

Getting Started with WAsP 7

**Niels G. Mortensen, Duncan N. Heathfield,
Lars Landberg, Ole Rathmann, Ib Troen and
Erik L. Petersen**

**Risø National Laboratory, Roskilde
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Abstract The Wind Atlas Analysis and Application Program (WAsP) is a PC-program for horizontal and vertical extrapolation of wind data. The program contains a complete set of models to calculate the effects on the wind of sheltering obstacles, surface roughness changes and terrain height variations. The analysis part consists of a transformation of an observed wind climate (wind speed and direction distributions) to a wind atlas data set (regional wind climate). The wind atlas data set can subsequently be applied for estimation of the wind climate and wind power potential, as well as for siting of specific wind turbines. The electronic version of the WAsP 7 Help Facility includes a Quick Start Tutorial, a User's Guide and a Technical Reference. It further includes descriptions of an Observed Wind Climate Wizard, the WAsP map editor tool, the Air Density Calculator, the RIX program for calculating the ruggedness index of a site in complex terrain and the DXF Translator.

This report consists of excerpts from the electronic version of the WAsP 7 help facility:

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The WAsP 7 Help Facility contains several more sections than the ones printed in the present report, for example the WAsP User's Guide, Modelling with WAsP, Technical Reference, WAsP Tools and more... and Appendices. These sections and their topics may be printed directly from the help facility.

1 Introduction

1.1 Welcome

In 1987 the Wind Energy and Atmospheric Physics Department at Risø National Laboratory introduced WASP – a powerful tool for wind data analysis, wind atlas generation, wind climate estimation and siting of wind turbines. Over the years, the program has become the industry standard for wind resource assessment and siting of wind turbines and wind farms and it has been employed in more than 70 countries all over the world.

A new release of this indispensable tool for everybody working with wind energy is now available – WASP for Windows 95, 98, NT 4 and 2000. The program has been developed by the same team who worked out the Danish Windatlas, the European Wind Atlas and previous versions of the WASP programs.

The algorithms at the heart of the WASP software have been tested and applied for more than 15 years in many different parts of the world. As time has passed, most of our efforts have been devoted to refining the WASP algorithms and supporting the existing software. Meanwhile, user interface design standards have moved on. Many users (and prospective users) have indicated their desire for a new, modern, user interface. WASP 7 is intended to meet these demands.

WASP is 100% 32-bit Windows software, which runs under Windows 95, Windows 98, Windows NT 4.0 and Windows 2000. It conforms to standard windows software user-interface conventions, making it easy to learn and easy to use. We recommend that you work through the Quick Start Tutorial – to see for yourself what WASP 7 is all about. If you're already using the existing DOS versions of WASP, you might read on here before entering the tutorial.

With the release of WASP 7, we also plan to handle feedback and support in a much more systematic and dynamic way than before. The main focal point for these efforts will be the WASP home page. Among other things, we plan to maintain a list of Frequently Asked Questions (FAQ), a list of Known Issues, a list of User Requested Features as well as information on our own ideas for the future development of WASP. Last, but not least, there will be a Download Page where you can download the latest version of the software and help file. Users who do not have access to the Internet may receive free updates on disk.

As it says in the License Agreement and Copyright Statement, the WASP software is provided 'as is' and 'does not represent a commitment on the part of Risø National Laboratory' etc. However, we are of course aware that the programs may contain errors, programming bugs and inconsistencies – especially with the introduction of this major upgrade. Therefore, we guarantee that we will do our best to check, maintain and correct the programs in the WASP package, and that we'll make available or distribute corrected versions to registered users of the software.

We wish you the best of luck with your wind projects and hope WASP 7 can help you reach your goals.

The WASP team at Risø

1.2 What is WAsP?

WAsP is a PC-program for the vertical and horizontal extrapolation of wind climate statistics. It contains several models to describe the wind flow over different terrains and close to sheltering obstacles. WAsP consists of five main calculation blocks:

Analysis of raw data. This option enables an analysis of any time-series of wind measurements to provide a statistical summary of the observed, site-specific wind climate. This part is implemented in a separate tool, the Observed Wind Climate (OWC) Wizard.

Generation of wind atlas data. Analyzed wind data can be converted into wind atlas data sets. In a wind atlas data set the wind observations have been 'cleaned' with respect to site-specific conditions. The wind atlas data sets are site-independent and the wind distributions have been reduced to some standard conditions.

