contains the following fields:

- Direction (direction of the wind rose arm)
- SpeedLower (lower limit of the data interval)
- SpeedUpper (upper limit of the data interval)
- Events (number of events within this direction and data interval)
- Legend (legend used within the application)
- R (red component of the colour)
- G (green component of the colour)
- B (blue component of the colour)

By means of specific queries, these fields should allow to represent the wind rose within the GIS viewer with exactly the same colours and legend captions used within WindRose PRO.
The last record of the DBF file will contain information about the calms, provided the "Analyse calms" checkbox has been checked (see 7.3.4). The fields Direction, SpeedLower and SpeedUpper of this last record will be all equal to -999, and the value of the Legend field will always be Calms.
The percentage circles are not exported in the shapefile.
The shapefile can be exported in any existing directory selected by the user and with any name. Four files will be produced within such directory with the same name and the following extensions: SHP, DBF, SHX and PRJ.

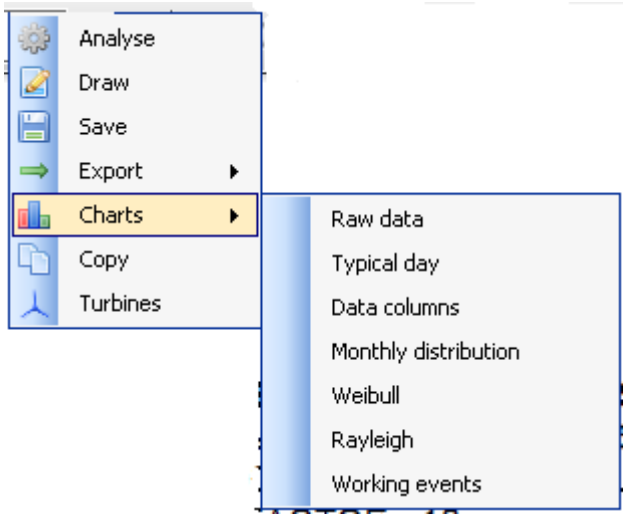
7.4.5.5 Actions > Export > DXF

This menu item allows to export the wind rose as a DXF file that can be loaded, for example, in AutoCAD (Autodesk, Inc.). Note than **only wind roses can be exported in DXF format**, not other types of plot.
The DXF file can be exported in any existing directory selected by the user and with any name. The DXF file is produced according to versions R11/R12 and should be readable from all the new versions.
An example of image obtained importing in AutoCAD (Autodesk, Inc) a DXF produced with WindRose PRO is shown below.

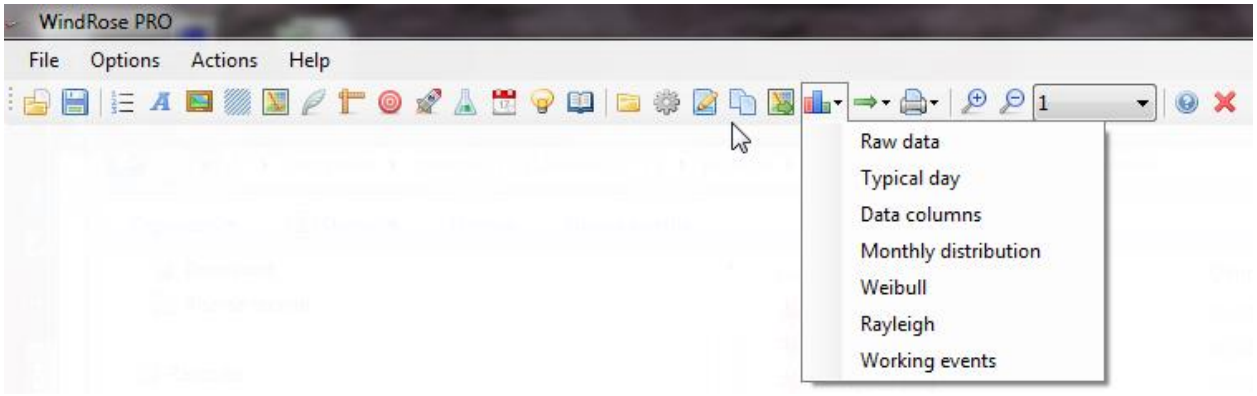


7.4.6 Actions > Charts

The `Actions > Charts` menu item allows to view some charts that are automatically produced by the software, as shown in the next figure.

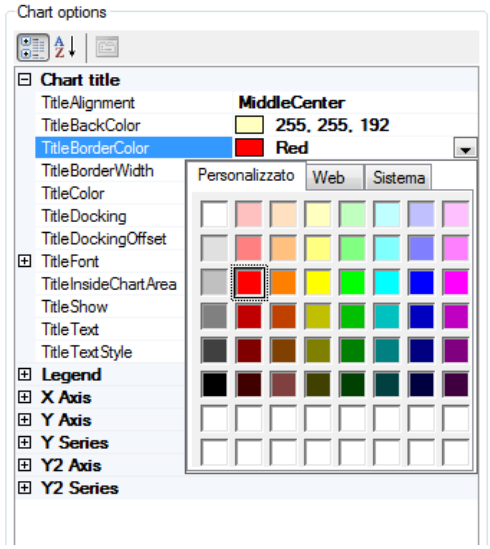


The same action is carried out by clicking the button shown in the next figure.



7.4.6.1 *Feature common to all the charts*

All the charts have a right panel with elements which allow to modify their features, as shown in the next figure. Such elements are within seven groups according to the features that they control: `Chart title`, `Legend`, `X Axis`, `Y Axis`, `Y Series`, `Y2 Axis` and `Y2 Series`. After modified, the new features will appear on the chart by clicking the  button. Note that, depending on the chart, some options might not have effect even if they can be modified. For example, the options under Y2 Axis and Y2 Series have not effect for charts without the Y2 Axis.



The chart can be copied, saved and printed by means of the three buttons placed at the bottom of the chart options.

The possible file formats to save the chart are:

