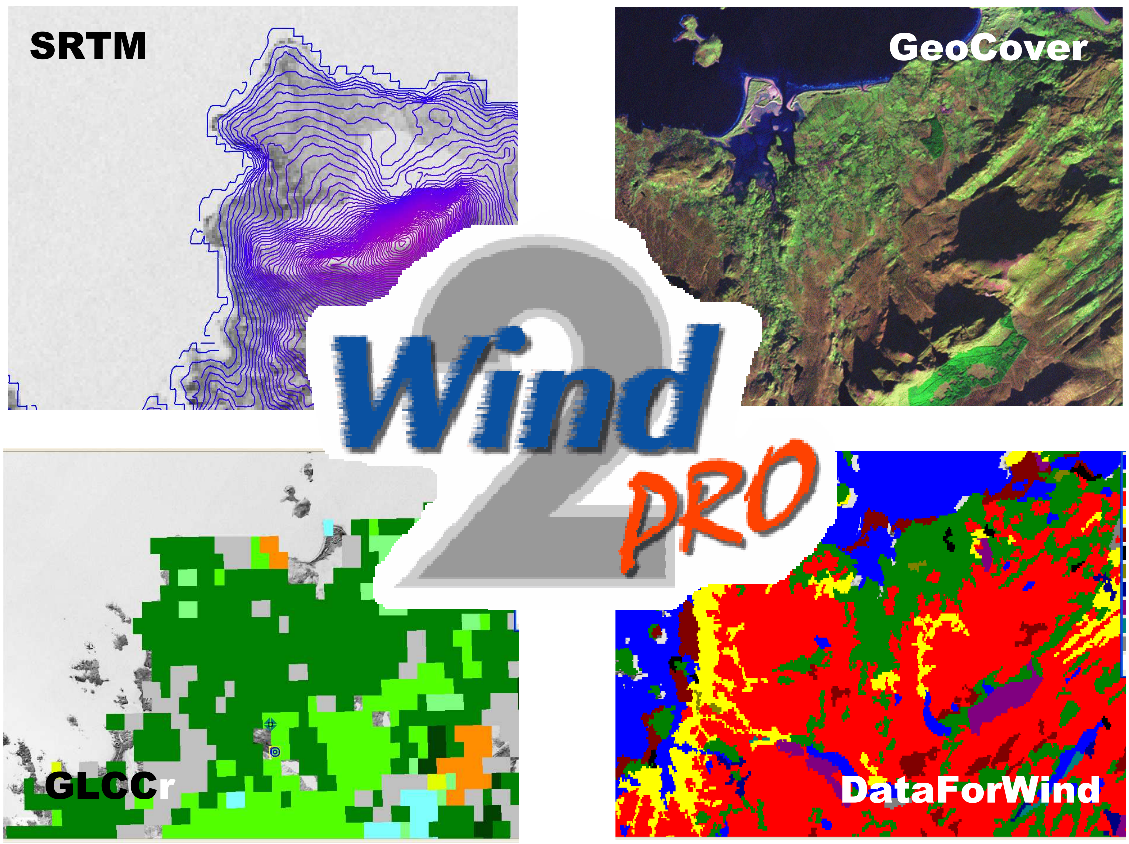
WindPRO / ONLINE

Remote Sensing Data and Other Data for Download in WindPRO



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Document history

18-05-2007	1st draft – Morten Lybech Thøgersen, M.Sc., mt@emd.dk
01-11-2007	2^{nd} draft - Added ModisVCF algorithm description
17-04-2009	Added wind data description
24-06-2009	Revised structure, now with user interaction description in introduction chapter (1)
30-09-2009	DEM models: CGIAR and Viewfinder Panoramas
26-02-2010	WTG data added, revised for WindPRO 2.7, including new ModisVCF algorithm, Alster GDEM (PN, MLT, LS)

Front cover

The front cover shows the on-line data download logo in upper left corner. If you see this logo appear in WindPRO, then online data are available. . Also shown are data samples from a site in Ireland. The samples show map data, roughness data and height contour data. Data sources are the Shuttle Radar Topological Data (SRTM), the GeoCover satellite images, the Global Land Cover Classification (GLCC) and finally the DataForWind 200x200m gridded data.

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1. Introduction to WindPRO Online Data

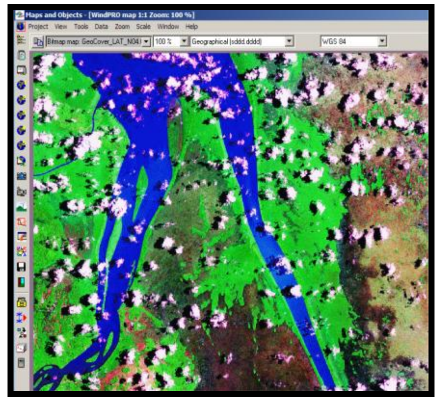


Figure 1: Satellite Image of the North-Eastern Part of Brazil from the GeoCover Map Dataset.

This document gives an introduction to the origin of the datasets available through the EMD / WindPRO internet server services. These services are implemented in order to aid the access to global or regional datasets of:

- Height contours
- Roughness data
- Map data
- Wind data
- Existing turbines

This chapter gives an introduction how to operate/access/ load the different online datasets from within WindPRO. For a description of the individual datasets please refer to the succeeding chapters.

Most of these datasets are directly from the individual objects in WindPRO holding the dataset of interest, e.g. roughness data are loaded from the 'Online Data' button in the area object of WindPRO. Note, that even if the datasets delivered may be convenient to use in many wind turbine projects, then a critical review of the data are always needed, as these typically is delivered from remote sensing devices, where the accuracy is not as high as typically required within such applications. Another issue is, that due to the global or large regional coverage of these datasets, then a erroneous data are bound to exist, even if automated quality checks have been performed – as well as site specific evaluations of the data by the WindPRO team. Thus, when working on a specific site, it is crucial that you do a quality evaluation of the online-datasets that you choose to use.

These manual pages give a brief introduction to all of the datasets, as well as references to their origin. Before using the datasets, please consult the individual dataset descriptions and internet resources to clarify the details and limitations for these data and any restrictions in their appliance.

Pre-requisites in order to access the EMD online services

- You must hold a valid service agreement with EMD regarding the WindPRO software. Customers with expired service agreements cannot access the online services.
- The individual dataset require a license to the module(s) where the data are consumed. The module requirements are shown in the Figure 2.
- You must accept to send certain user information to EMD when downloading data, see the privacy warning in Figure 3.

Data service	Module licenses needed
Height contours (Line object)	Basis
Roughness data (Area object)	Basis
Map data (Project properties)	Basis
Wind data (Meteo object)	Basis + Meteo + MCP
Existing turbines (Data menu)	Basis + Existing turbines

Figure 2: Module Requirements to Access Specific Online Datasets.

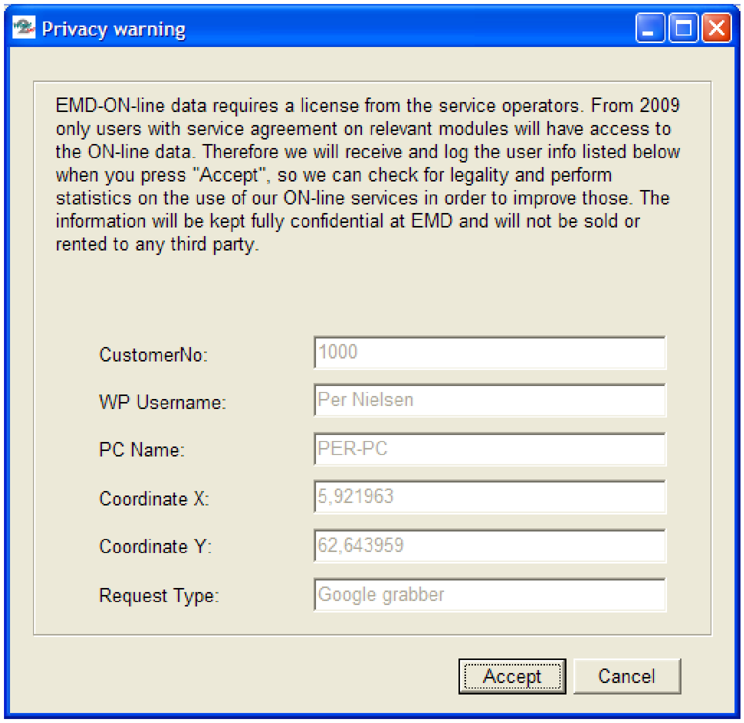


Figure 3: The service requires you to accept this "privacy warning".

A Note to Potential Data Providers

At EMD we constantly strive to improve our online services offered to the WindPRO users. If you have knowledge about or access to databases that would be useful for a large number of WindPRO users, please feel free to contact us at the following email address: WindPRO@emd.dk.

1.1 Accessing Height Contour Data through the Line Object

The elevation data are downloaded via the online option in a Line Object with the purpose set to "Height contour lines". You find the "Online data" button in the lower right corner (see below). After pushing the button you have to choose the relevant dataset. The server will provide a list of the relevant datasets based on the specific position of you inserted line object.

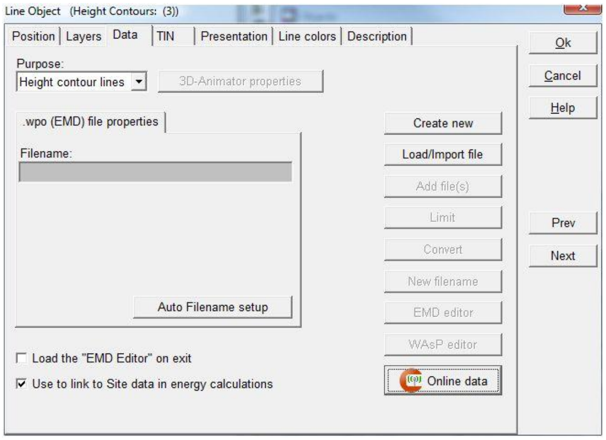


Figure 4: Data Tab in the WindPRO Line Object.

Finally the spatial extent of the file to download must be defined by the user. For typical use (energy calculations) activate "Convert to lines" to obtain a file of height contour lines. Note that you must consider the grid resolution of the original data when selecting the equidistance (contour separation). As an example, the SRTM data is stored with a 90m grid resolution. In this case an equidistance of 5-20 m can be justified, and 10 m is given as default. Using very small equidistance (e.g. 2 m) cannot be justified in any way, as the original SRTM data source are do not permit such accuracy.

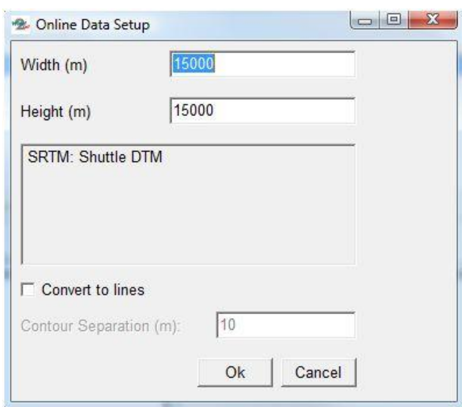


Figure 5: Selecting the Spatial Extent of the DHM Data.

1.2 Accessing Roughness Map Data through the Area Object

The data are downloaded via the online option in an Area Object with the purpose set to "Roughness data". You find the "Online data" button on the top-tab Import/Export and then bottom-tab "Online Data" (see below).

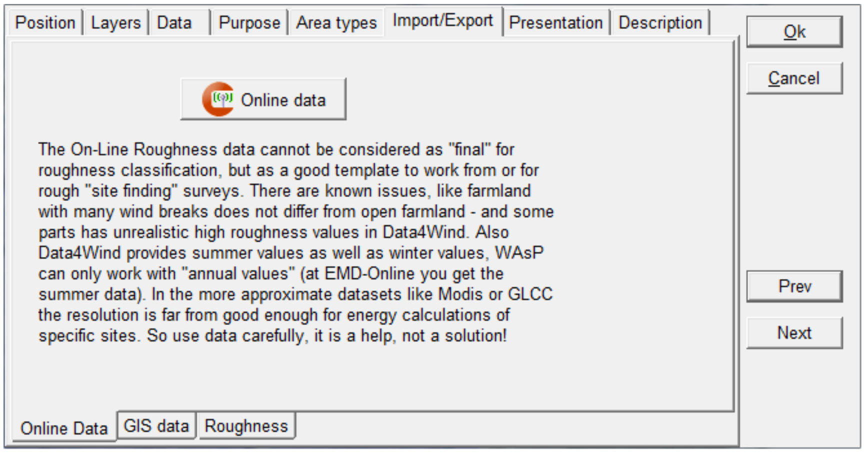


Figure 6: Online Access to Roughness Data.

After that the relevant data source must be chosen and then the spatial extent of the file must be specified.

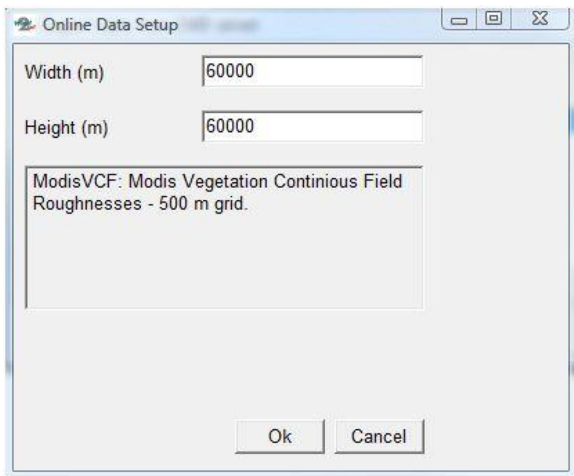


Figure 7: Selecting the Spatial Extent of the Roughness Data

Please note that for area-type roughness data the user has to manually specify the background roughness level of the map. A possible choice could be to use the most frequent value (largest area covered) in the dataset, and then delete this layer from the data set, which also will make the data handling faster.