Wind climate estimation. Using a wind atlas data set calculated by WAsP or one obtained from another source – e.g. the European Wind Atlas – the program can estimate the wind climate at any specific point by performing the inverse calculation as is used to generate a wind atlas. By introducing descriptions of the terrain around the predicted site, the models can predict the actual, expected wind climate at this site.

Estimation of wind power potential. The total energy content of the mean wind is also calculated by WAsP. Furthermore, an estimate of the actual, annual mean energy production of a wind turbine can be obtained by providing WAsP with the power curve of the wind turbine in question.

Calculation of wind farm production. Given the thrust coefficient curve of the wind turbine and the wind farm layout, WAsP can finally estimate the wake losses for each turbine in the farm and thereby the net annual energy production of each wind turbine and of the entire farm, i.e. the gross production minus the wake losses.

The program thus contains analysis and application parts, which may be summarised as follows:

Analysis

time-series of wind speed and direction → wind statistics

wind statistics + site description → wind atlas data sets

Application

wind atlas data sets + site description → estimated wind climate

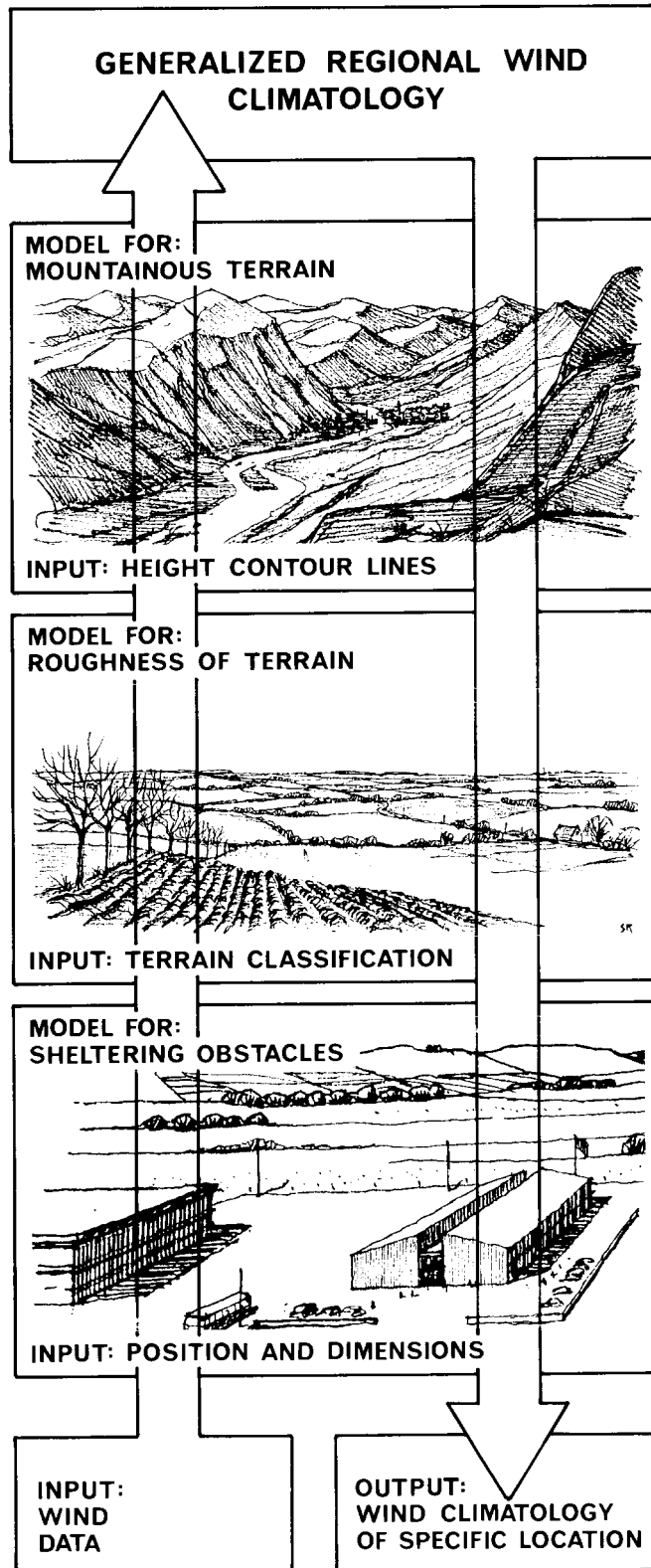
estimated wind climate + power curve → estimated power production

Wind farm production

estimated power productions + wind turbine / farm characteristics →

gross and net annual energy production of each turbine and of entire wind farm

The WAsP models and the wind atlas methodology are described in more detail in the European Wind Atlas. The figure below illustrates the wind atlas methodology.