BMP Windows Bitmap

JPG JPG/JPEG Format

GIF Compuserve GIF

EMF Enhanced Metafile Format

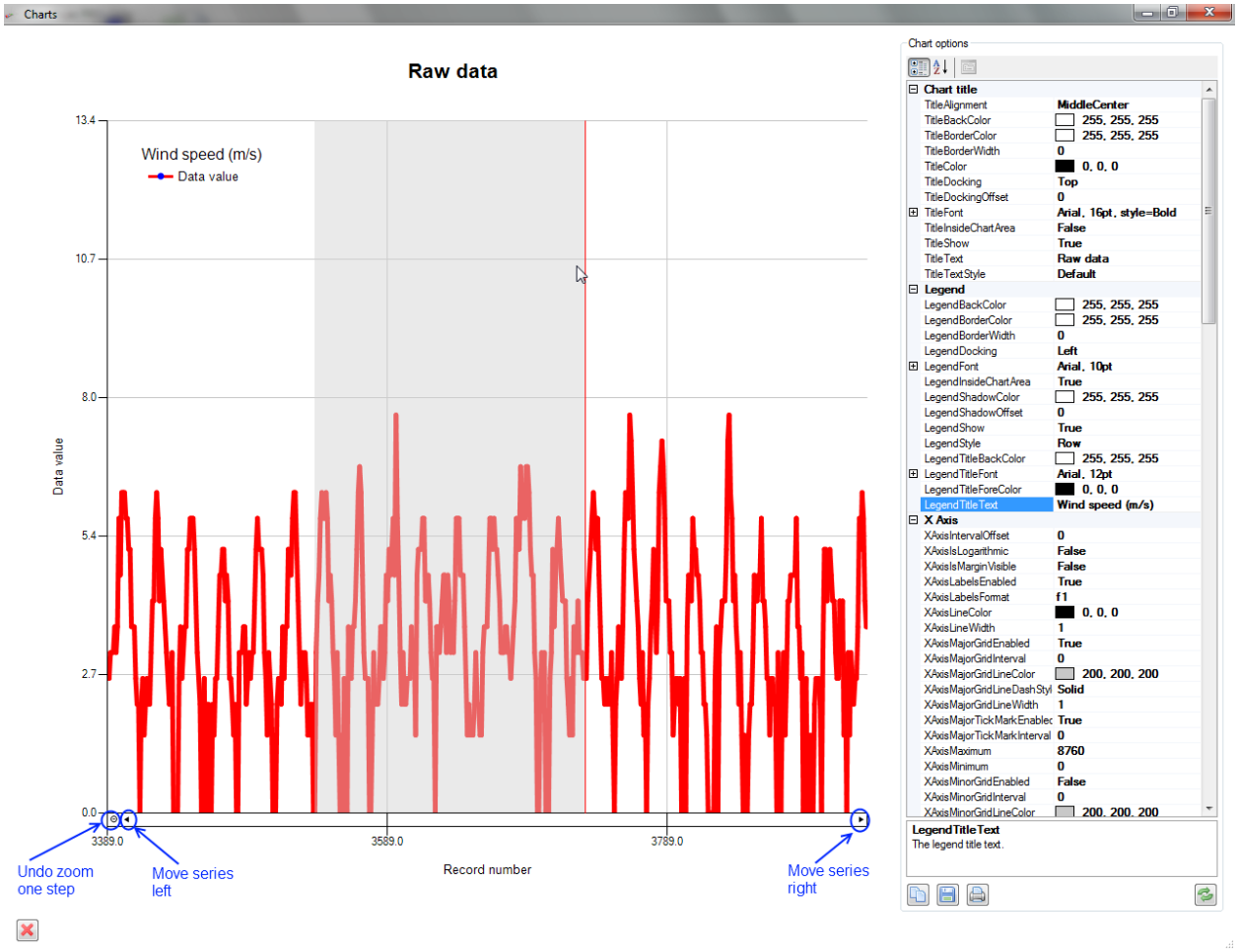
PNG Portable Network Graphics

TIFF Tagged Image File Format

Note that by clicking over the chart and dragging the mouse pointer it is possible to zoom over a specific part of the data (see next figure for example). Once zoomed, it is possible to move the series of data to the left or to the right by means of the arrows within the blue circles at the bottom of the chart. The small circle placed at the bottom right part of the chart allows to undo the zoom of one step each time it is clicked.

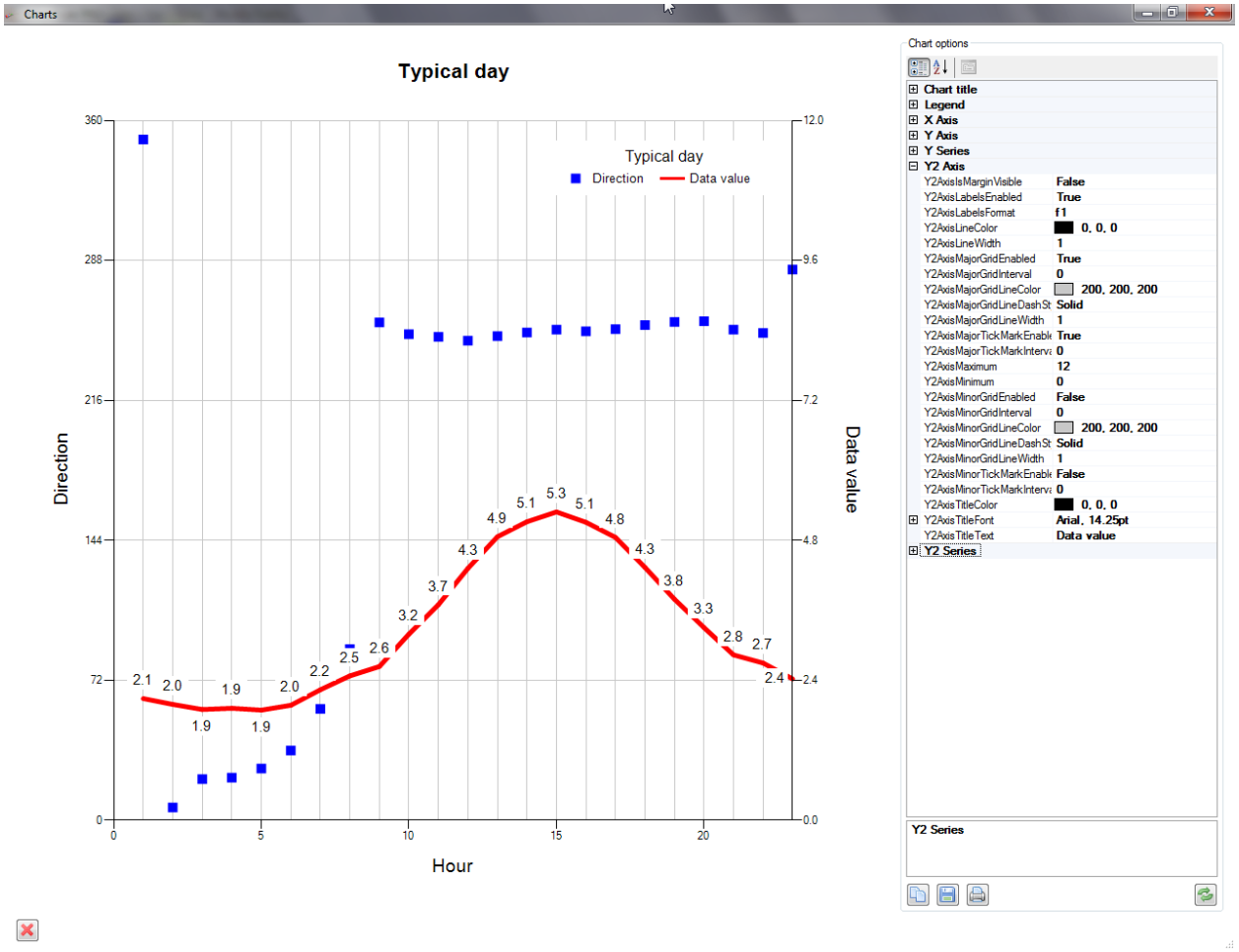
7.4.6.2 Actions > Charts > Raw data

This chart represents all the data (i.e. the values of the directional variable) independently of their directions. An example is shown in the next figure for wind speed. Note that the options under Y2 Axis and Y2 Series have no effect for this chart.