Note the datasets available typically are not sufficient in order to do a complete surface roughness description, but they can be a good support tool in the roughness classification.

1.3 Accessing Background Map Data From Project Properties

In order to attach a background map from an online source, simply press the project properties button in WindPRO, select the 'Background Maps' tab, and click the 'Online Map' icon, see the Figure 8. Then choose which background map that you want, see Figure 9. Finally choose the size of your map area – see Figure 10 – the selected map will now be downloaded and added to your list of maps. Note, that the map resolution will typically be set automatically in order to give a reasonably small file size that can be downloaded immediately, usually within a minute or less, depending on the speed of your internet connection. For some data sources you can choose to set the resolution manually. The online maps are stored as *.BMI files, which is the internal WindPRO background map format.

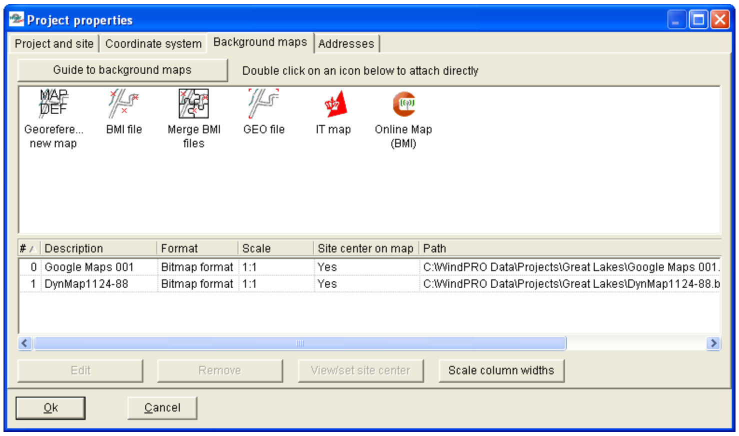


Figure 8: Online Maps in WindPRO.

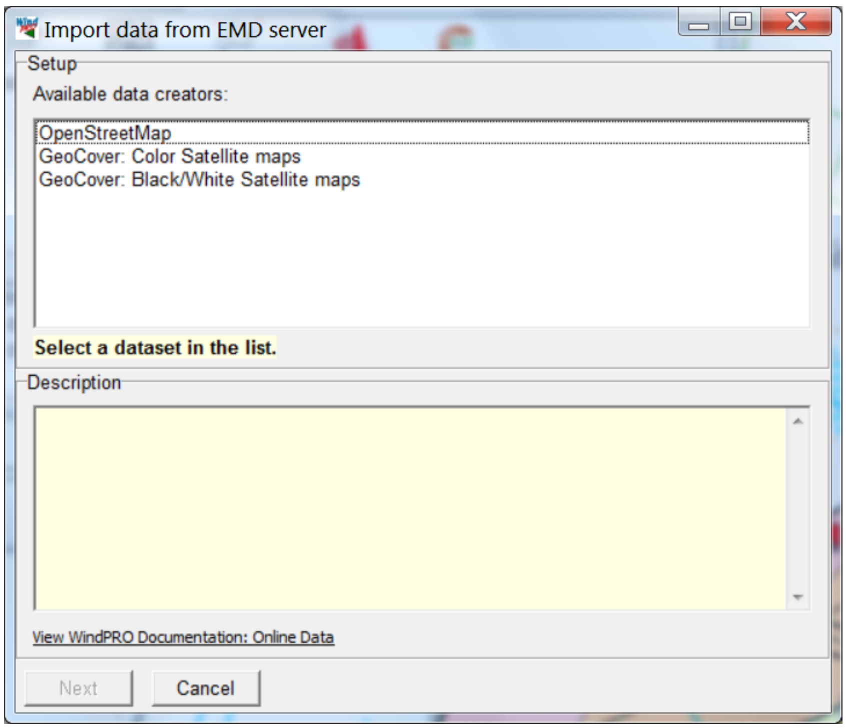


Figure 9: The online service detects which maps there are available around the location of the specified project site.

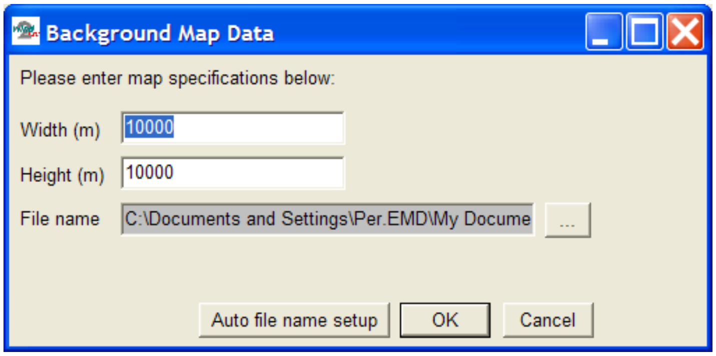
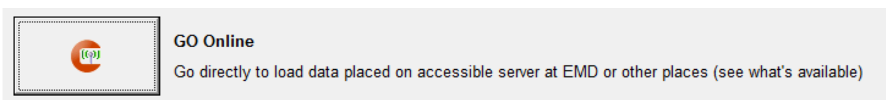


Figure 10: After selecting the source, you can specify the width and height of the map.

1.4 Accessing Wind Data From the Meteo Object

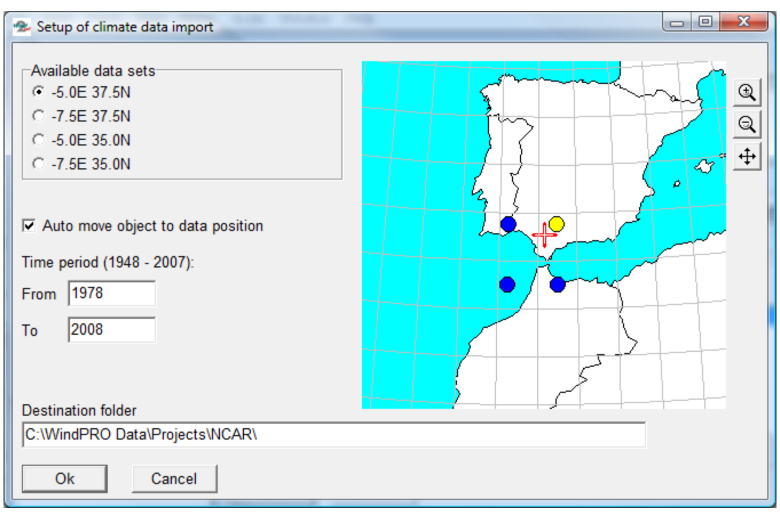
The process of obtaining online wind data in WindPRO is quite simple, so in order to access the data please follow this procedure:

1. Insert a new meteo object at a random position (at your site). In the initial window of the meteo object simply press the "on-line" button (see below).



2. Choose the appropriate dataset (available data sets near the location will be provided). Press "Next button and then accept.

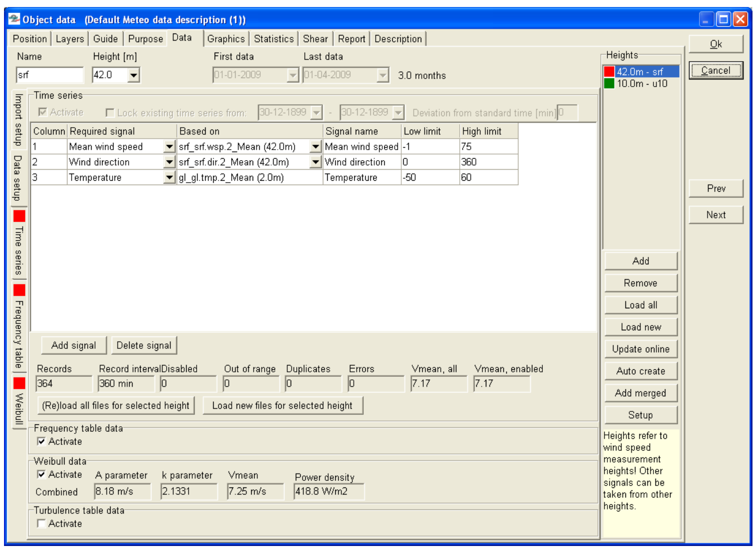
3. Next the window below pops up giving the user 4 nearest data points to choose from, as well as the possibility to adjust the length of the time series.



4. As default the Meteo object will automatically be moved to the position of the grid point chosen and the data loaded into the meteo object. Sample data from a NCEP/NCAR Reanalysis data is shown in the figure below. This dataset contains wind speeds in the height of 10 m ("u10") and 42 m ("srf"). Also the temperature is loaded from the file.

Column	Header	First data	Channel	Type	Sub type	Unit	Height	Name	Converted
1	year	1978		Time stamp	Year		0		1978
2	month	1		Time stamp	Month		0		1
3	day	1		Time stamp	Day		0		1
4	hour	0		Time stamp	Hour		0		0
5	srf.dir.2	69.33	srf	Wind direction	Mean	Degrees	42.00	srf_srf.dir.2_Mean	69.3 Degrees
6	srf.wsp.2	11.33	srf	Wind speed	Mean	m/s	42.00	srf_srf.wsp.2_Mean	11.33 m/s
7	u10.dir.10	83.88	u10	Wind direction	Mean	Degrees	10.00	u10_u10.dir.10_Mean	83.9 Degrees
8	u10.wsp.10	5.63	u10	Wind speed	Mean	m/s	10.00	u10_u10.wsp.10_Mean	5.63 m/s
9	gl.tmp.2	9.35	gl	Temperature	Mean	Deg C	2.00	gl_gl.tmp.2_Mean	9.3 Deg C

5. Choose to use optional data – if required (extra data stored in the data source files, but not loaded into the meteo object time series tab). As an example the default setup for the NCEP/NCAR Reanalysis data sample – as shown below - is configured to use time stamp, surface and 10 m wind only – but source files also holds an optional temperature column. Also, if for instance you want to use the rain_flag column in the QuikScat dataset, then you may manually load the additional column by adding an additional signal in the 'Data Setup' tab of the meteo object. As described, the data files in some cases contain more signals than is setup in the default import; add these by using the tab named "Import setup".



6. If you - at a later stage - need to update your data (with more, new months), you simply open the meteo-object with the downloaded data. Now the "Go Online" option is changed to "refresh Online" – simply click this and the most recent data is now loaded. Please note, that by using the "Meteo analyzer" you may refreshing several Meteo objects in one operation: In that tool, you simply click the "refresh all" button.

1.5 Importing of Existing Turbines from the Data Menu

Existing turbines are very helpful when designing a new wind farm in a region where turbines already are established. These can be used for several purposes, such as checking the calculated wind resource (if production data are available), for calibration of photomontages or to include in noise calculations. As existing turbine data is a valuable resource, it is also an important feature in WindPRO. Currently (2010), we are looking for data providers to supply such data for a number of countries where it potentially would be available. Such data though, may require an additional license code for WindPRO.

Currently (2010), it is possible to import Existing Danish WTGs only. This feature requires a separate license module/code, see the Figure 2. The update is automatically accessed when choosing "Import online WTG data" from the left menu bar of the WindPRO 'map and objects' window, see the Figure 11.

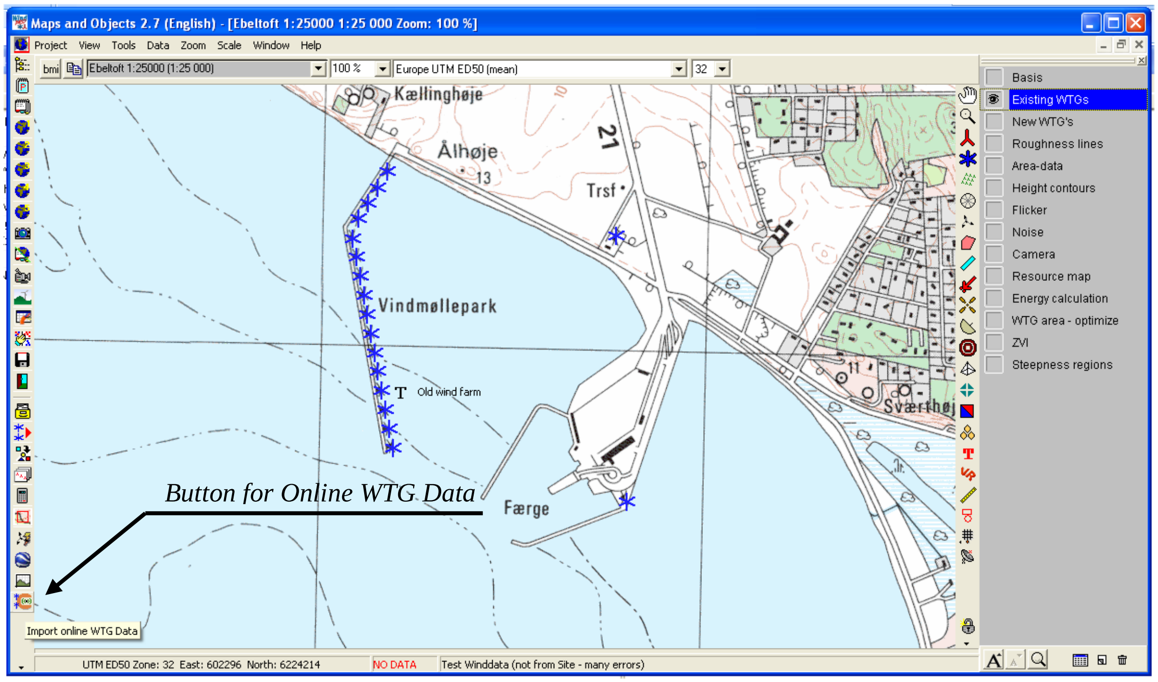


Figure 11: Button for Import of Online WTG-Data.

When you click the button, then a download window appears: You will then be asked to specify within which range (radius) you will want the download turbine data, see the Figure 12.