The wind atlas methodology of WASP. Meteorological models are used to calculate the regional wind climatologies from the raw data. In the reverse process — the application of wind atlas data — the wind climate at any specific site may be calculated from the regional climatology (Troen and Petersen, 1989).

1.3 What's new in WAsP 7?

WAsP 7 is not just another update of WAsP 6; it contains new functionality, an improved user interface, a much improved help facility and several new or updated auxiliary software packages. Some of the major changes and additions compared to previous versions are:

- Wake loss and wind farm efficiency calculations implemented
- New wind farm windows and wind farm file support
- New power curve window and wind turbine file support
- WAsP help facility updated and expanded significantly
- Power curve library updated and expanded
- www.WINDPOWER.org updated to version 3.0
- WAsP 5.2 (32-bit, DOS) now included
- WAsP 4.2 (16-bit, DOS) now included
- An Air Density Calculator included
- The DXF-file Translator included
- Internet Explorer 5.5 included
- Adobe Acrobat 5.0 included

A more detailed list of fixes and changes in WAsP 7.2 (relative to version 7.0 released in Feb 2000) is given below (last update 2001-08-21):

Licencing

- Licensing system is less sensitive to machine configuration changes
- Added executable binary version of Licence Manager (in case of problems with HTML version)
- Licence manager HTML pages now run OK under Internet Explorer 4 as well as under IE5.

General

- Can run the application without a licence installed, but no calculations...
- Fixes toolbar problem under Win2K
- Cosmetic changes to labels and so on
- More changes to displayed units (yellow labels)
- Added updated and expanded sample data and workspaces
- Various bugs in the graphic user interface have been fixed

Embedded Help

- Added an updated and expanded help file
- Changed path settings for the help file
- Added help link for new windows in OWC wizard

Hierarchy

- Workspace hierarchy tree can now be collapsed to project level
- Workspace hierarchy tree members can now appear without type names

OWC-Wizard

- Default discretization bin width's set to 1/1000 of the raw data units
- Fixed erroneous rounding by the OWC wizard of some values to integers (min and max speed)
- OWC Window display now deals correctly with bin width not equal to one
- Alert raised in OWC wizard if more than 50 bins
- OWC Wizard deals more elegantly if number of valid selected entries is 0

Roughness description

- DOS-WASP Roughness description files correctly written if no change lines in a sector
- Bad problem with reading roughness rose files from DOS WASP now fixed
- Roughness descriptions using the "comma and gaps for missing data" format now read in correctly

Wind farm object

- Various enhancements to list views in wind farm window
- Cut and paste from wind farm window lists now has correct tabbing
- Correct import of DOS-WASP random rsf files to make wind farm
- Can import wind farm from a text file list of position pairs (such as could be produced from Excel easily)
- Correct naming of new or imported site locations for wind farms from rsf- and text-files
- Correct import of locations list in text field to make wind farm
- Air density setting facility withdrawn from the wind farm wake modeling. In case of an old wind farm file containing a non-standard air density specification, this specification is cancelled and the user is informed that this option is not supported. The effect of non-standard air density must be taken into account by using an air-density specific turbine power curve.
- Wake modeling calculation now has progress monitor and can be interrupted
- Wind farm now correctly saves specific height setting and restores it.
- An algorithmic inaccuracy occurring for wind distributions with high Weibull A-parameters, sometimes resulting in small negative wake losses, has been fixed.
- The wake effect module algorithm has been revised to give full consistency with the WASP kernel. Two different methods can be used to calculate the all-directions AEP :
 - a) by all-directions Weibull distribution (used in the WASP kernel); and
 - b) by sum of sectorial contributions (used internally in the wake effect calculation).
- In the wake effect module the difference between these methods has been dealt with by "harmonizing" the latter, and no warning nor error message is issued in case the difference is "large". In a later version of WASP a switch will be introduced to enable the user to choose between the two options for the WASP kernel (wake-effect-free production) and the wake effect calculation in common.