7.4.6.3 Actions > Charts > Typical day

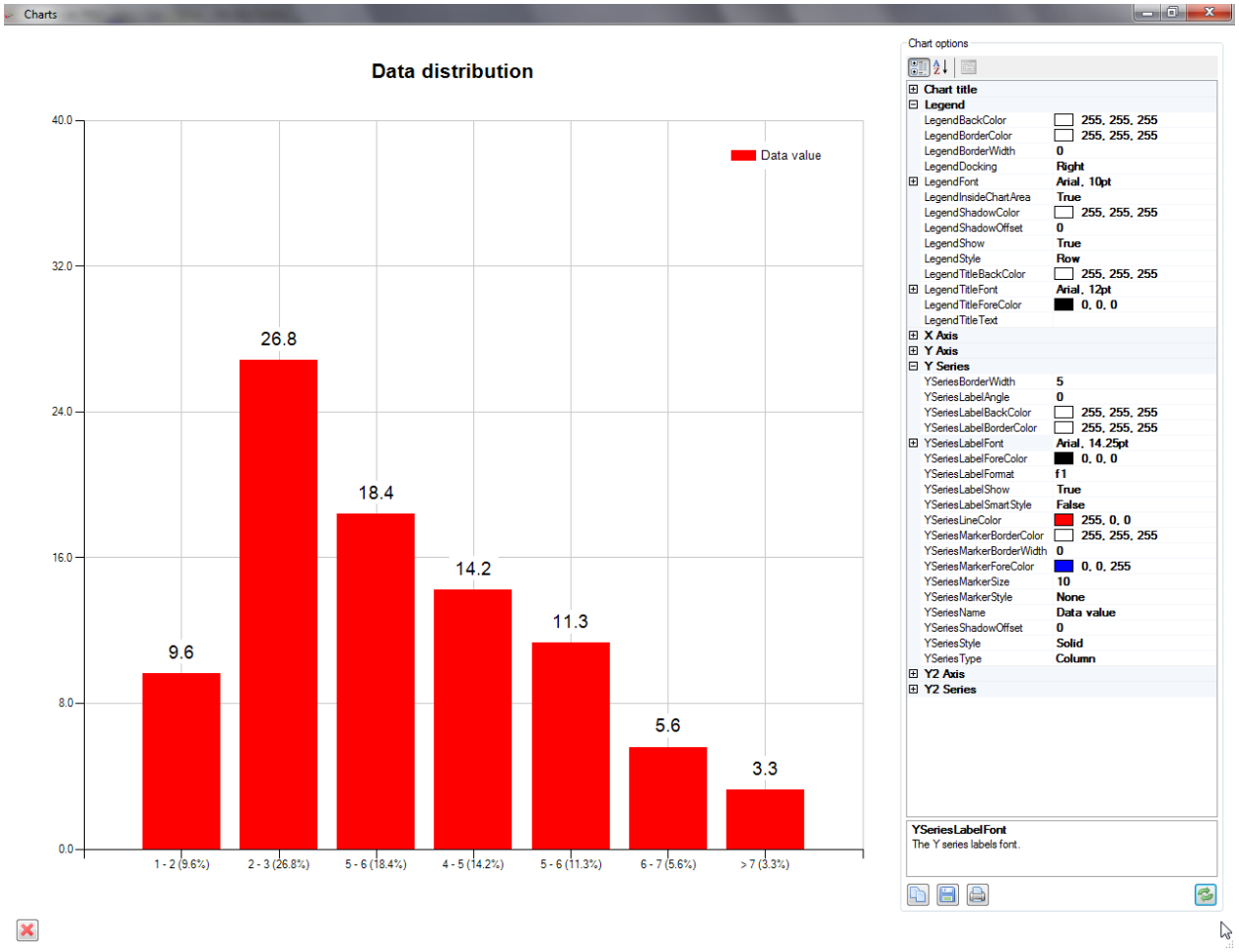
This chart represents the typical day for direction and directional variable on the same plot. The typical day is obtained by averaging the values for a fixed hour of the day. An example is shown in the next figure for wind direction and wind speed.



7.4.6.4 Actions > Charts > Data columns

This chart represents the percent distribution of the values of the directional variable within the classes specified by the user. An example is shown in the next figure for wind speed. For example, wind speeds between 1 m/s and 2 m/s account for 9.6% of the data, while speeds between 2 m/s and 3 m/s account for 26.8% of the data.

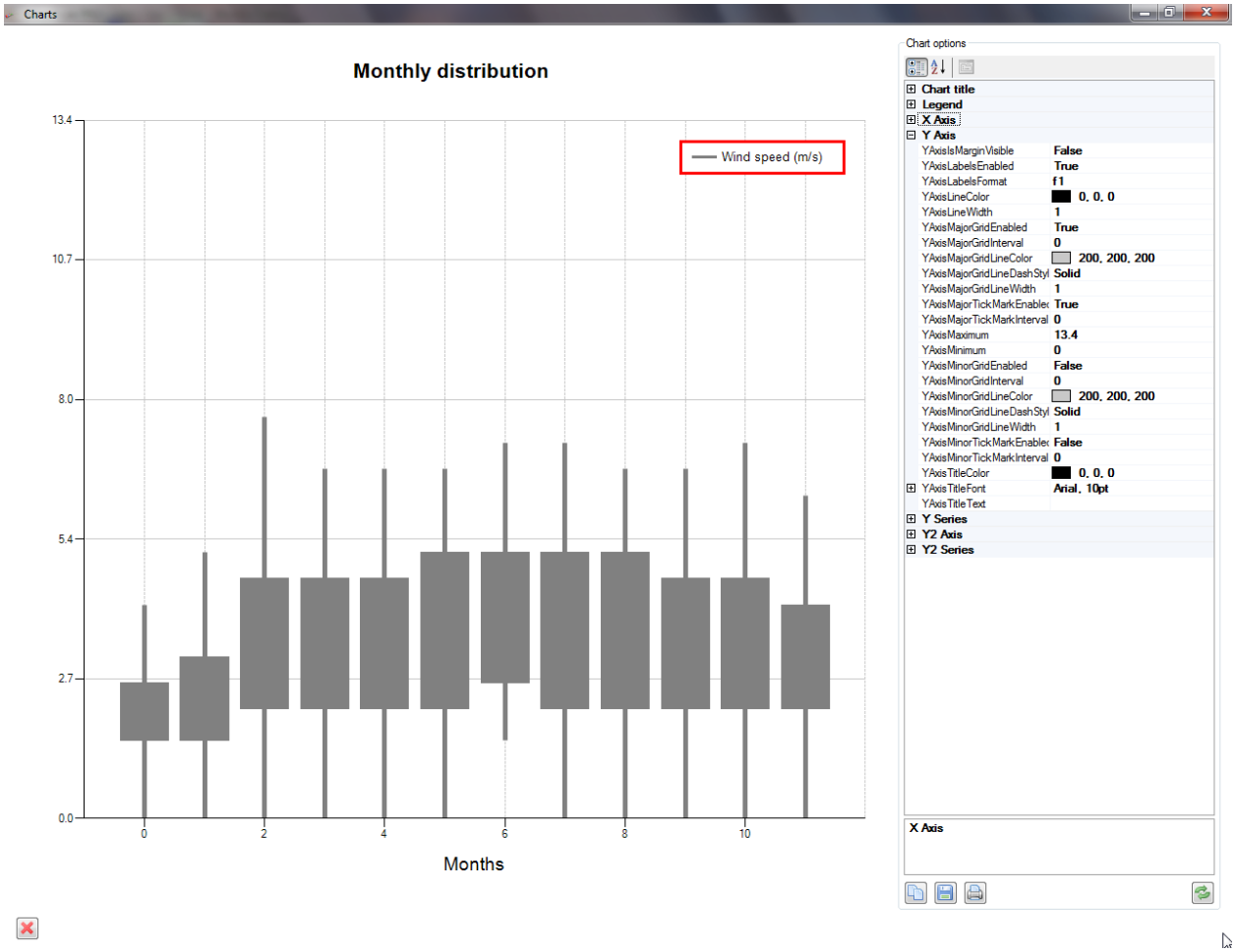
Note that the options under Y2 Axis and Y2 Series have no effect for this chart.