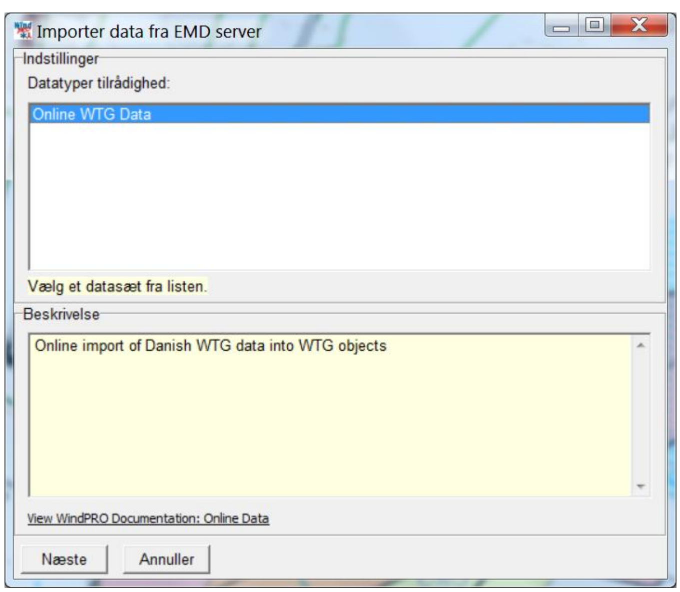


Figure 12: Download of Existing Turbine Data.

A note on backward 'WTG Import' compatibility using WEX files: The file based importer as shown in the Figure 13 is still a valid approach. However, the file has not been updated since 2006. Maintenance of this file is discontinued, so the data get slowly less and less representative. With the next version of WindPRO 2.8, the feature will be removed as a part of optimizing the data structure for external data where everything is accessed online.

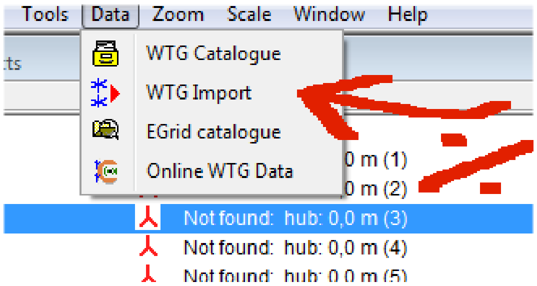


Figure 13: Download of Existing Turbine Data (Discontinued Approach).

1.6 Communicating to the Server Holding the Online Data at EMD

Currently, all of the datasets are stored at a dedicated on data-server at EMD in Denmark. When accessing this server, you will need quite a fast internet connection. We recommend using like a >1 MBit/s xDSL line or another faster technology. All communication with this server is done using the HTTP protocol using the standard port 80. If you use firewall software, then you may need to enable the WindPRO software for internet access. An outline of the connection procedure is shown in Figure 14.

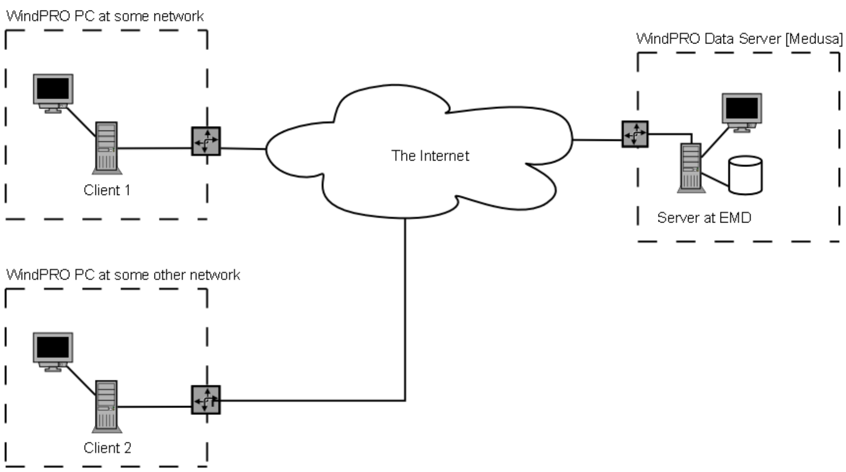


Figure 14: Outline of Client-Server Communication.

2. Digital Height Models (DHM)

The digital height model in WindPRO is based on open internet resources. Currently, the only available DHM source is the Shuttle Radar Topography Mission (SRTM) data.

When using the remote sensing digital height models, you must manually consider the accuracy of the dataset used. This is especially important in the vicinity of the wind farm and the meteorological masts erected. Typically – when applying remote sensing DHMs - the height contour lines must be validated against local topographical map.

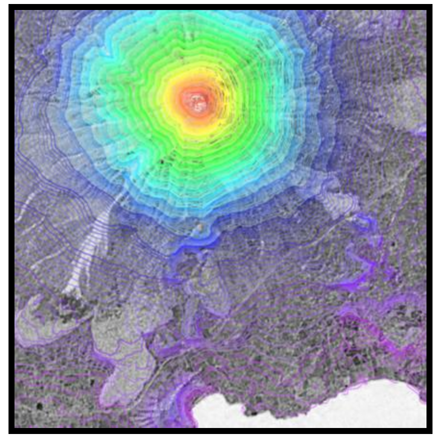


Figure 1: Satellite Image with DHM Overlay. The image shows a part of the Ometepe Island in Lake Nicaragua with SRTM height contour data.

2.1 Shuttle Radar Topography Mission (SRTM)

The Shuttle Radar Topography Mission (SRTM) data originate from an 11 day mission flown by the space shuttle Endeavour back in February, 2000. The raw data was collected using an instrument named “Spaceborne Imaging Radar-C”. The raw data was later processed and released as usable digital grid files.

About 80% of the total landmass of the Earth is mapped by the STRM data, covering all land between 56 degrees south and 60 degrees northern latitude. A view of the data coverage is shown in Figure 2.

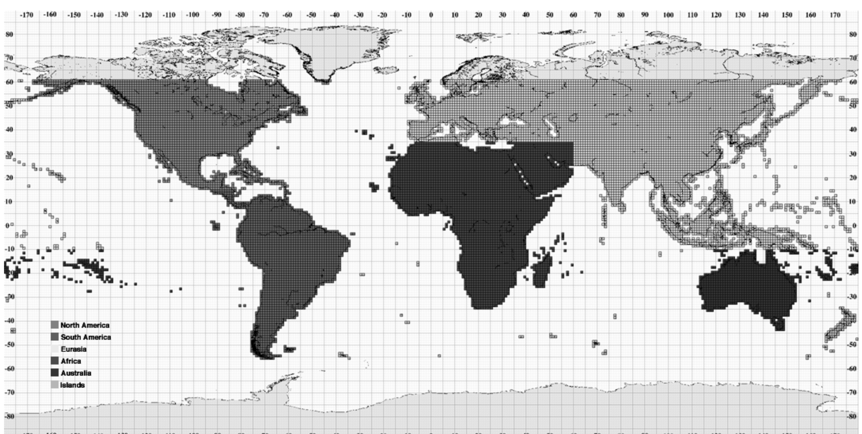


Figure 2: Near Global Coverage of the SRTM Data.

The SRTM data are delivered as gridded data with a spatial resolution of the dataset corresponding to 3 arc seconds, i.e. approximately 90 m distance between grid points. As a part of the processing of the SRTM data from our EMD server, the user has an option of choosing whether the data downloaded should be received as either raw gridded data or converted to height contour lines. In order to use the data for energy yield calculations, the data must be converted to contours.

Different versions of the SRTM data exist; at EMD we currently distribute the STRM data version 3.The difference between various versions is primarily that more error checking and validation is applied at later versions.

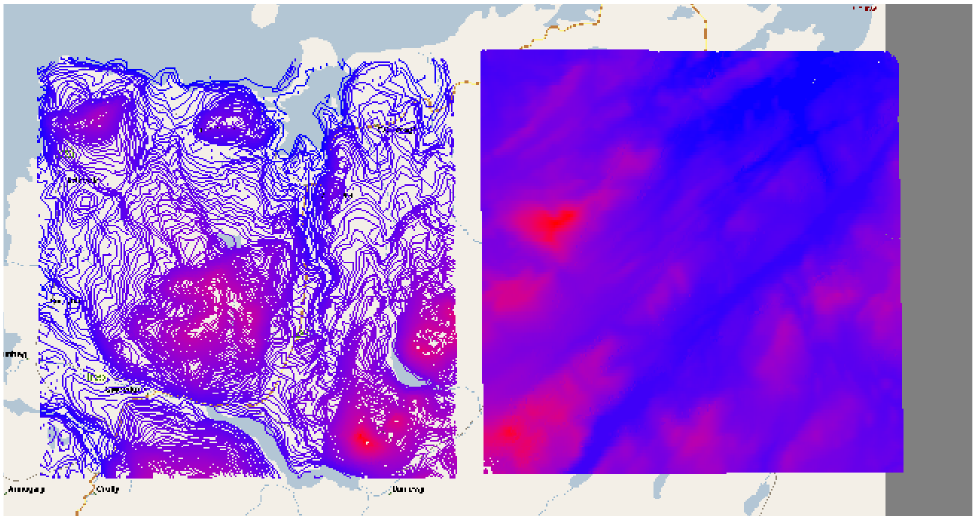


Figure 3: SRTM data in Northern Ireland: Left: As Height Contours, Right: As Gridded Data.

An alternative SRTM dataset with a higher spatial resolution of 1 arc second (about 30 m) is also available for the US and its territories. Currently this dataset is not available through the EMD online services, but it is possible to manually download the data and load the data into a line object.

You will be able to locate the STRM data on at the following URL: http://srtm.csi.cgiar.org/.

2.2 CGIAR – SRTM 90 m Digital Elevation Data

An alternative SRTM dataset has been developed by the CGIAR consortium for spatial information (CGIAR-CSI). This dataset is also based on the original SRTM dataset published by the U.S. Geological Survey; however it has been post-processed by a number of additional advanced voids filling algorithms as well as utilizing a number of better auxiliary DHM-datasets. Please refer to the CGIAR website for more information on this dataset (http://srtm.csi.cgiar.org/).

The spatial coverage of this dataset is the same as for the original SRTM data – as described in the section 2.1 above.

At EMD we have evaluated the differences in the datasets through calculations on three different sites, where all relevant data except the DHM model is replaced. The results are shown in the table below, where the annual energy yields from the proposed wind farms are evaluated. The AEP from the original contour model is set to 100%; these are typically based on data from the local ordinance survey offices. The calculation model used is WindPRO/WAsP.

Site	Original DHM	SRTM v. 3.0	SRTM / CGIAR
Wishek, USA	100%	99.64%	99.64%
Cronalaght, Ireland	100%	99.87%	99.86%
Ometepe, Nicaragua	100%	99.91%	99.77%

Figure 4: Annual energy yield on selected projects using three different digital elevation models.

2.2.1 Use of the CGIAR Data

The CGIAR data has been generated by not-for-profit institutions with the objective of supplying accessible and useful information to developing country organizations. They actively encourage use of these products for scientific purposes. This is not however the case for commercial purposes. The entire dataset is available for commercial use at a modest cost, but permission must be sought. Commercial sectors interested in using this data should contact Dr. Andy Jarvis (a.jarvis@cgiar.org). This dataset should be cited as follows: Jarvis, A., H.I. Reuter, A. Nelson, E. Guevara, 2008, Hole-filled SRTM for the globe Version 4, available from the CGIAR-CSI SRTM 90m Database: http://srtm.csi.cgiar.org.

Due to these license conditions, we currently do not distribute the CGIAR dataset. However, it you meet the requirements; then please visit the CGIAR website.

2.3 Viewfinder Panoramas DEM

The Viewfinder Panoramas dataset is a digital elevation dataset with focus on the areas outside SRTM coverage, see the Figure 5. Also, the dataset has been focusing on fixing the voids in the SRTM dataset, e.g. by improving the DEM data in mountainous terrains. The dataset is developed by Jonathan de Ferranti and published on his website www.viewfinderpanoramas.org. Raw data are stored in the HGT format, i.e. the same distribution format as the SRTM dataset. Sources for the DEM models are typically Russian military maps in scales 1:100000 and 1:200000, but also other local and global sources are used, see the table below.

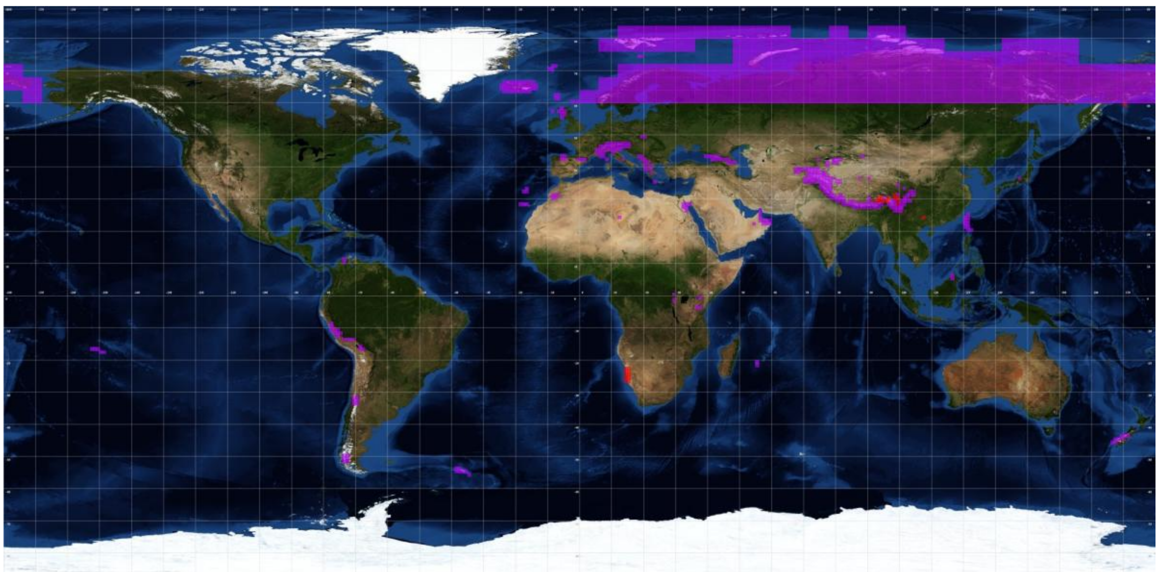


Figure 5: Coverage for the ViewFinder Panoramas Dataset. Please note, in addition to the purple and red regions with coverage; then also Antarctica and Greenland are covered.