Other objects

- Fixes export problem with so-far-unsaved resource grids
- All problems with blank extra lines in trb and pow files now fixed
- Obstacles are now inserted to the bottom of the list, not the top
- Added some new Vestas turbines to the library
- Corrected the Vestas V47 turbine *.pow and *.trb files

Computational/algorithmic core

- Fixes the 'Cairo' bug: A wind atlas can now be produced without a specified map, i.e. a flat terrain with a constant (default) roughness length of 0.03 m is assumed.
- Fixes the 'Fulla' bug (no more mysterious DOS windows popping up!)
- Model radius lower limit lowered to 5000 m
- Fixed misc. bugs in error handling
- Azimuthal resolution can now be set to 1, 2, 3, 4, 5, 6, 9, 10, 12, or 15
- Fixed bugs regarding memory allocation in connection with non-default azimuthal resolutions.
- Better bounds checking of azimuthal resolution
- Increased working memory sizes to fix 'Too large map file' errors
- In the AEP (Annual Energy Production) calculation algorithm, a minor inaccuracy, resulting in a slight overestimation in case of very "high" Weibull distributions, has been fixed.
- WAsP 7.2 may now treat very detailed orography description in a map, i.e. densely spaced height contour lines within the calculational domain around a site being treated. Such conditions have in previous versions caused the calculation to break down when analyzing an observed wind climate (i.e. creating a regional wind climate *.lib), or when calculating wind resources at a site (in connection with single turbines, wind farms or wind resource grids). Fortunately, this annoying limitation has now been removed.

1.4 Known issues

With the release of WAsP 7, the Park model has been included in the WAsP program through the wind farm member. In some respects, the wind farm model acts as a separate model and it also has its own settings and dump file. It is important to note the following:

- WAsP uses an air density of 1.225 kgm^{-3} when calculating power density. Similarly, power production is calculated for this standard air density if one of the sample power curves is used.
- Only if the power curve is specified for the actual site air density, or an existing power curve has been scaled to the site air density (this is only recommended for some turbines though), will the wind turbine power production calculated by WAsP correspond to this air density.
- When invoking **Edit in map editor** from the map's right-click menu, any changes to the map are not automatically used in WAsP; the map must be saved from the map editor and reloaded into WAsP for the changes to take place.

You should also check the list of known issues at the WAsP home page.

1.5 Copyright and trademarks

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1.7 Acknowledgements

The WASP program was originally developed, designed and implemented by Ib Troen, Niels G. Mortensen and Erik L. Petersen from Risø National Laboratory, with financial support from the Commission of the European Communities (DGXII).

The present Windows-version was developed by a team consisting of Lars Landberg, Niels G. Mortensen and Ole Rathmann from the Wind Energy Department at Risø, Sofus S. Mortensen from Lambda Soft (DK) and Duncan N. Heathfield from World in a Box Limited (UK).

The ruggedness index concept was developed and tested by Anthony J. Bowen from the University of Canterbury, New Zealand.

Artistic drawings by Søren Rasmussen.

2 WAsP 7 installation

This brief guide describes the installation procedure for WAsP, version 7.2. Great care has been taken to ensure that the installation will run successfully, but as with all Windows software installations, there is a risk that running it could upset the normal functioning of your system. It is strongly recommended that you exercise some caution in choosing when to run the installation program. Please contact the WAsP team at Risø before installing if you need any specific advice. To use the full range of features in a software product from Risø, you must have a valid product licence. The installation is therefore divided into two separate steps:

1. Installing the WAsP software
2. Installing the WAsP licence

2.1 The installation disk

The WAsP installation files are shipped on a CD-ROM, which contains the following software packages:

- WAsP 7 for Windows 95/98/ME/NT4/2000
- WAsP 4 (16-bit) and 5 (32-bit) for DOS
- Adobe Acrobat Reader 5.0
- Internet Explorer 5.5 (SP2)
- www.WINDPOWER.org, version 3.0
- Golden Software demos of Didger, Surfer, Grapher and MapViewer

The WAsP software package

This package is described further in the following topics and in this help facility. The package contains all the programs and data needed to run WAsP, including the complete User's Guide, Quick Start Tutorial, Technical Reference, etc.