7.4.6.5 Actions > Charts > Monthly distribution

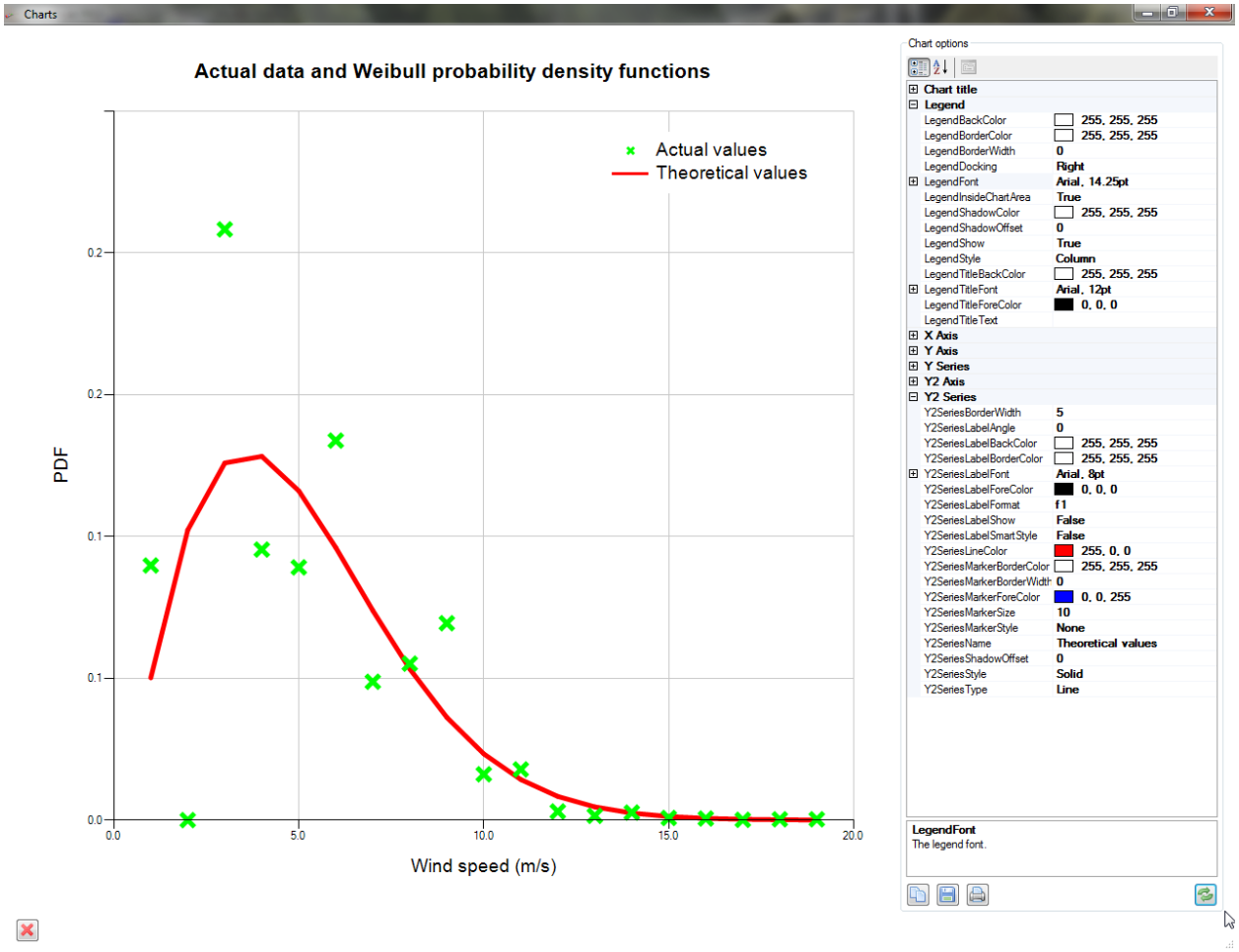
This chart represents the monthly distribution of the values of the directional variable through twelve candlesticks, one for each month. An example is shown in the next figure for wind speed. Each candlestick represents four values of the distribution, respectively from bottom to top: 5th, 25th, 75th and 95th.

Note that the options under Y2 Axis and Y2 Series have no effect for this chart.