The table in Figure 6 summarizes the different regions in the Viewfinder Panoramas dataset, as well as the sources used by Jonathan de Ferranti in developing the models. Please refer to www.viewfinderpanoramas.org for further details.

The dataset is available in WindPRO by courtesy of Jonathan de Ferranti and his website www.viewfinderpanoramas.org.

Dataset Region	Sources
High Asia	SRTM, Russian 1:100000 and 1:200000, Nepal 1:50000 and various other
Andes	SRTM, local 1:50000 and 1:100000 topographical maps
Alps	Local 1:25000 and 1:500000; Russian 1:100000; SRTM (limited use only)
Greenland	1:250000 and 1:500000 topographical maps of Greenland. There is some input from a 1:100000 map of the Gunnbjorn area, and from SRTM data south of 60°21' of latitude.
North Eurasia, including Scandinavia and Siberia	Russian 1:100000 and 1:200000, 1:50000 topographical maps of Norwegian Jotunheimen, More and Romsdal. There is some input from SRTM for Finland and Russia south of 60°21'; otherwise these data are wholly from topographic maps.
North Atlantic, including Iceland, Faeroes and Shetland	Russian 1:100000 and 1:200000; 1:100000 topographical maps of Iceland and Svalbard
Other Europe	Varies: Russian 1:50000, 1:100000, 1:200000; more detailed topographical maps locally, SRTM
Africa	SRTM, local maps, photographs, Russian 1:100000,
Antarctica	200m DEM from Radarsat Antarctic Mapping Project Digital Elevation Model Version 2 (NSIDC). The data was re-sampled to 3".
Others	Varies: SRTM, Landsat, Russian 1:100000 1:200000, Local maps 1:25000 1:50000 1:100000 1:250000,

Figure 6: Data Sources in the Viewfinder Panoramas dataset.

2.4 Aster GDEM

The Aster Global Digital Elevation Model is a joint US and Japanese effort. It is based on data from sensors on board on the NASA Terra satellite launched in 1999. The first release of the Aster GDEM dataset was in June 2009. It has a 30 m resolution with a 99% global coverage. However, the current version of the dataset is marked as 'research grade', and is reported to contain serious artifacts and spikes. Currently, the dataset is not included with WindPRO, but you may choose to manually download the source DEM's and then import it into WindPRO. You may download the data from the Aster GDEM site at:

http://www.gdem.aster.ersdac.or.jp

3. Digital Roughness Models (DRM)

The digital roughness models in WindPRO are based on open internet resources, all providing estimates of the roughness lengths or roughness classes based on remote sensing sources.

Note, that these sources - when considering wind energy applications - are typically not sufficient for a detailed and accurate roughness classification of a site. However, they may prove helpful for an initial analysis and as support for a more detailed analysis. Especially, the roughness levels assigned to the digitized areas need to be verified and normally needs adjustments by the user.

3.1 Modis VCF

The Modis VCF (Vegetation Continuous Fields) data holds a global 500 x 500 m resolution dataset on the vegetation cover. The dataset consists of three files: Percent trees, bare ground and herbaceous vegetation. WindPRO online data service converts these three files into a roughness classification legend. The Modis VCF is an annual representation of the period November 2000 to November 2001. The coverage is near global. Only Antarctica and the polar region above 80 degrees north is missing. Please note that this roughness classification is based on a vegetation index only. Thus, urban areas must be added manually. In addition, the conversion from vegetation cover to roughness classification is still experimental only.

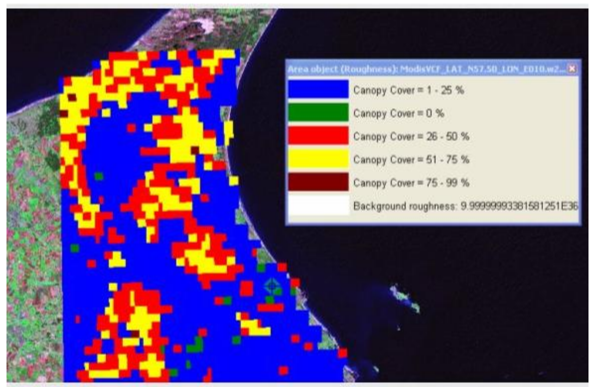


Figure 1: Modis VCF Data for the North-Eastern Part of Jutland, Denmark.

An overview is of the EMD legend is shown in the table below. This legend is created by using a simple algorithm for the conversion from canopy cover to roughness class. For now, this algorithm is a simple linear relationship – a function of the canopy cover only. At a later stage, this algorithm may be improved by adding dependencies on herbaceous vegetation and bare ground percentages.

Description / Label	Height	Roughness Length	Roughness Class
Inland water or ocean	0 m	0.0005 m	0.20
Canopy Cover: 0%	0.0 m	0.0320 m	1.20
Canopy Cover: 1% – 25 %	2.5 m	0.0100 m	2.00
Canopy Cover: 26% - 50%	5.0 m	0.3031 m	2.80
Canopy Cover: 51% - 75%	7.5 m	0.4000 m	3.00
Canopy Cover: 76% - 100%	10.0 m	0.5278 m	3.20
Bad data	0.0 m	N/A	N/A

Figure 2: Interpretation of MODIS VCF Input Data in WindPRO 2.7

In the case that you are using this dataset near oceans, please make sure that you manually convert the roughness classes for the water areas from roughness class 0.2 to 0.0, as the WAsP model then will use a more appropriate stability model.

The WindPRO version 2.7 interpretation is shown in Figure 2. Please note that the interpretation has changed since the version 2.6; now slightly higher roughness classes are assumed for lower values of the canopy cover. However, based on even more recent experiences, the 76-100% canopy cover interval should probably be increased to class 3.5 – 4.0, with an additional increase for the lower intervals also. Please do consider such experiences when you use this dataset, and remember to apply a proper screening and calibration of the data for your particular purposes.

Acknowledgement**:** Source for this data set was the Global Land Cover Facility, www.landcover.org.

3.2 DataForWind

The DataForWind roughness data is a European 200 x 200 m roughness contour dataset with coverage between 31°N - 72°N and 11°W - 32°E. Please note, that most European countries are covered with the exception of Norway and Sweden, see the Figure 4.

Our data holdings are based on an extract from www.dataforwind.com web site [2]. This dataset is further processed and ready to be used in WindPRO directly as roughness areas.

Acknowledgement**:** Source of this data set is DataForWind, www.dataforwind.com. Note, that you may also download the data directly from the www.dataforwind.com web site: In this case you will have to use the importer facilities in the WindPRO area object.

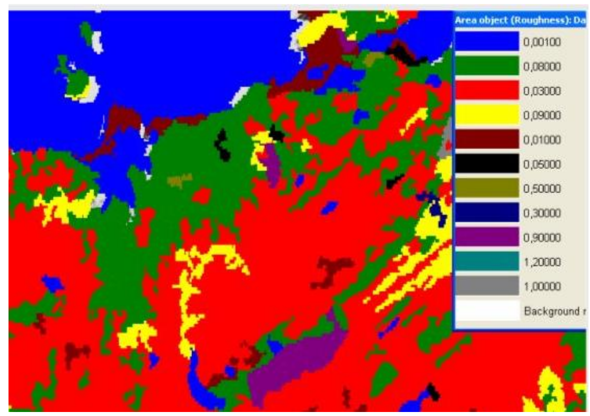


Figure 3: An Irish Site: WindPRO Roughness data in 200x200 m grid originating from DataForWind.

Figure 4: Coverage of the DataForWind Dataset.

A sample of the classes in Data4Wind dataset legend is shown in the Figure 5. As you see, the legend is holding the roughness length (m) as well as the roughness class. Be aware of the class 1.8-1.9. This is “open land” for the summer data set. These two layers are typically merged and given the “annual average open land roughness”, which can be anything from class 1 to class 3, depending on how the open land are in the region of consideration. In some regions in Denmark as example, there are many wind breaks, making the roughness close to class 3, while in other regions the open land are large open fields just with grass, and thereby close to class 1.

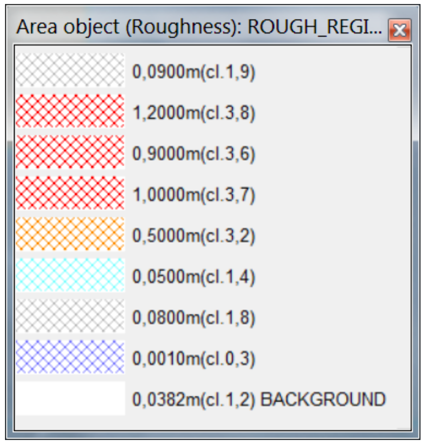


Figure 5: Sample legend for the DataForWind Dataset.

3.2.1 Known Issues

When using the DataForWind data in the eastern part of Europe, we have found that data may be misaligned when comparing to maps and other data sources. You may need to adjust the positioning of the data some hundred meters. This may be done directly by invoking the ‘EMD Editor’ connected to an Area Object. Use the “Transform” option, which enables you to directly use an arrow to “push” the data to the right map location.

3.3 Global Land Cover Characteristics (GLCC)

This dataset has a global coverage. It is based on a 1 km x 1 km grid, so note that such a resolution is to coarse for Micro scale AEP calculation models! This data is the version 2.0 of the global land cover characteristics data base, see the USGS web site [1].

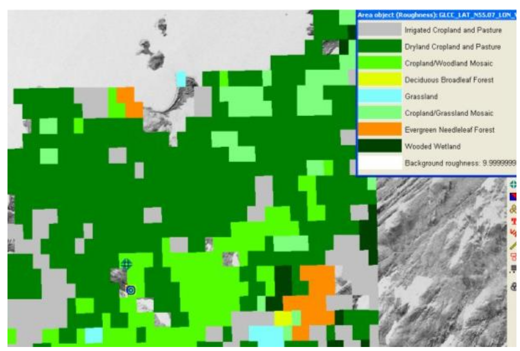


Figure 6: Global Land Cover Roughness Data.

Initially, the dataset was developed for land cover characterization in the range of environmental research and modelling applications. It is derived from the Advanced Very High Resolution Radiometer (AVHRR) data spanning a 12 month period from April 1992 to March 1993. The ACHHR is a space-borne sensor mounted on the National Oceanic and Atmospheric Administration (NOAA) family of polar orbiting platforms.

Various legends exist for this dataset. At EMD, we use the legend from the US Geological Survey, see Table 1. In addition to the legend, we also suggested a roughness length. This length is shown in parenthesis in Table 1.

1: Urban and Built-Up Land (z_0=0.400)	13: Evergreen Broadleaf Forest (z_0=0.500)
2: Dryland Cropland and Pasture (z_0=0.100)	14: Evergreen Needleleaf Forest (z_0=0.500)
3: Irrigated Cropland and Pasture (z_0=0.100)	15: Mixed Forest (z_0=0.400)
4: Mixed Dryland/Irrigated Cropland and Pasture (z_0=0.100)	16: Water Bodies (z_0=0.0002)
5: Cropland/Grassland Mosaic (z_0=0.070)	17: Herbaceous Wetland (z_0=0.030)
6: Cropland/Woodland Mosaic (z_0=0.150)	18: Wooded Wetland (z_0=0.100)
7: Grassland (z_0=0.050)	19: Barren or Sparsely Vegetated (z_0=0.02)
8: Shrubland (z_0=0.070)	20: Herbaceous Tundra (z_0=0.050)
9: Mixed Shrubland/Grassland (z_0=0.060)	21: Wooded Tundra (z_0=0.150)
10: Savanna (z_0=0.070)	22: Mixed Tundra (z_0=0.100)
11: Deciduous Broadleaf Forest (z_0=0.400)	23: Bare Ground Tundra (z_0=0.030)
12: Deciduous Needleleaf Forest (z_0=0.400)	24: Snow or Ice (z_0=0.001)

Table 1: USGS Legend for the GLCC Data with Roughness Classification Data.

3.4 References

[1] Global Land Cover Characteristics Data Base Version 2.0, http://edcsns17.cr.usgs.gov/glcc/tabgeo_globe.html
[2] DataForWind web site at www.dataforwind.com.
[3] Hansen, M., R. DeFries, J.R. Townshend, M. Carroll, C. Dimiceli, and R. Sohlberg, Vegetation Continuous Fields MOD44B, University of Maryland. Web: http://glcf.umiacs.umd.edu/data/vcf/

4. Digital Map Models (DMM)

4.1 Introduction

Several free and commercial sources of relatively high-resolution satellite images are now available on the Internet. These images come in resolutions down to approximately 15-30 meters per pixel, thus opening for the possibility to identify details as large roads and houses. In WindPRO these photos may be used as background maps and as nice textures for virtual reality presentations (3D animator).

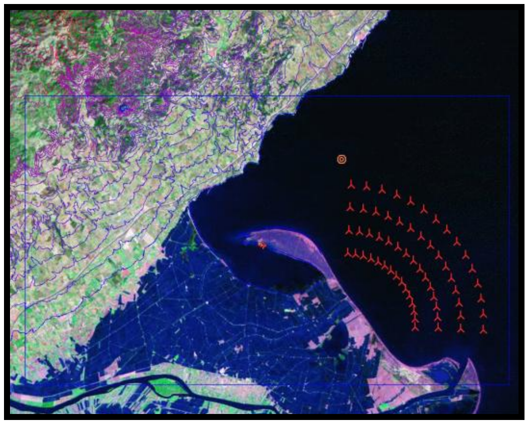


Figure 1: GeoCover Map in WindPRO.