The WAsP for DOS packages

Also included on the WAsP installation CD are the latest releases of the 16- and 32-bit versions of WAsP for DOS. Read the readme.txt and wasp42.txt to learn how to install the WAsP 4 package; read the readme.txt and wasp52.txt to learn how to install the WAsP 5 package. No part of these packages is required to run WAsP for Windows; they are shipped only for the convenience of WAsP users who wish to be able to exploit the characteristics of this DOS software in existing projects and analyses.

www.WINDPOWER.org

For general information about wind power, as well as links to other web sites related to wind power, a good place to start is the award-winning home page of the Danish Wind Turbine Manufacturers Association. A recent download of this entire home page is provided for your perusal on the WAsP distribution disk, in the folder \Windpower. The pages exist in English, German, French, Spanish and Danish, and may be read with Internet Explorer 4 or Netscape 4, or later. To start reading, **Open** the file index.htm in either of the five folders English, Deutsch, Francais, Espanol or Dansk. The actual home page can of course also be accessed over the Internet.

This comprehensive source of information is brought to you by courtesy of the Danish Wind Turbine Manufacturers Association. Please observe the copyright statements and other conditions for use given in the pages.

2.2 Software requirements

Before installing WAsP, you should check the following points carefully.

Windows 95 version

If you're running Windows 95, check the Windows version. Invoke **Settings** in the **Start** menu, then **Control Panel** and in the control panel choose 'System'. In the General page under the heading 'System', you will find the actual version of Windows 95. The version number, e.g. 4.00.950, should be followed by an 'A' or a 'B', meaning that Service Pack 1 or 2 has been installed.

If this is not the case, you should get Windows 95 Service Pack 1 from the Microsoft Download Center. The download is free of charge. Be sure to get the right International Language Update if you are not using the standard English version of Windows 95.

Internet Explorer version

If you're running Windows 95 or NT 4.0, make sure that you have Internet Explorer 4 or later installed. If not, you may install an English version from the WAsP CD: Run Ie5setup.exe in the directory \IE5 (or Ie4setup.exe in the directory \IE4) and follow the instructions. A 'minimal' installation is sufficient and we further recommend not to install the Active Desktop.

If you have an International Language version of Windows 95 and Internet Explorer, you should get the corresponding update at Microsofts Download Center and not install it from the WAsP CD. Internet Explorer 4 or 5 may update some of your system files and is required for full functionality of the WAsP licence manager and help facility.

If you're running Windows 98 you don't need to install Internet Explorer.

Minimum software requirements

The minimum requirements for installing and running WAsP successfully are thus Windows 95A and Internet Explorer 4.

You should also read the 'License Agreement for the use of WAsP' before installing the program.

2.3 Installing the WAsP software

First, close all active programs on the PC. Then, if you're upgrading from an earlier WAsP version:

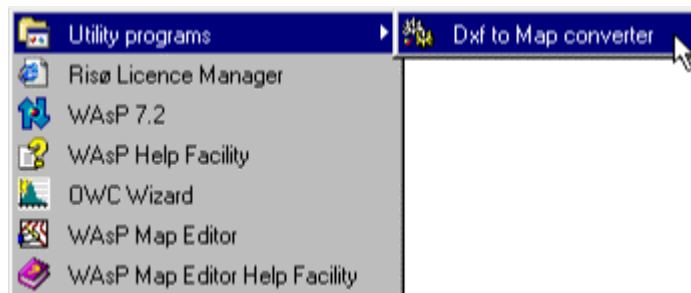
1. Un-install WAsP using the Control Panel un-install facility
2. Install the WAsP 7 programs from this CD

If you're installing WAsP 7 onto a computer with no previous version of WAsP:

1. Except for Windows 98, ensure IE is installed (at least version 4.0)
2. Install the WAsP 7 programs from this CD

WAsP can be installed from the CD by invoking Wasp7Setup.exe and MapEditorInstall.exe. Invoke these files using **Run** in the **Start** menu. And, as with any other power tool: 'read, understand and follow the instructions' – in this case those given by the installation programs. Agree to the default values and folders suggested by the installation programs unless you are absolutely confident with what you are doing.

WASP, some utility programs and sample data files will be installed in the folder \Program Files\Wasp and several sub-folders. They will also appear in the **Start** menu, in a 'WASP' folder under the **Programs** menu item. This folder should contain seven installed items:



For fast and easy access to the WASP software, you can also make short-cuts to the programs on your Windows desktop.