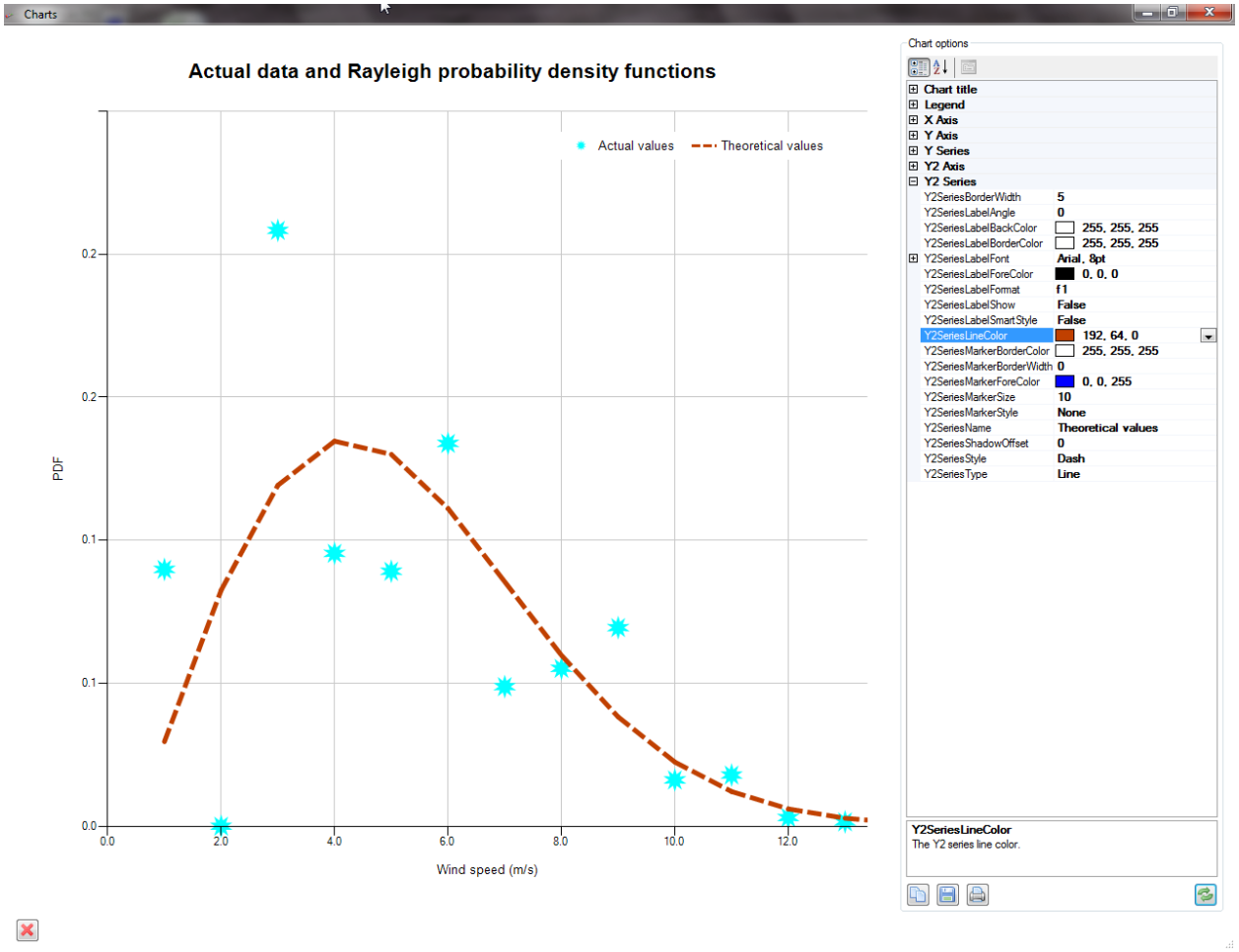
7.4.6.6 Actions > Charts > Weibull

This chart represents the theoretical Weibull distribution of the directional variable values, calculated starting from them, and their actual distribution. An example is shown in the next figure for wind speed. Note that the options under Y2 Axis have no effect for this chart. On the contrary, the Y Series refers to the actual distribution, and the and Y2 Series refers to the theoretical distribution.



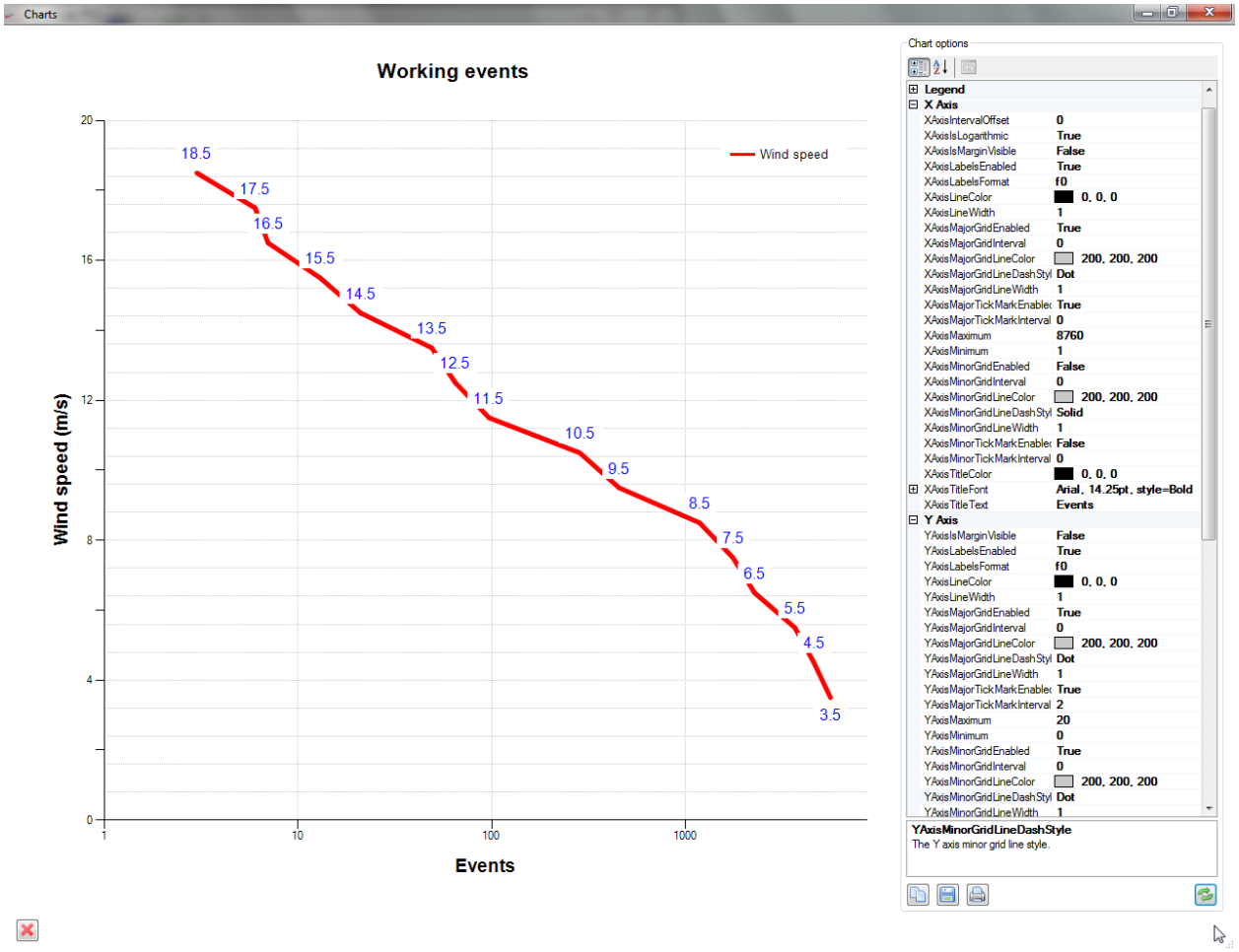
7.4.6.7 Actions > Charts > Rayleigh

This chart represents the theoretical Rayleigh distribution of the directional variable values, calculated starting from them, and their actual distribution. An example is shown in the next figure for wind speed. Note that the options under Y2 Axis have no effect for this chart. On the contrary, the Y Series refers to the actual distribution, and the and Y2 Series refers to the theoretical distribution.



7.4.6.8 Actions > Charts > Working events

This chart represents the distribution of the working events of a specific wind turbine. The X axis of the curve represents the number of events between the cut-in and cut-out values of the turbine, while the Y axis represents the wind speed. The number of working events will increase for low wind speeds, which are more frequent. An example is shown in the next figure. Note that the options under Y2 Axis and Y2 Series have no effect for this chart.