4.2 Satellite Imaging and Remote Sensing

Many of the free satellite photos come from the Landsat Series of Satellites, where the images of an area are not recorded in true colors. The satellite carries a camera instrument that records images of the Earth using different filters (wave lengths). The Landsat TM (thematic mapper) instrument on Landsat 5 used seven different bands, each sensible to the different parts of the reflected solar energy. It is possible to convert individual bands into either true color pictures or artificial (false) colour pictures. The option of using artificial color pictures are widely used within the field of remote sensing, when studying e.g. changes in global vegetation, pollution etc.

4.3 GeoCover Dataset

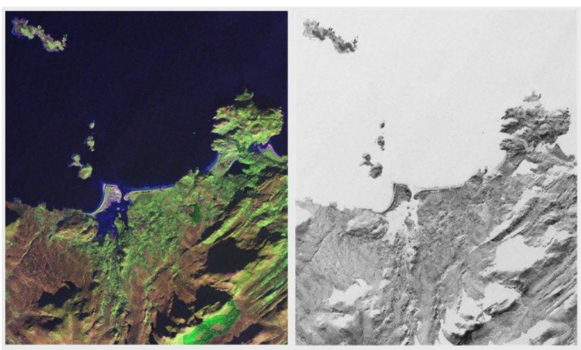


Figure 2: GeoCover Data - Site in Ireland

These satellite images are based on the US GeoCover database. The image is a mosaic based on data from three spectral bands from the Landsat TM mission: The mid-infrared light which is displayed as red (Band 7), a near-infrared light which is displayed as green (Band 4) and visible green light (band 2) which is displayed as blue. Note, that these data covers most of the globe except Antarctica.

You may find more information about this dataset at the following internet addresses:

https://zulu.ssc.nasa.gov/mrsid/ or
http://glcf.umiacs.umd.edu/data/landsat/.

The maximal spatial resolution is 14.25 m per pixel. Most data is from the period 1997-2003.

4.4 Open Street Map

Open Street Map is an open and editable map. It has a global coverage, and is edited by a community effort. Samples of two selected places in Denmark and Austria are shown in Figure 3. Please visit the project homepage in order to learn more and also how to contribute to build an even better map. The project is located at the following URL:

http://www.openstreetmap.org

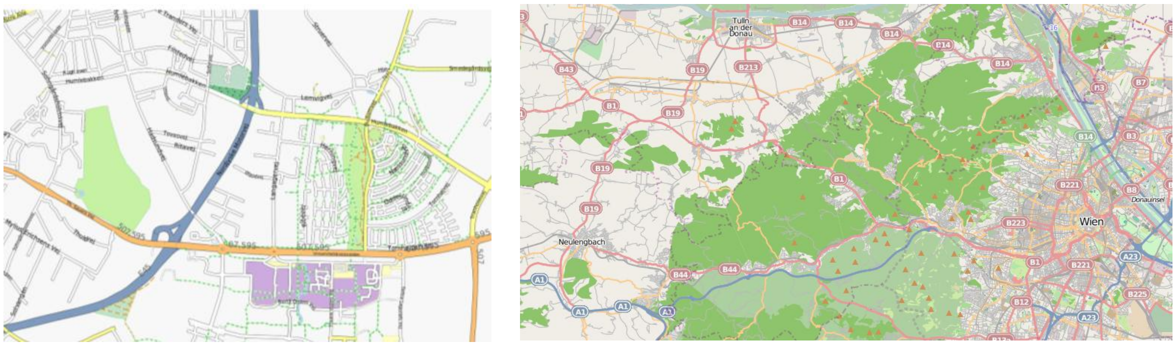


Figure 3: Samples of Open Street Map (left: Part of Aalborg, Denmark, right: Part of Vienna, Austria)

4.5 Other Datasets

EMD is currently investigating the option of including other datasets into our DMM service.

5. Wind Data

5.1 Introduction

A number of reanalysis projects exists which combine environmental measurements and climate modeling. These model data have proven valuable as sources for long term correction of local wind data. In WindPRO we offer an easy access to some of these datasets through our online-services, where it is possible to load these wind data directly into a Meteo Object.

The datasets typically originate from general climate modeling projects, thus offering a wide range of climate variables. Typically we limit our service to distribute only the wind and temperature data.

Figure 1: Wind Speeds: Local data (purple), NARR data (red) and NCEP/NCAR (green).

In 2010 - with the release of the WindPRO 2.7 - we have included also our wind data service to hold real measurements. These datasets are the METAR (airport data) and SYNOP (weather stations) data.

5.2 NCEP / NCAR Global Reanalysis Data (also named NNGR data)

Data from the NCEP/NCAR reanalysis project is currently available to users of WindPRO as part of the on-line services from the EMD server. A connection to the internet is thus required. Users may download updated data from the present moment (typically the preceding month) back until 1948. The sub-set of the NCEP/NCAR Global Reanalysis Data that we hold at EMD is updated on a monthly to bi-monthly update cycle.

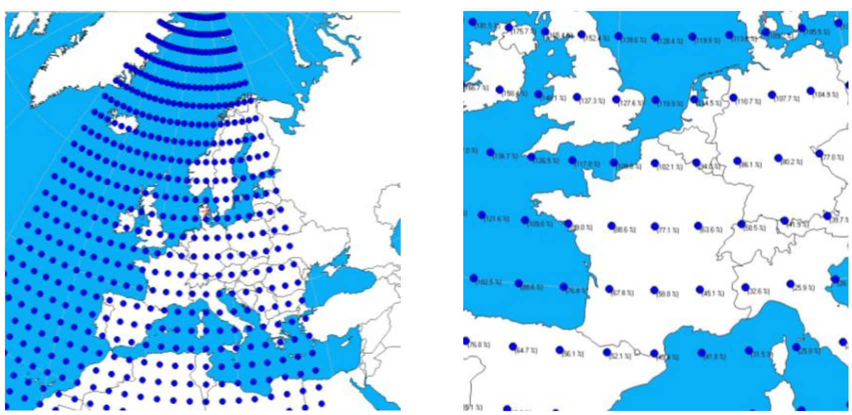


Figure 2: NCEP/NCAR Global Reanalysis Data Nodes:
Left = Nodes Covering Western Europe. Right = Nodes Covering France.

5.2.1 Data Description

The NCEP/NCAR model dataset is immense, containing a very wide range of descriptive atmospheric model data. The actual measured climate data sources used in the global reanalysis model are:

- Upperair rawinsonde observations of temperature, horizontal wind, and specific humidity (i.e. weather balloons)
- Operational Television Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS) vertical temperature soundings from NOAA polar orbiters over ocean, with microwave retrievals excluded between 20°N and 20°S due to rain contamination

- TOVS temperature soundings over land only above 100 hPa
- Cloud-tracked winds from geostationary satellites
- Aircraft observations of wind and temperature
- Land surface reports of surface pressure
- Oceanic reports of surface pressure, temperature, horizontal wind, and specific humidity

These data are used as input into a frozen global assimilation system and processed by a spectral model in order to provide the model output of the variables in the grid.

5.2.2 NCEP/NCAR Global Reanalysis Dataset At EMD

At this time of writing, currently two types of NCEP/NCAR modeled wind data are available from the EMD server. Both types of data are distributed through the NCAR_Basic dataset from the EMD server. The raw data are processed by EMD as the original data holds the vector components for the wind speeds only (U and V – winds). We convert the raw data into a format appropriate for use with wind turbine applications, i.e. wind speed and direction instead.

Name	Surface Data
Abbreviation	srf
External URL	http://www.cdc.noaa.gov/cdc/data.ncep.reanalysis.surface.html
Data valid at time	Instantaneous values at the reference time
Referred to as	“Wind" at level "sig995" under main title "Surface"
Level	99.5% of surface pressure (approximately 42m a.g.l. for standard atmosphere conditions)
Grid	2.5 degree latitude x 2.5 degree longitude global grid (144x73)
Columns in data-file	srf.dir.2 = Wind Direction at sigma level 0.995, i.e. 42 m a.g.l srf.wsp.2 = Wind Speed at sigma level 0.995, i.e. 42 m a.g.l gl.tmp.2 = Temperature at sigma level 0.995, i.e. at 42 m a.g.l

Name	10 m Data
Abbreviation	u10
External URL	http://www.cdc.noaa.gov/cdc/data.ncep.reanalysis.surfaceflux.html
Data valid at time	Forecasts valid 6 hours after the reference time
Referred to as	"Wind at 10m" at level: "surface" under main title "Surface Fluxes"
Level	10 m above ground
Grid	T62 Gaussian grid with 192x94 points
Columns in data-file	u10.dir.10 = Forecast of Wind Direction at 10 m a.g.l u10.wsp.10 = Forecast of Wind Direction at 10 m a.g.l

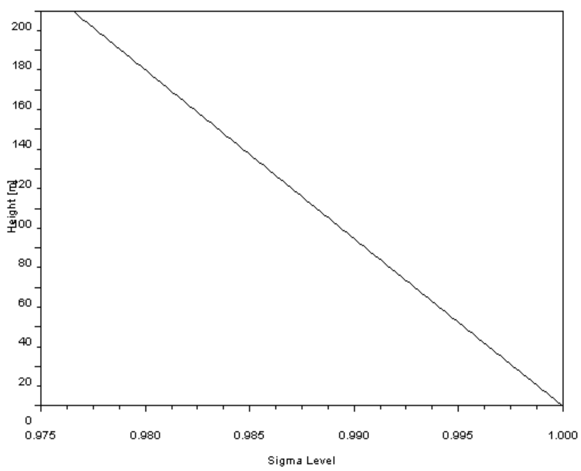
You may learn more about these data by visiting the NCEP / NCAR web site holding the data at the URL http://www.cdc.noaa.gov [1] or by reading the paper Kistler et al. (2001) published in Bulletin of the American Meteorological Society[2] (available for free at: www.atmos.umd.edu/~ekalnay/Kistleretal.pdf). Although the NCEP/NCAR data are simulations giving the “instantaneous values” every 6 hours, these are based on model simulation and there will be some “smoothening” compared to real measurements. We therefore recommend seeing the data as 10 min average values, although this is not specified as so in the documentation.

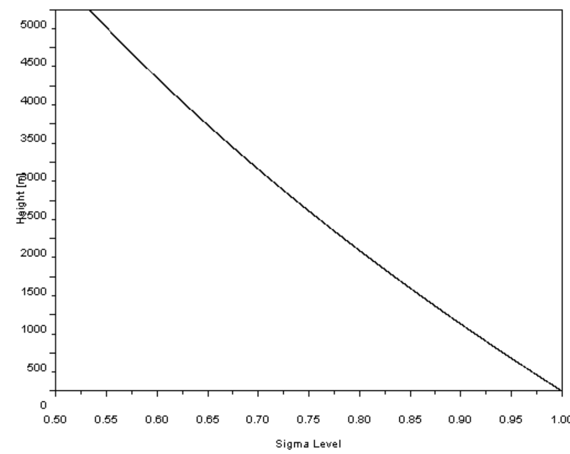
5.2.3 Converting Sigma Levels Coordinates into Physical Heights

Many of the NCEP / NCAR datasets are actually (internally) reported using sigma level coordinates. By definition, the sigma coordinate is the pressure at the current vertical level divided by the surface pressure level:

$$\sigma = \frac{\text{pressure}}{\text{pressure at surface}}$$

Using the definition above, as well as the US standard atmosphere model (see the WindPRO manual on Air Density Adjustments); it is possible to relate the sigma level coordinate to the physical height (by the assumption of the standard atmosphere parameters). This is shown in the figures below.





The 0.995 sigma level coordinate is used in many of the ‘surface’ NCEP/NCAR datasets. This coordinate corresponds to a physical height equal to 42.2 m.

5.2.4 Some EMD Experience on Using the NCEP/NCAR Reanalysis Data

For long term correction of local measurements, the 10m forecast data or the surface data give the best correlation. An additional upper air pressure level data set also exists, but has not been distributed via the EMD server. Our experience shows that the pressure level data does not seem to be quite as useful for long term correction purposes, but might be usable as input for meso scale models.

Data seem best applicable in colder climates, where the wind systems mainly are pressure driven at the synoptic scale. In warmer regions (southern Europe and further south), the data does not seem to adequately account for the temperature driven wind systems, and can therefore differ quite much from local measurements – but still reasonable correlations can be found for some regions and by scaling properly, the data might also be useful in these regions.

We recommend using the wind index method when performing long term correction with NCAR data – the frequency and direction distribution are often not good enough to allow the use of the other methods.

Be aware of that the energy level based on only 1 year local data can be as much as 10% off – this is what numerous analyses, mainly in Northern Europe show. Having 3 years of local data the energy level probably will be up to 5% off.

Also be aware of that the source for the NCEP/NCAR data is changing over time, so the older part of the data might be quite poor quality. Therefore we do normally not recommend to use data older than 1960 – and often you might not go further back than 1978. For Northern Europe, where the wind climate is heavily affected by the North Atlantic Oscillation (NAO Index [3]), you should go back to around 1961 to get a reasonable representative long term data period, holding as well low as high wind climate periods, see figure. Using like 1985-2005 for sure will provide too high long term reference level – if history repeat, but nobody does know how the wind will be the next 20 year!

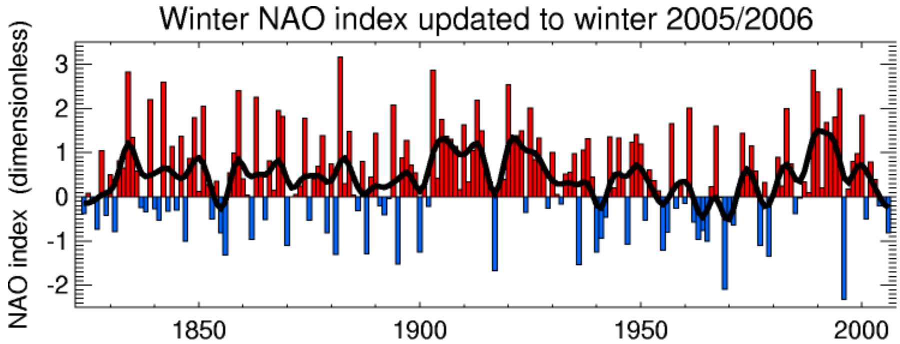


Figure 3: NAO Index.