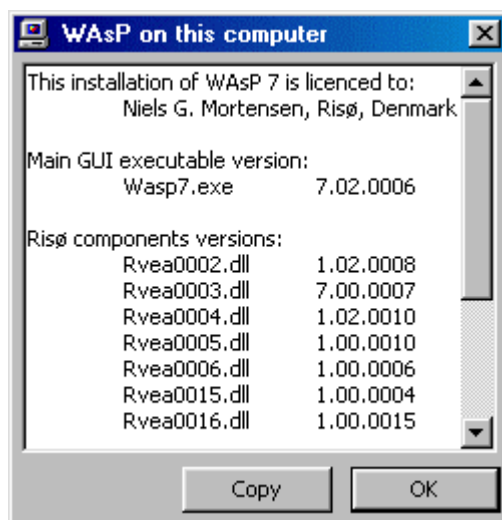
2.4 Obtaining and installing the licence

The Risø Licence Manager is invoked from the **Start / Programs / WASP** menu. This program will guide you through the three-stage process of installing the licence:

1. You apply for a product licence unlock code by sending us your machine ID number.
2. We send you your product licence unlock code.
3. You enter the product licence unlock code to install the licence.

The unlock code and user name information is sent to you by Risø and must be entered exactly as it is written by Risø; including spaces, special characters and punctuation marks use copy and paste to transfer this information. When the user name and license unlock code have been entered correctly, WASP can be executed.

The User Name can be displayed any time in the WASP **Help** menu under the menu point **WASP on this computer...**



This information window further contains the version numbers of the installed components.

2.5 Running WAsP

We suggest you start by reading through the 'Introduction' section of the WAsP help facility. If you are already using the existing DOS versions of WAsP, you might read on in the 'Notes for users of previous versions' section. Next, we recommend that you work through the Quick Start Tutorial – to see for yourself what WAsP is all about.

The documentation and User's Guide to the WAsP program are contained in the WAsP help facility. Here you should be able to find most of the information required to run WAsP.

If you have problems using the WAsP software please send an e-mail to the WAsP support staff. If you do not have e-mail, you may send a fax to the number given here.

You should also check the list of known issues at the WAsP home page and/or the list of Frequently Asked Questions, which will be introduced and maintained at the same Web address.

Keeping your installation up to date

The latest version of the WAsP program may be downloaded from the WAsP download page in the form of an update file to the main installation on the CD-ROM. Note, that it will only run on the PC computer where the original WAsP installation was made. Updates of other WAsP files and programs may be available as well (WAsP Help Facility, RIX etc.).

Great care is taken to ensure that WAsP installations and updates will run successfully, but as with all Windows software installations, there is a risk that running it could upset the normal functioning of your system. It is recommended that you exercise some caution in choosing when to update your WAsP installation. Please contact the WAsP team before updating if you need any specific advice.

The latest version of Internet Explorer is available from Microsoft's Download Center. You may also visit Microsoft's Windows Update site to download and install the latest Windows updates for your computer.

3 WAsP Help Facility

3.1 Introduction

This help facility should eventually become the complete, on-line User's Guide and Technical Reference for the WAsP program. The main characteristics of the WAsP Help Facility are:

- Based on Microsoft HTML help
 - Requires Internet Explorer 4.0 or later for full functionality
- Complete on-line documentation
 - Text, tables and images
 - Table of contents, index and keywords
 - Books and topics can be printed
- Fast and easy to use
 - Context-sensitive help (F1-help)
 - Full-text search facility
- Hyperlinks to topics, URL's and e-mail addresses
- Easy to update and distribute

The help facility can be invoked and used in two different ways: as context-sensitive help or as a stand-alone application/document.

The help facility is far from static, but is being developed continuously. New versions will be made available at the WAsP home page and you'll receive a notification when this happens – if you have informed us about your e-mail address.