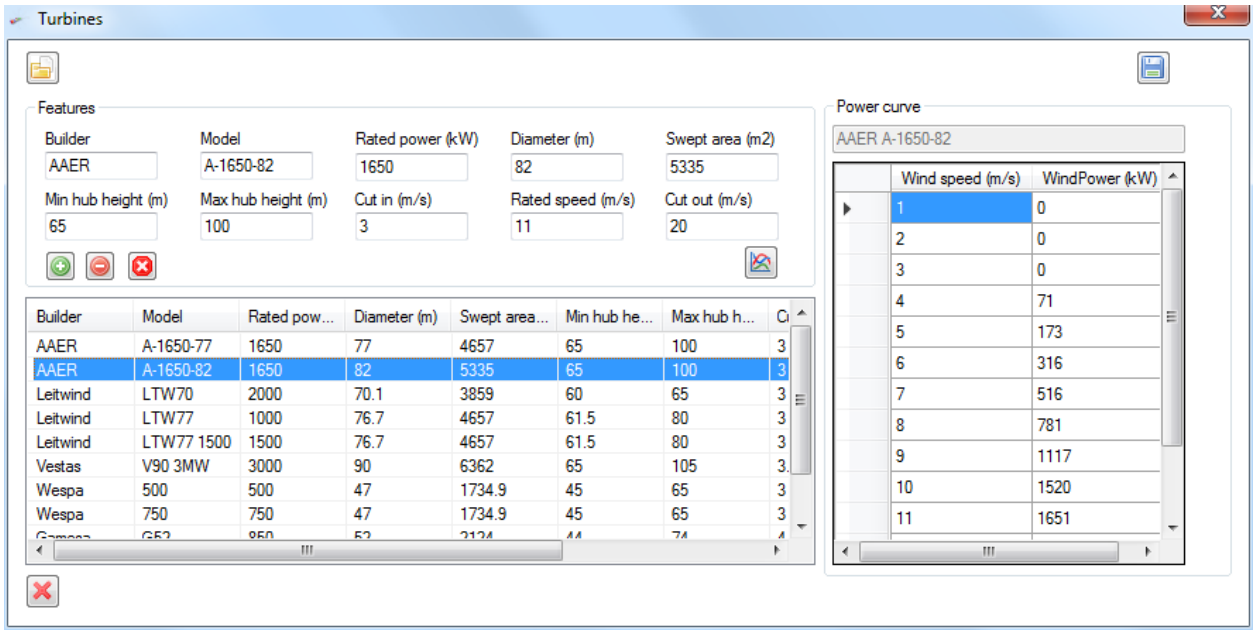


7.4.7 Actions > Turbines

The `Actions > Turbines` menu item shows the mask for inserting wind turbine properties, and save or load them. The turbines mask can also be loaded by means of the button shown in the next figure.

The turbines mask appears as shown in the next figure. The user may insert the main features of a turbine and save them in a specific file, with XML format, which will have a TRB extension. A TRB file will be loaded, and a specific turbine will be chosen, for

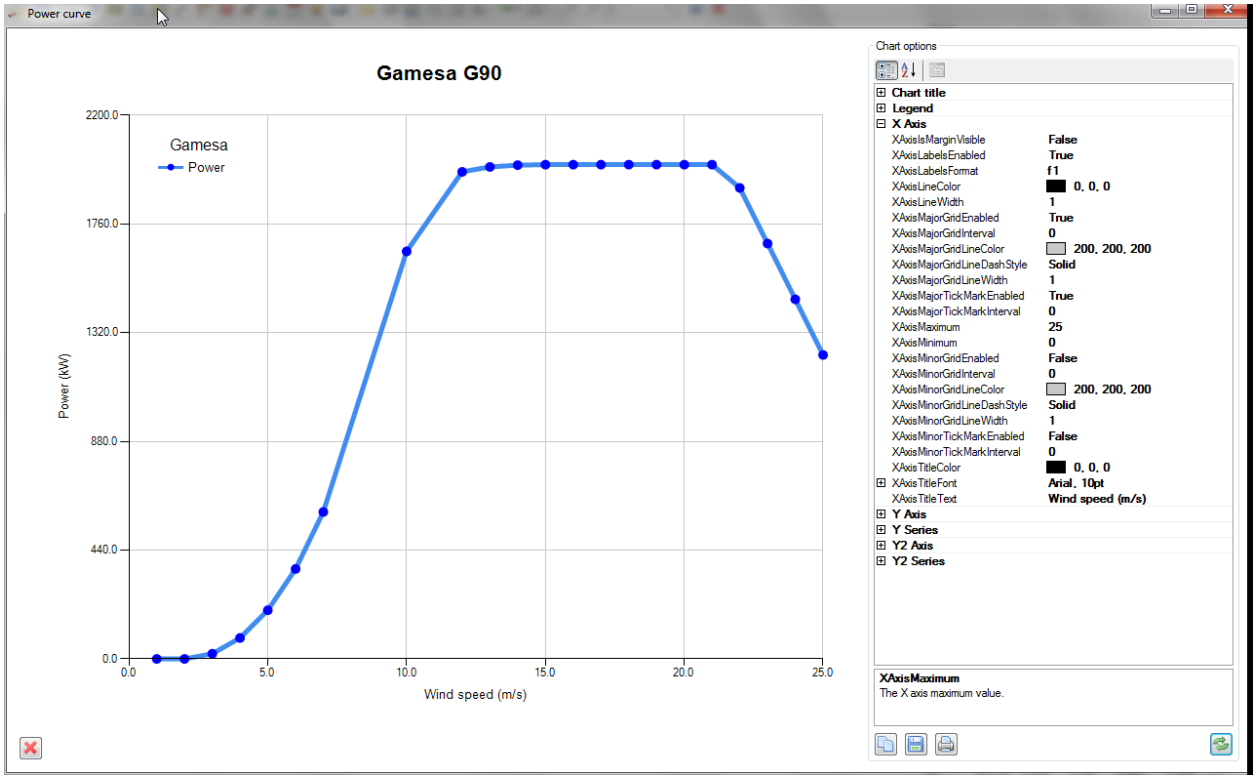
evaluating the wind power potential (see 7.3.12). Through the TRB files each user will be able to create a personalised wind turbines database.



Each turbine can be added or modified by inserting the corresponding values within the text boxes and clicking the button. A single turbine can be deleted by selecting it within the grid and clicking the button, while the button deletes all the turbines within the grid.

The power curve part of the mask is automatically prepared with wind speeds values as soon as the user has specified the cut-in, the rated and the cut-out speeds. The user then will insert the power value for each speed.

The power curve can be graphically represented by means of the button, as shown in the next figure. The chart features can be modified by means of its right panel. Each modified option is made visible on the chart only after the button is clicked. The chart can be copied, saved and printed by means of the three buttons placed at the bottom of the chart options.