5.2.5 A Note about NCEP / NCAR Reanalysis Node Positions in WindPRO

As the default behavior when online wind data is loaded into the WindPRO meteo object, the object will automatically be moved to the position of the data referring to the (in case of the NCEP/NCAR data the position of the 2.5 by 2.5 degrees data node). This means that in principle the "10m" data in the meteo is shown at a slightly wrong position – as these data are given on a Gaussian grid - which is also indicated in the header of the data file downloaded from the EMD on-line server. However, firstly this position error for the "10m" data should be small as the two grids are not very different and secondly EMD does not recommend the use of NCEP/NCAR for any purposes where the exact position is critical. The main purpose of NCEP/NCAR global reanalysis data is still long-term correction, where the position of the grid point only plays a role for selecting the relevant model data. The position of the grid nodes for the data used are given in the file header provided by the EMD server. The time stamps for the 10 m data – which is actually forecast values of wind speeds and directions – are automatically adjusted in the Meteo Object so they match actual time of the forecast, i.e. the values refer to the time of the forecast (original time stamp is added 6 hours).

5.3 NCEP North American Regional Reanalysis Data (NARR)

The NCEP North American Regional Reanalysis Data is a high resolution high frequency assimilated dataset covering the North American region. The model area is shown in Figure 4. The spatial resolution is 32.4 km, resulting in a total of 96673 nodes covering the area. The temporal resolution is 3 hours. The dataset covers a period from 1979 until the present moment. The dataset assimilates data from rawinsondes, dropsondes, pibals, aircraft, selected surface stations and geostationary satellites [4]. For a detailed overview of the NARR model, please refer to the paper by F. Mesinger et al [5]. The paper may be located at the following URL: http://www.emc.ncep.noaa.gov/mmb/rreanl/.

The full dataset consists of more than 400 climate variables which – when stored in NetCDF files – require storage of about 30 Terra Bytes. At EMD we hold and distribute a subset of the NARR data. The raw data is processed by EMD as the original data holds the vector components for the wind speeds only (U and V – winds). We convert the raw data into a format appropriate for use with wind turbine applications, i.e. wind speed and direction instead.

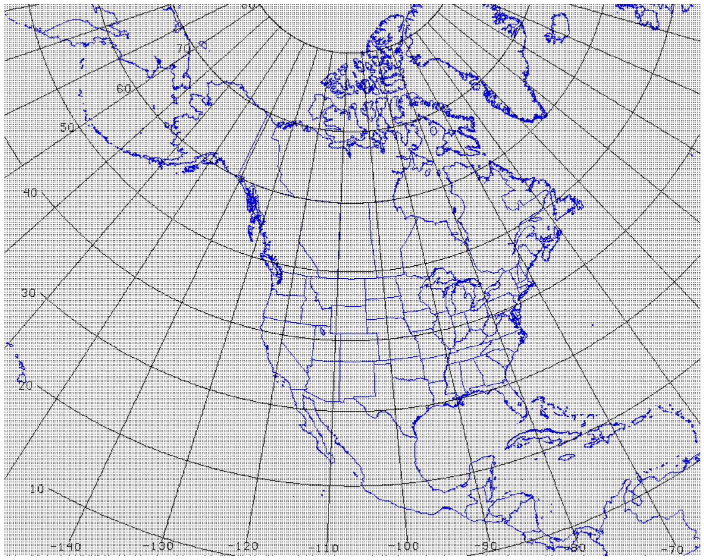


Figure 4: The NCEP 221 Grid used in the NARR model.

5.3.1 The NARR Dataset at EMD

The NARR dataset at EMD currently holds 10 m and 30 m wind speeds as well as 2 m temperature data. An overview of the data is given in the tables below. Please refer to these tables when interpreting the headers in the files received from the EMD server.

Name	10 m and 30 m wind data
Abbreviation	u10 = 10 minute averaged wind speeds,
External URL	http://www.emc.ncep.noaa.gov/mmb/rreanl/
Data valid at time	Data valid at the analysis/reference time
Referred to as	"Wind" at level: "10 m above ground level" or "30 m above ground level"
Level	10 m above ground
Grid	Regional - NOAMHI - High Resolution North American Master Grid
	Lambert Conformal with 349 x 277 nodes
Columns in data-file	u10.dir.10 = Wind Direction at 10 m a.g.l
	u10.wsp.10 = Wind Direction at 10 m a.g.l
	u10.dir.30 = Wind Direction at 30 m a.g.l
	u10.wsp.30 = Wind Direction at 30 m a.g.l

Name	2 m temperature data
Abbreviation	tmp = temperature
External URL	http://www.emc.ncep.noaa.gov/mmb/rreanl/
Data valid at time	Data valid at the analysis/reference time
Referred to as	"temperature" at level: "surface" under main title "Surface Fluxes"
Level	10 m above ground
Grid	Regional - NOAMHI - High Resolution North American Master Grid
	Lambert Conformal with 349 x 277 nodes
Columns in data-file	tmp.2 = Temperature at 2 m a.g.l. (in degrees Celsius)

5.3.2 NARR Sample Data at Fargo, ND

In Figure 5 data from the NARR dataset is compared with local data from a 30 m sensor mounted on a local mast in Fargo, ND. Also shown is the NCEP/NCAR Reanalysis Data with its 6 hour temporal resolution.

The NARR node is located about 16 km from the local mast; while the NCAR Reanalysis node is located approximately 90 km from the site. It seems obvious, that the NARR is an improvement relative to the NCAR Reanalysis data – due to its increased accuracy and improved temporal and spatial resolution. An MCP analysis shows that the 'Weighted mean of sector-wise correlation' is about 0.75 for the NARR dataset versus the local data; while the value is 0.68 for the NCAR Reanalysis data versus the local data.

Figure 5: 30 m Wind speeds from the NARR dataset (green line) compared with local data (red line) and the NCEP/NCAR Reanalysis Data (purple) at Fargo, North Dakota, USA.

5.3.3 Known Issues

The NCEP NARR internet homepage "Regional Reanalysis Questions and Answers" [6] has reported an issue when using the 30 m wind data around coastlines. The issue occurs at coastlines with a non-negligible topography. Currently we recommend using the 10 m data at such places. Note that points over land are not affected (if the neighboring nodes have topography above the sea level). Please refer to reference [6] for detailed information about this issue. When considering nodes 'close' to the boundaries of the model, then the variables will be heavily affected by the boundary conditions. Please validate the NARR data thoroughly against local measurements when you are near the model boundaries.

Important Note: An issue has been reported for the NARR data when using it for long term correction purposes. A step change in the wind speeds seem to occur in the NARR data around 2002, see the Figure 6. The figure originates from a presentation at the US wind resource assessment workshop by Justin Sharp, Iberdrola Renewables, USA [8]. The WindPRO team at EMD has performed its own investigations find similar step change. This means that the NARR data only should be used from 2002 and onwards unless the possible step change is handled!

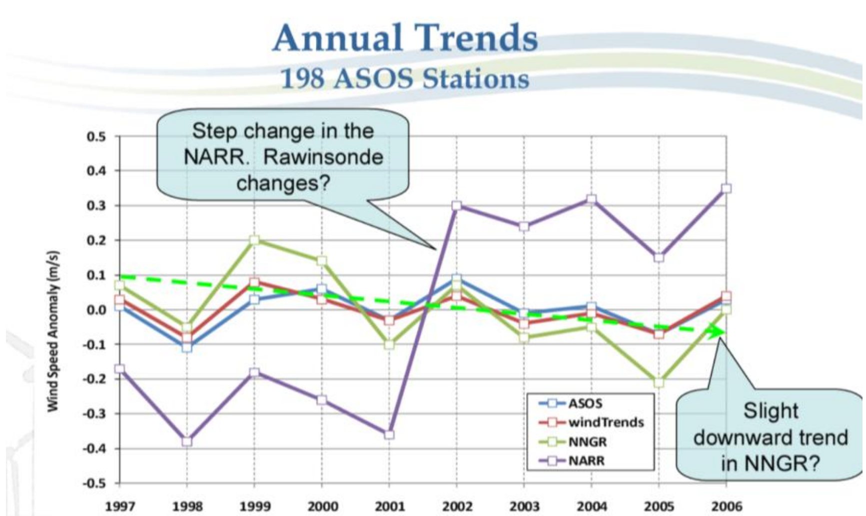


Figure 6: Annual Trends of NARR and Other Datasets.

5.4 QuikScat Offshore Wind Dataset

QuikScat is an offshore wind dataset based on remote sensing from a satellite instrument.

> Discontinued Dataset!
>
> The rotating antenna on the QuikScat satellite malfunctioned by the end of November 2009. While the satellite was designed with an expected lifetime of 5 years, it actually was in operation in 10 years. Currently, there are no plans of a replacement satellite, but at EMD we are investigating the option of a replacement dataset.

The QuikScat wind data are derived from a remote sensing microwave scatterometer that is mounted on the QuikScat satellite; the satellite was launched in June 1999. The scatterometer is a special type of radar that is used to analyze the roughness of the sea. This fine scale roughness is highly correlated to near-surface winds and directions – and as such it is possible to infer the wind conditions based on the scatterometer data.

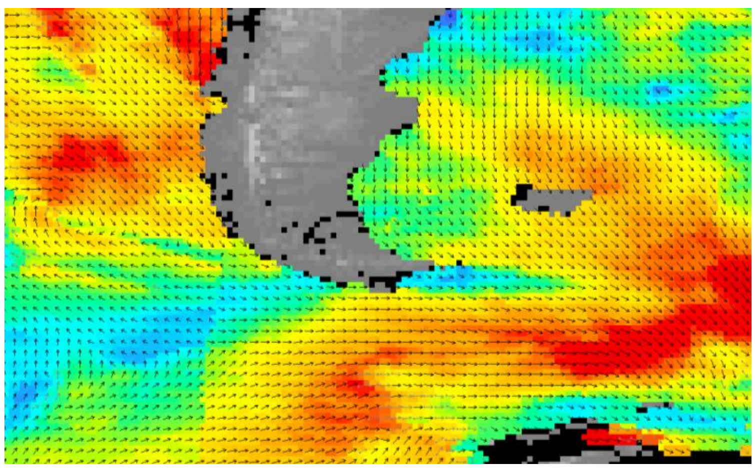


Figure 7: QuikScat Map of Wind Speeds and Direction in the Cape Horn Region.

The QuikScat dataset at EMD currently holds 10 meter wind speed derived from the fine scale surface roughness of the sea surface. According to the documentation on the QuikScat data, the wind corresponds to an 8-10 minute averaged wind speed [7]. The temporal coverage is at maximum 2 times a day, but with a number of gaps with data missing due to problems, such as the instrument being turned off. The spatial coverage is near global for sea areas with a resolution of 0.25 degrees. The spatial coverage is shown in Figure 8.

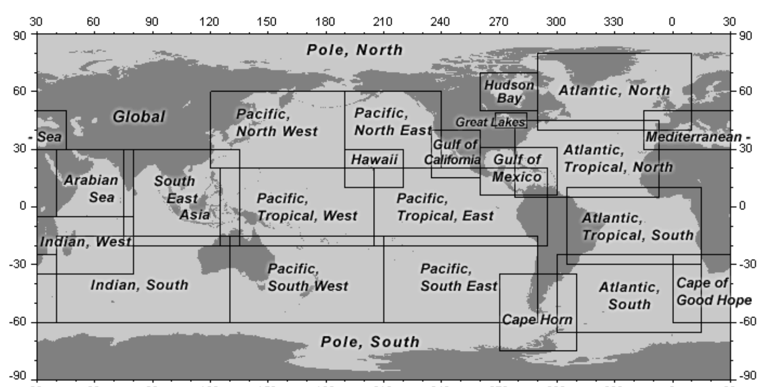


Figure 8: Spatial Coverage of the QuikScat Dataset.

The accuracy of this method is decreased during rain events or during sea-ice events. When receiving the data from WindPRO, then all data is enabled as default. If you do not want do use the wind data that occurs during rain events, then you will manually have to disable those data. The data files received from WindPRO holds an extra column named 'rain_flag'; this column is easily applied for this purpose (but it is a manual operation!).

Name	10 m wind data
Abbreviation	u10 = 8-10 minute averaged wind speeds,
External URL	http://www.ssmi.com/qscat/
Data valid at time	Data valid at the reference time
Level	10 m above ground
Grid	0.25 degree latitude – longitude grid
	Near global coverage for sea areas
Columns in data-file	wsp.10= Wind Speed at 10 m a.g.l
	dir.10 = Wind Direction at 10 m a.g.l

Figure 9: QuikScat data (purple), NARR data (red) and NCEP/NCAR Reanalysis Data (green) on an offshore position of the coast of San Francisco, USA.

5.5 METAR Data

The NCEP ADP METAR (Aviation Routine Weather Report) dataset is based on measurements from various airports and permanent weather observation stations around the globe. Currently, about 5000 stations are included in this global dataset. An example of the spatial coverage is shown in the Figure 10 for the available stations near Tasmania, Australia. The purpose of the METARs is to provide guidance for pilots and the aviation industry, however some stations may also provide useful for the wind energy industry as reports of wind speed, wind directions and temperature are available, see the sample in Figure 10.

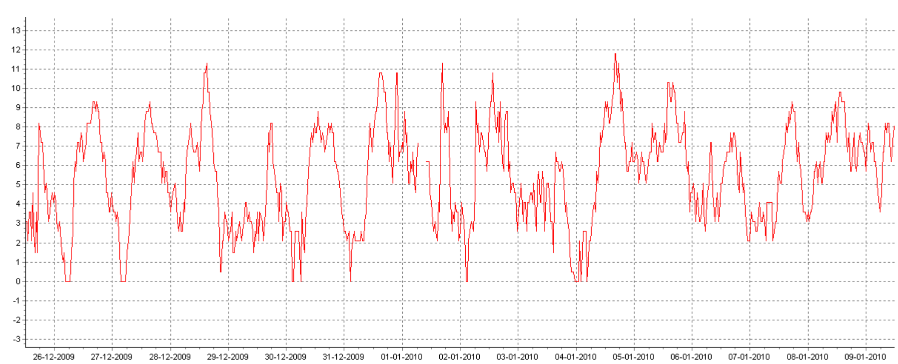


Figure 10: METAR data from the Launceston Airport in Australia.
This airport provides data every 30 minutes.

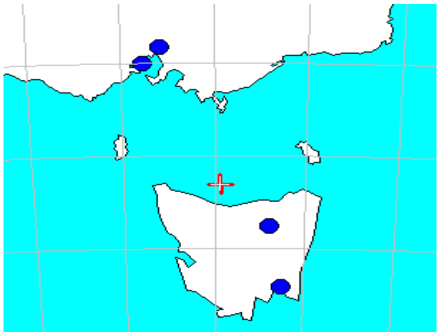


Figure 11: Dataset Coverage of METAR Stations near Tasmania, Australia.

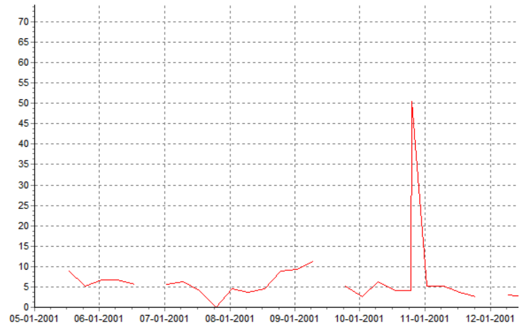


Figure 12: Spike in METAR Wind Report for the Mount Sant'Angelo Station.

When applying this dataset, please consider the following issues:

1) The reporting frequency varies: Some stations report a few days per year, others only during daytime hours, while others report continuously with 10, 30 minute or hourly intervals.
2) The position of the station may be uncertain. Typically latitude and longitude is only reported with an accuracy of two decimals (with position in decimal degrees).
3) The height of the meteorological mast is uncertain, often 5, 10 or 30 meter masts are used; however the standard is 10 meters.
4) Since an automated data collection procedure is used at NCAR; then errors may occur in data (such as spikes, see the figure above) and position encoding.

Please take proper care to validate the METAR data against local measurements and to validate the position against local maps. This dataset is processed by EMD and originates from the NCAR website. For further information about the METAR sites, please consider investigating the online resource at:

http://weather.gladstonefamily.net/site

If you enter the four digit ICAO airport code, you may see additional information about the airport of consideration. You can find the airport code in the source files header in the WindPRO meteo object.

Acknowledgement: The METAR data are from the Research Data Archive (RDA) which is maintained by the Computational and Information Systems Laboratory (CISL) at the National Center for Atmospheric Research (NCAR). NCAR is sponsored by the National Science Foundation (NSF). The original data are available from the RDA (http://dss.ucar.edu) in dataset number ds461.0.

5.6 SYNOP Data

This NCEP ADP SYNOP (surface synoptic observation) dataset is based on measurements from manned and automated weather stations around the globe. Currently, about 7000 stations are included in this global dataset; see a subset of the stations around the North Sea in Figure 13. The purpose of the SYNOP data is to provide input to weather reports and numerical models. However, some stations may also provide useful for the wind energy industry as reports of wind speed, wind directions and temperature are available. As in the case of a METAR dataset, when applying this dataset, please consider the following issues:

1) The reporting frequency varies: Some stations report a few days per year, others only during daytime hours, while others report continuously with 10, 30 minute or hourly intervals.
2) The position of the station may be uncertain. Typically latitude and longitude is only reported with an accuracy of two decimals (with position in decimal degrees).
3) The height of the meteorological mast is uncertain, often 5, 10 or 30 meter masts are used; however the standard is 10 meters.

4) Since an automated data collection procedure is used at NCAR; then errors may occur in data and position encoding. Please take care to validate this SYNOP dataset against local measurements and the position against local maps.

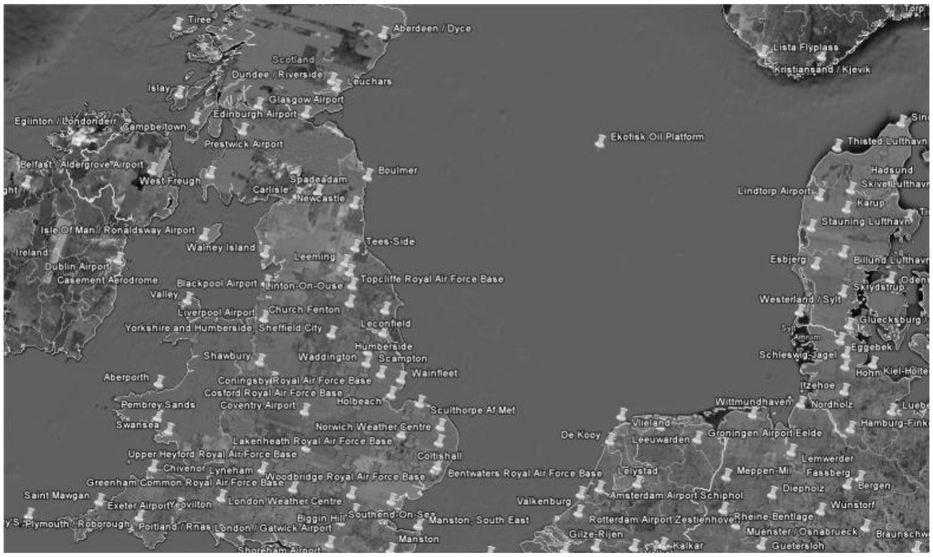


Figure 13: Dataset Coverage of SYNOP Stations around the North Sea.

Important note: An issue has been reported for the SYNOP stations in 2001 and 2002, where data seem to have wind speeds about the double of what is expected. This issue is caused by the station not reporting in the correct unit (such as m/s or knots). Please take care to evaluate the data before applying it in tasks such as long term correction. As an example, see the sample in Figure 14 from Cape Grim, Australia, where this error occurs from February 1st 2001 until June 12th 2002.

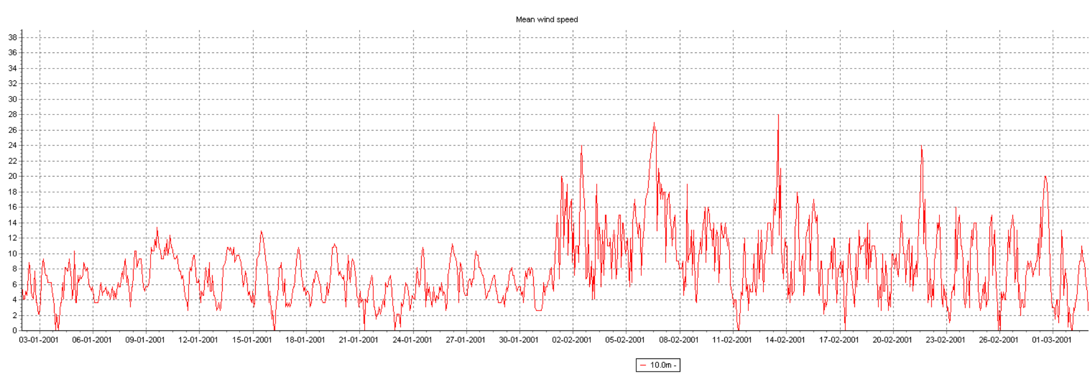


Figure 14: Double Wind Speed Data (Erroneous Data) in SYNOP dataset.

Acknowledgement: The data for this study are from the Research Data Archive (RDA) which is maintained by the Computational and Information Systems Laboratory (CISL) at the National Center for Atmospheric Research (NCAR). NCAR is sponsored by the National Science Foundation (NSF). The original data are available from the RDA (http://dss.ucar.edu) in dataset number ds461.0.

5.7 References

[1] The NCEP Reanalysis data was provided by the NOAA-CIRES Climate Diagnostics Center, Boulder, Colorado, USA, from their Web site at http://www.cdc.noaa.gov/.
[2] Robert Kistler et al: *The NCEP–NCAR 50-Year Reanalysis: Monthly Means CD-ROM and Documentation*, Bulletin of the American Meteorological Society, 2001 (available for free at: www.atmos.umd.edu/~ekalnay/Kistleretal.pdf).
[3] Tim Osborn, North Atlantic Oscillation Index Data (http://www.cru.uea.ac.uk/~timo/projpages/nao_update.htm)
[4] Beth L. Hall & Timothy J. Brown: *Comparison of weather data from the Remote Automated Weather Station network and the North American Regional Reanalysis*, 14th Symposium on Meteorological Observation and Instrumentation, 2007
[5] Fedor Mesinger, Geoff DiMego, Eugenia Kalnay, Kenneth Mitchell, Perry C. Shafran, Wesley Ebisuzaki, Dusan Jovic, Jack Woollen, Eric Rogers, Ernesto H. Berbery, Michael B. Ek, Yun Fan, Robert Grumbine, Wayne Higgins, Hong Li, Ying Lin, Geoff Manikin, David Parrish, and Wei Shi: *North American Regional Reanalysis*, Paper Submitted to the Bulletin of the AMS, 2005
[6] Homepage for *Regional Reanalysis Questions and Answers* at http://www.emc.ncep.noaa.gov/mmb/rreanl/.
[7] *Homepage for the QuikScat data*: http://www.ssmi.com/qscat/.
[8] Presentation, US Wind Resource Workshop Minneapolis 2009: *Long-term Wind Resource Adjustments Using Non-MCP Model Based Methodologies*; Justin Sharp, Iberdrola Renewables, USA

6. Databases on Existing Turbines

6.1 Introduction

Import of existing turbines in a WindPRO project is a strong and convenient feature that allows the user to validate input and results from a number of the models used within WindPRO. Typically, such data can be directly used in environmental calculations, such as the WindPRO modules covering noise, photomontage and shadow calculations. In the case that the database also contains energy production data, the data is a valuable resource for calibration of the associated wind model. In order to utilize data from existing turbines in WindPRO, a turbine database needs to fulfill the following minimum requirements:

1. Positions
2. Turbine Type: Manufacturer and model
3. Rated power
4. Rotor diameter
5. Hub height
6. Manufacturer
7. (Monthly production data)

The #1 - #6 are required for the general application of the database within WindPRO, while the #7 is needed in relation to energy yield estimations.

6.2 Utilizing the Databases on Existing Turbines

Databases on existing turbines are very useful for environmental calculations, where existing turbines might be needed as part of the documentation – and as calibration objects used when setting up the WindPRO camera objects.

In the case that the database contains production yield data (as in case of Existing Danish WTGs, see below), these data are a very valuable resource for calibration of the expected wind conditions. A recalculation of the expected energy yield (using the WindPRO PARK module) by using data from the nearest existing turbines combined with the wind distribution and terrain modeling will provide an answer whether the modeling predicts accurately - or if it needs additional refining and calibration.

In order to access the information on the Wind index Corrected Production (WCP), please right click on an existing turbine in the WindPRO map window. Now open the tab-sheet named "Statistics". Here the production data is shown as well as how many months of data are used when calculating the estimate. You may choose to copy the object data to the clipboard; the numbers for each WTG can be pasted to tools like Excel. This is done by selecting a number of existing turbines in the object list of the WindPRO map window; then right-click and choose *copy object(s)*.

Furthermore, if you have included any existing turbines when you do a PARK calculation, then the WCP is included and compared to the calculated annual energy yield. Here, the “Goodness”-parameter is calculated as the *Actual WCP* divided by the *Calculated AEP*.

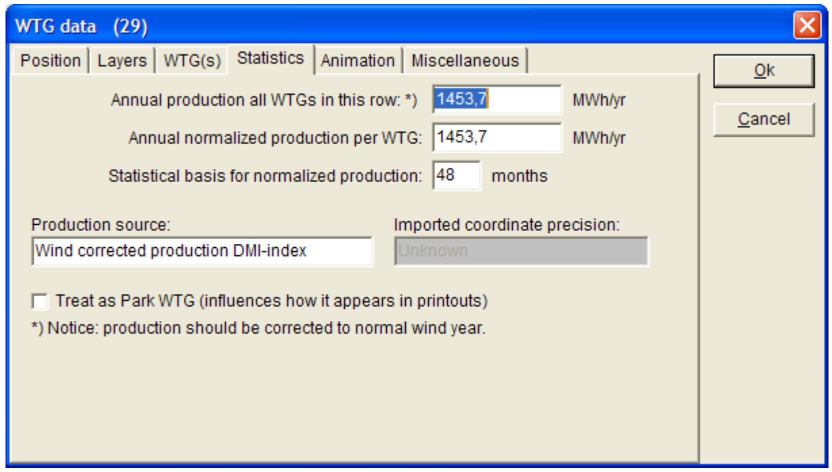


Figure 1: Statistical Information from a Turbine with Actual Production Data.

6.3 Database on Existing Turbines in Denmark

Currently (2010) WindPRO contains a database with data from existing turbines in Denmark. The data for Denmark is derived from a central database maintained by Danish Energy Agency (DEA). The DEA database is based on data delivered by the utilities. The raw database can be found on the homepage of the DEA, see the reference [1].

This dataset is updated typically once a year. The 2009 update of the data contains the following improvements over older data:

- Dataset reflecting the actual conditions as of ultimo 2009: New turbines erected during 2009 have been included; the turbines taken down during 2009 have been excluded/deleted.
- Improved Coordinates: EMD has made a few modifications, where obvious errors are found.
- Wind index corrected production (WCP) is calculated by EMD for all turbines including the recorded production data from 2009.
- EMD has established a link to the WindPRO WTG data catalogue. Now most turbine types are indentified by WindPRO when doing an import.