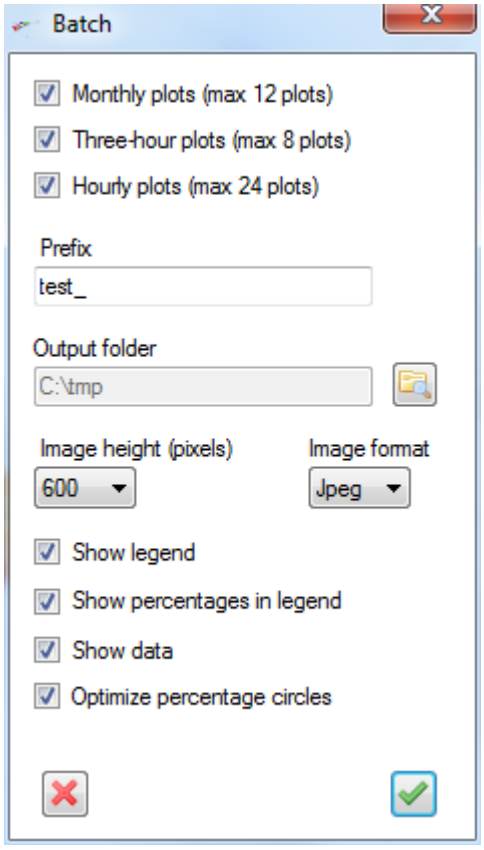
Zooming operations are also possible by clicking over the chart and moving the mouse pointer.

7.4.8 Actions > Batch processing

The `Actions > Batch` processing menu item allows to produce hourly. Three-hourly and monthly wind roses starting from a single input file. The batch processing can be also activated by means of the button shown in the next figure.

It is important to note that the batch processing can be activated only when the **input data are associated to date and time** and **after a wind rose has been plotted**.

The batch processing mask is shown in the next figure.



The user must specify at least a type of plot selecting among monthly, three-hour and hourly plots. Depending on how hours are expressed in the input data (i.e. from 00 to 23 or from 01 to 24), the three-hour plots will be prepared for hours 00-02, 03-05, …, 21-23, or from hours 01-03, 04-06, …, 22-24.

Any date/time filtering applied by the user to the input data will be also applied during the batch processing. For example, if the user has excluded from the analysis the months of May and June, the wind roses for such months will be not produced.

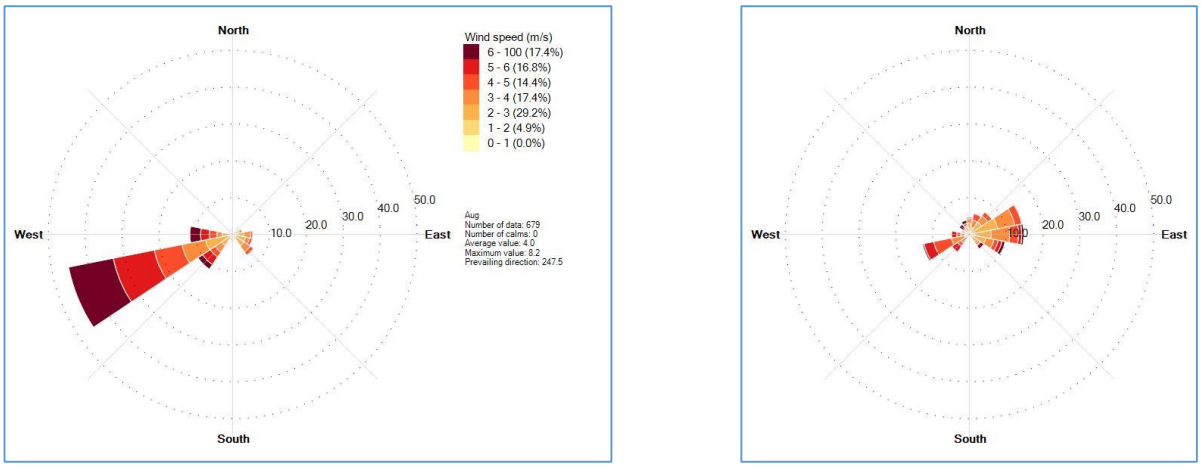
The optional Prefix text box allows to add a prefix to the name of the output files written in the selected output folder. The output file names in the output folder are (assuming no prefix has been specified):

- MON.format (for monthly files)
- HH.format (for hourly files)
- HI-HF.format (for three-hour files)

Where *MON* is the three-letter abbreviation of the month name (e.g. Jan. Feb, …), *HH* is the hour, *HI* and *HF* are respectively the initial and final hours of the three-hour period, *format* is one of the possible output format (Jpeg, Png, Bmp).

All the plots referring to a specific period (monthly, hourly, three-hour) are created using the same scale; therefore, for example, all the monthly plots will be comparable.

The aspect ratio (i.e. ratio between width and height) of the plots is 4:3 or 1:1, depending on the user choice to depict on the plot the legend and/or additional information about the data (e.g. number of data, average value, etc.). See next figure for an example. If the user does not specify to represent the legend over each plot, a Legend.bmp file is produced in the output folder (a prefix will precede the name, if specified).

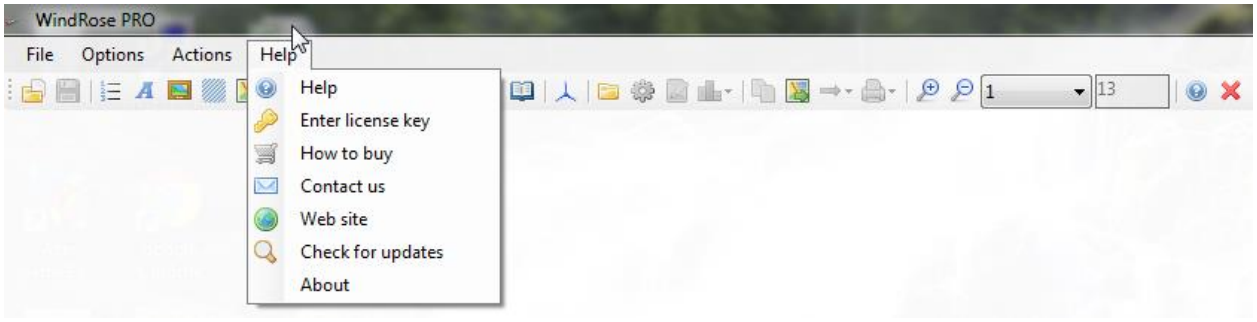


It is possible to optimize the number of percentage circles represented on the plot to make them clearly visible. If such an option is not selected, some labels may be overlapped.

A Processing.log file (a prefix will precede the name, if specified) is also created in the output folder. Such a file contains additional information about the processing.

7.5 Help

The *Help* menu item allows to carry out the operations described in the following list.



7.5.1 Help > Help

Opens the WindRose PRO User's Guide (this document).

7.5.2 Help > Enter license key

This menu item opens the Registration mask (see 5), which can be used for obtaining an evaluation license and for buying the software.