Please note, that the production source is always the DEA database while the wind index corrected production, WCP, are calculated by EMD using the version 0.6 of the EMD regional wind index. Information on the wind index published by EMD is found at the EMD web-site [2].

6.3.1 Naming Convention for the Existing Danish Turbines

The naming of the existing Danish turbines is generated from the identification number in the DEA database along with the rated power, the manufacturer and the site name. In case the site name is not included in the database, then the municipality name will be used. Examples of the turbine names after import in WindPRO are shown in the Figure 2. A limited number of turbines may be labeled as “not found”; typically because the turbine type have not been identified by the WindPRO wind turbine catalogue.

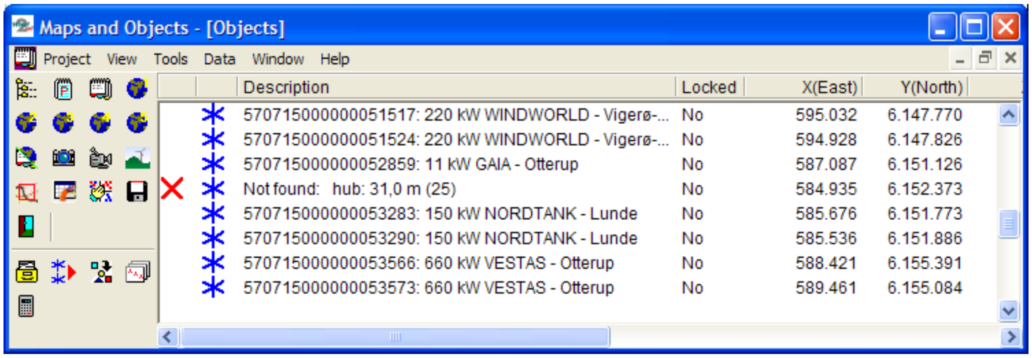


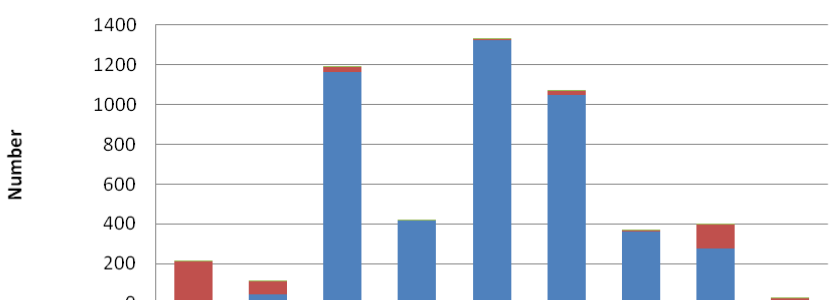
Figure 2: The object list gives the overview after import.

6.3.2 Method for Calculating the Wind Energy Index Corrected Production (WCP)

The expected long term production – WCP - is calculated based on all approved monthly data from January 2002 to December 2009, i.e. a period of a total of 96 months. Each turbine in the database has been subjected to the following approach:

1. Remove erroneous data: In case of months with index corrected production more than 150% above or less than 75% below "simple WCP average of all months", then these months are deleted from the analysis because of assumed data errors or low availability.
2. Turbines that do not deliver directly to the grid have been removed. Some smaller turbines with a rated power less than 25 kW do not deliver their full production to the grid, as they are a part of their owner's installation. For these turbines the WCP is not included. This is caused by the fact, that the DEA database contains only the production delivered to the grid, not including the production, the owner use directly from the turbine. I.e. the database records does not represent full production for these turbines.
3. Now, all approved monthly production data are summed
4. Finally, this sum is divided by the sum of all corresponding wind index for the local region

By following the approach above 1-4, the production data is assumed to be corrected for major events causing loss of availability. Our approach takes into account situations, where a turbine is out of order typically more than 25% of a month.



	0	55	100	300	600	750	1000	2000	3000
Share with	3%	40%	98%	100%	100%	98%	99%	70%	30%
Without WCP	204	68	24	2	2	18	5	118	19
With WCP	7	45	1162	416	1324	1048	361	278	8

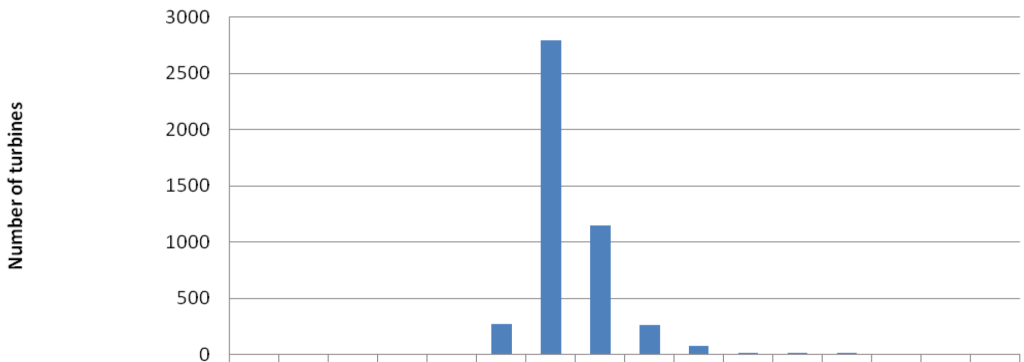
kW group (starting from, up to next)

Figure 3: WCP for 91% of the 5109 Existing Danish Turbines as of Ultimo 2009.

The Figure 3 outlines results from the WCP analysis. In the analysis, 91% of all Danish turbines had an appropriate data quality in order to calculate the WCP – the expected long term production. Typically the very new turbines are missing (still too few data to fulfill minimum requirements, 6 months approved data) and the small ones delivering power direct to owner. The large block from 2000 – 2999 kW without WCP is the new Horns Rev II wind farm with less than 6 months of data. For the block with turbines rated beyond 3000 kW, the new Sprogø offshore wind farm is the largest group without data.

6.3.3 Analyses Regarding WCP for Danish Turbines

The change in calculated WCP based on end 2008 and end 2009 data inclusion are shown in Figure 4. As seen the changes are very small - only 28 turbines changes more than +/- 5%. This is typically fairly new turbines, where last calculation was based on a somewhat poor data basis. Note: Only turbines with at least 6 approved months of data are included.



	-7%	-6%	-5%	-3%	-2%	-1%	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%
Change from 08 to 09	1	3	1	5	9	272	2797	1149	259	81	15	12	19	1	1	3

Figure 4: The change in calculated WCP based on end 2008 and end 2009 data.

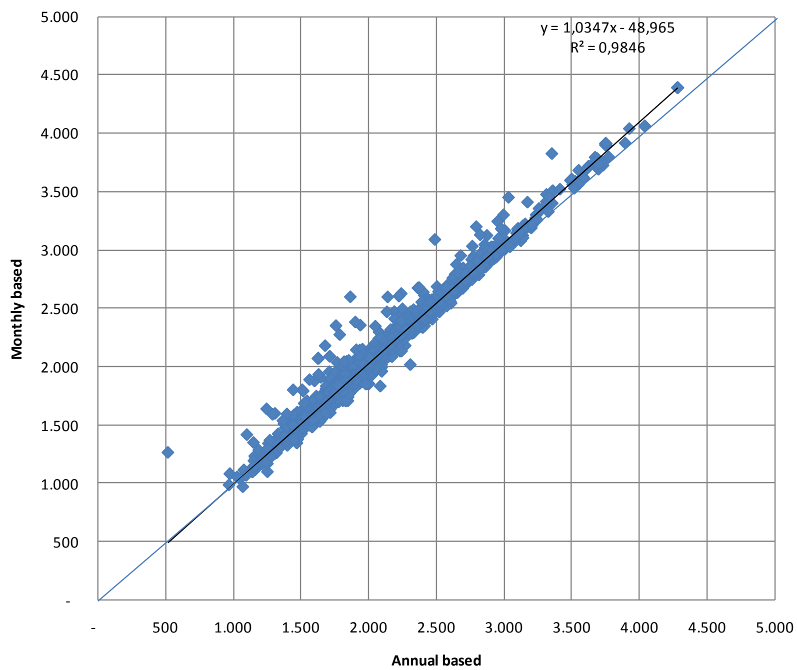


Figure 5: Wind Index Corrected Full Load Hours Based on Monthly and Annual Data..

There are some differences in calculations based on monthly and annual values, as annual values typically include more availability loss (this is taken out in monthly data by filtering), see the Figure 5. Looking at all data; the annual based WCP is 1.1% lower than the monthly based. This indicates that 1.1% major availability loss is a "typical value". In addition to this; there are the minor availability loss events (e.g. service events), which are not taken out by filtering the month data.

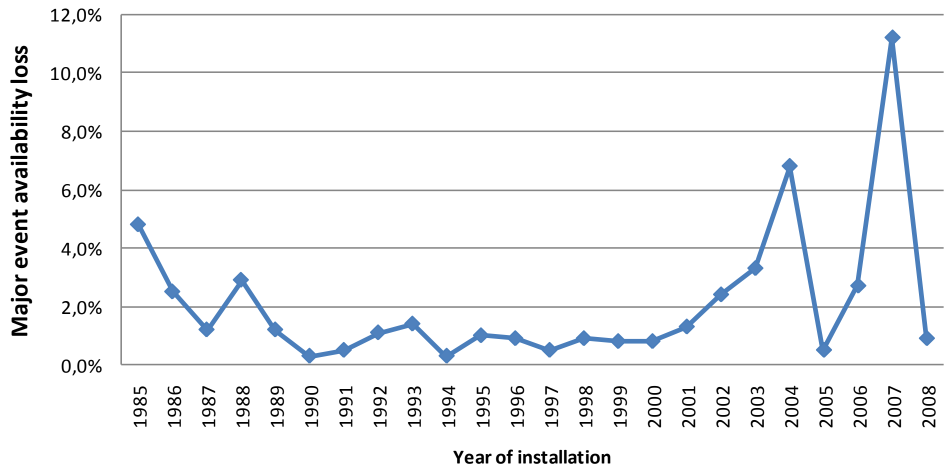


Figure 6: Analyzing the Major Availability Loss (by Considering Annual versus Monthly Data)

Considering the Figure 6, the "major event" availability loss is analyzed by observing the difference in WCP based on monthly and yearly data. The monthly WCP can be used to detect major availability losses, like if a turbine is out of order for a week or more. This is the case, as the monthly data will be much lower than the recorded average. Considering the yearly data this is not the case - unless it is a very long out of operation period. Finding the difference in WCP on yearly and monthly data therefore gives a good indication of the 'major event' availability losses. From the Figure 6; it is seen that the turbines established during the last 5 years seem to have an increasing availability loss. In this context, it must be noted, that the data basis is relative weak the most recent years due to few new Danish installations in this period. In the same period, more offshore turbines are included (most installed in years 2002-03).

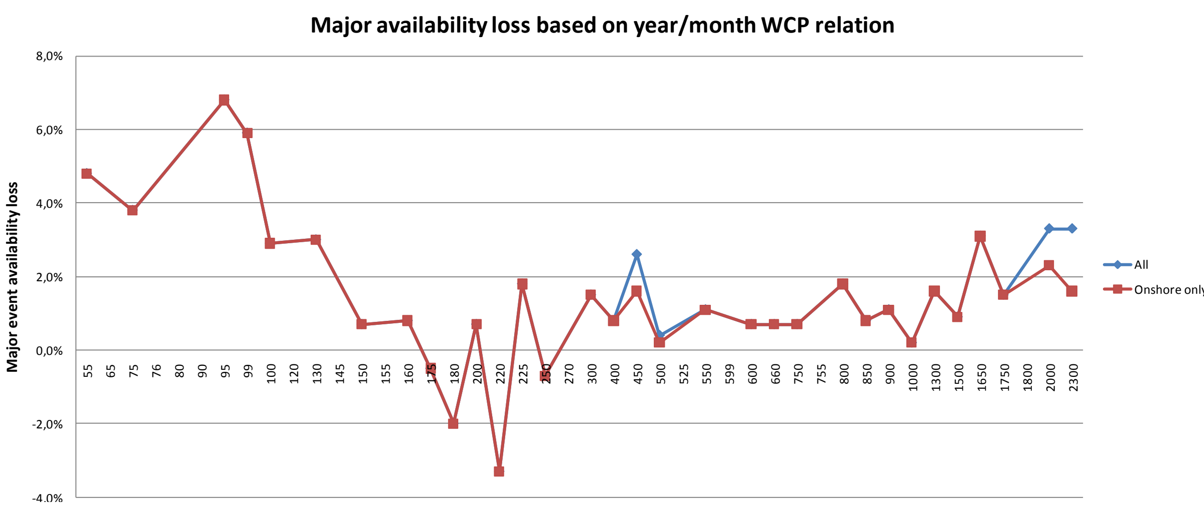


Figure 7: Major Availability Loss Divided into Groups With Different Turbine Size.

The Figure 7 shows the "major event" availability loss (as also shown in Figure 6); however the ***Figure 7*** shows the WCP divided into groups with different turbine size. Here we - in addition – also look at the differences between offshore and onshore turbines. It is clear that the offshore has larger "major event" availability losses. It is also clear that the very large turbines in general have larger availability losses compared to the large 600-750 kW generation of turbines, which has below 1%. The very large ones have around 2%. The smaller ones, - below 150 kW - seem to have the highest “major event” availability losses. This group is also very old, and only a few are actually left. In our analysis, we have included only groups with more than 5 turbines. The ones with negative losses are groups with very few turbines; where the statistical basis is very poor.

6.4 References

[1] Homepage for the Danish Energy Agency, (go to ‘*Stamdataregister for vindmøller*’)
http://www.ens.dk/da-DK/Info/TalOgKort/Statistik_og_noegletal/Oversigt_over_energisektoren; Accessed February 2010.
[2] EMD homepage for the Danish wind indexes:
http://www.vindstat.dk, Accessed February 2010.