7.5.3 Help > Contact us

This menu item allows to send a feedback or report an error via email. Note that the message subject is automatically prepared for containing software name, version and date (e.g. Feedback for: WindRose PRO 3.1.48.0 (2013-05-31))

7.5.4 Help > Web site

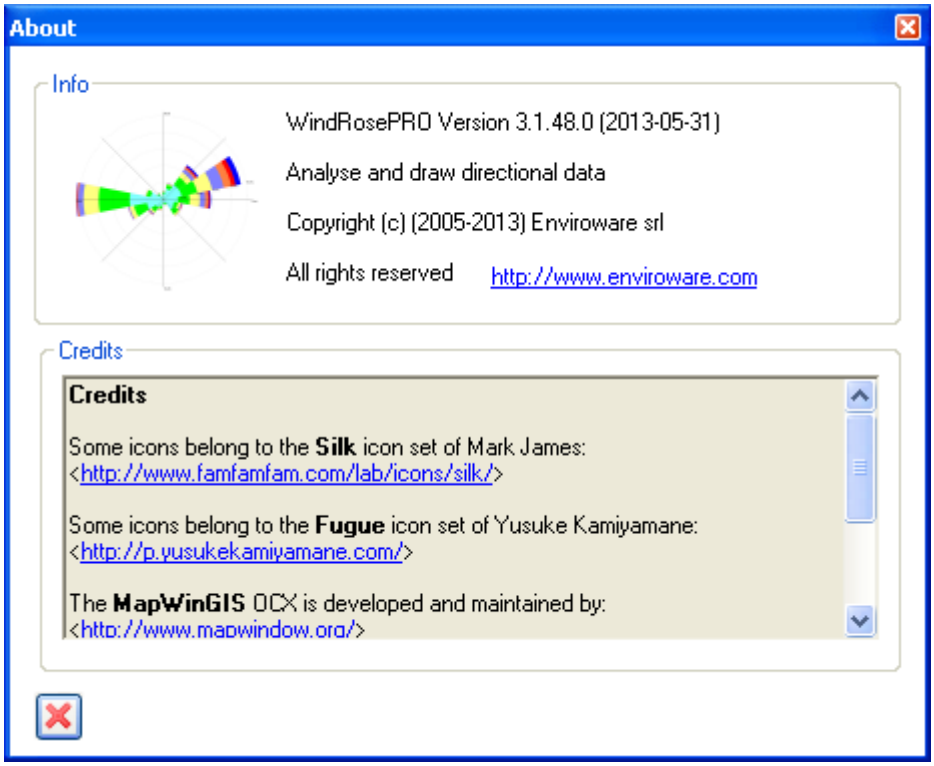
This menu item opens the WindRose PRO web page on the Enviroware's internet site.

7.5.5 Help > Check for updates

This menu item checks for software updates connecting to the Enviroware internet site.

7.5.6 Help > About

This menu item opens the About mask which contains information about the software version and date.


About
Info
WindRosePRO Version 3.1.48.0 (2013-05-31)
Analyse and draw directional data
Copyright (c) (2005-2013) Enviroware srl
All rights reserved
http://www.enviroware.com
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Credits
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Some icons belong to the Fugue icon set of Yusuke Kamiyamane:
<http://p.yusukekamiyamane.com/>
The MapWinGIS OCX is developed and maintained by:
<http://www.mapwindow.org/>

8. PUBLICATIONS

The following is a brief list of publications where WindRose PRO3 was used:

- Bellasio R. (2014) Analysis of wind data for airport runway design. Journal of Airline and Airport Management 09/2014; 4(2):97-116. DOI: 10.3926/jairm.26.
- Pezzoli A. and Bellasio R. (2014) Analysis of Wind Data for Sports Performance Design: A Case Study for Sailing Sports. Sports 11/2014; 2:99-130. DOI: 10.3390/sports2040099.
- Pedersen A., Kocurek G., Mohrig D. and Smith V. (2015) Dune deformation in a multidirectional wind regime: White Sands Dune Field, New Mexico. Earth Surface Processes and Landforms. DOI: 10.1002/esp.3700
- Zhang J.J.Y. et al. (2015) Development of Land-Use Regression Models for Metals Associated with Airborne Particulate Matter in a North American City. Atmospheric Environment. doi:10.1016/j.atmosenv.2015.01.008
- Felix O.I. et al. (2015) Use of lead isotopes to identify sources of metal and metalloid contaminants in atmospheric aerosol from mining operations. Chemosphere. doi:10.1016/j.chemosphere.2014.11.057
- Capell Aris (2014) Wind Power Reassessed: A review of the UK wind resource for electricity generation. Adam Smith Institute/Scientific Alliance Publication (2014)
- Alolayan M.A., Brown K.W., Evans J.S., Bouhamra W.S., Koutrakis P. (2013) Source apportionment of fine particles in Kuwait City. Science of The Total Environment, Volume 448, 14–25.
- Pezzoli A. (2012) Meteorological analysis for the Europan rowing championships (Presentation in Italian). L.R. MeteoSport . U.O. Psycosport – Centro Ricerche Scienze Motorie – S.U.I.S.M. – Università di Torino. September 2012.
- Pezzoli A. (2012) Wind-wave interactions in enclosed basins: the impact on the sport of rowing. Physics of Sports, Ecole Polytechnique, Paris, 3-6 April 2012.
- Gupta A. and Dhir A. (2013) Estimation of horizontal pollution potential by calculating impact area for Patiala, Punjab using wind data. International Journal of Innovative Research in Science, Engineering and Technology, Vol. 2, Issue 6

- Burt S. (2012) The Weather Observer's Handbook. Cambridge University Press. 456 pages.
- Lerum V. (2007) High Performance Building. Wiley. 304 pages.
- Talpur S. (2013) Dynamic line rating implementation as an approach to handle wind power integration. A feasibility analysis in a sub-transmission system owned by Fortum Distribution AB. Master Thesis. The Royal Institute of Technology (KTH) Stockholm.
- A. Yousefi-Sahzabi et al. (2011) GIS aided prediction of CO2 emission dispersion from geothermal electricity production. Journal of cleaner production.
- Davis J. et al. (2009) Analysis of Local Spread of Equine Influenza in the Park Ridge Region of Queensland. Transboundary and Emerging Diseases. Volume 56, Issue 1-2, 31-38.
- Ren C. and Ng E. (2009) An Initial Investigation on Microclimatic Environment in High Density City — Spot Field Measurement Study in Hong Kong. The seventh International Conference on Urban Climate, 29 June – 3 July 2009, Yokohama, Japan
- Csavina J. et al. (2011) Metal and Metalloid Contaminants in Atmospheric Aerosols from Mining Operations. Water, Air, & Soil Pollution, Volume 221, Issue 1-4, 145-157.
- Istvánovics V. et al. (2008) Distribution of submerged macrophytes along environmental gradients in large, shallow Lake Balaton (Hungary). Aquatic Botany. Volume 88, Issue 4, 317-330.
- Ragosta et al. (2008) Trace elements in daily collected aerosol: Level characterization and source identification in a four-year study. Atmospheric Research. Volume 89, Issue 1-2, 206-217.
- Forest A. et al. (2010) Three-year assessment of particulate organic carbon fluxes in Amundsen Gulf (Beaufort Sea): Satellite observations and sediment trap measurements. Deep Sea Research Part I: Oceanographic Research Papers. Volume 57, Issue 1, 125-142.

- Johnson P.G. Et al. (2005) Pollen-Mediated Gene Flow from Kentucky Bluegrass under Cultivated Field Conditions. Crop Science. Volume 46, N. 5, 1990-1997.
- Pimonsree S. et al. (2008) PM10 dispersion during air pollution episode in Saraburi, Thailand. 12th International Conference on Integrated Diffuse Pollution Management. November 2008.

9. CONTACTS

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