3.2 Context-sensitive help

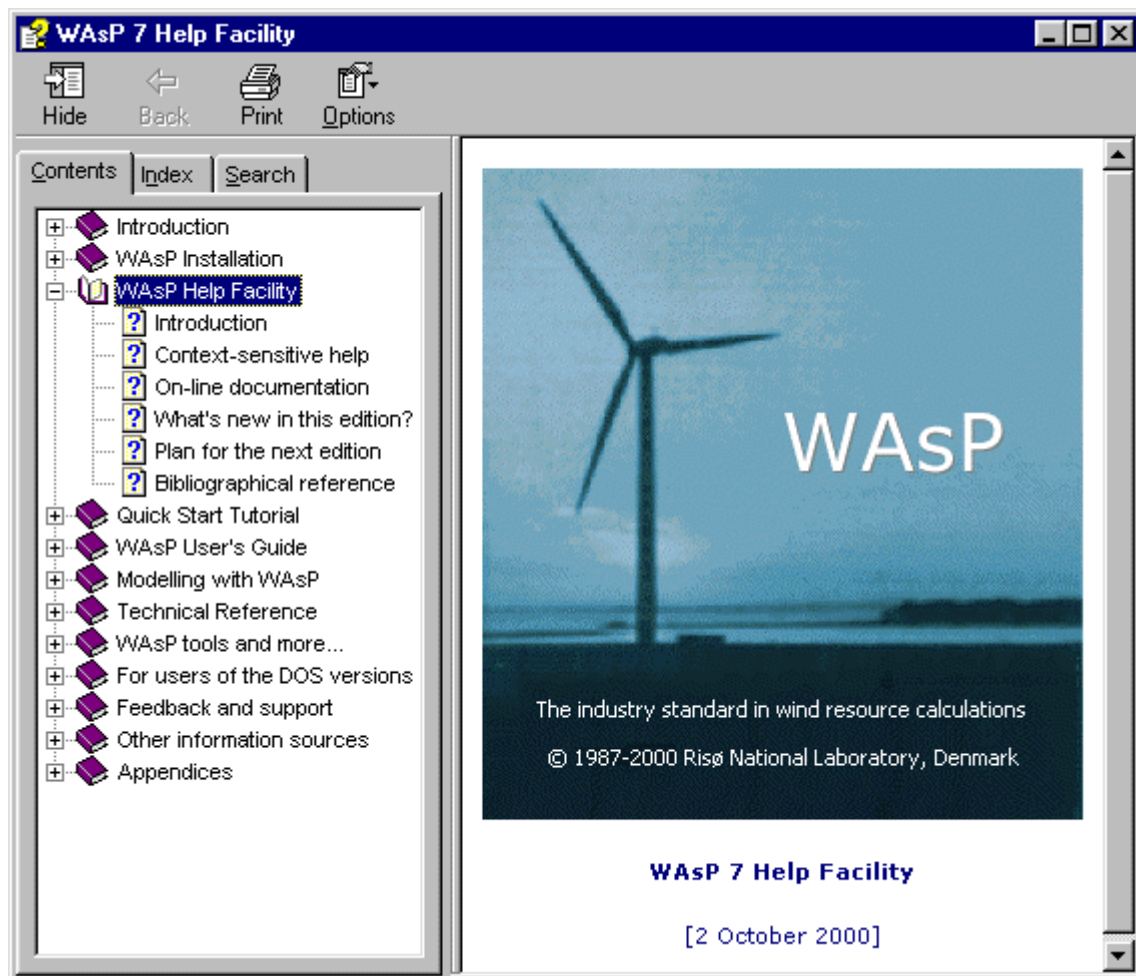
Pressing the **F1**-key on your keyboard invokes context-sensitive help for the active window or dialog. This works in the WAsP program as well as for the Observed Wind Climate Wizard. The WAsP map editor has its own help facility.

From the WAsP program you are guided directly to the User's Guide of the help facility; to a point from which you should be able to find the answer you're looking for. Use the **C**ontents tab to navigate the help facility via the table of contents, or use the related topics controls present on most **F1**-help entry pages.

You can also use the **I**ndex tab to navigate via the keywords of the index or you can use the full-text search facility by choosing **S**earch.

3.3 Complete on-line documentation

The help facility is the complete on-line User's Guide and Technical Reference for the WAsP program package. It can be invoked from the main menu of WAsP by choosing the **C**ontents and **I**ndex menu item from the **H**elp menu. Or, it can be invoked from the **S**tart / **P**rograms / **W**AsP menu in Windows. The opening screen looks like this:



The help facility can be browsed in several ways: you may use the **C**ontents tab to navigate the help facility via the table of contents, or you may use the **I**ndex tab to navigate via the keywords of the index. Finally, you may use the full-text search facility by choosing **S**earch.

In the different topics of the help facility you may find links to other topics and to Web pages; these can be invoked directly with the left-hand button of the mouse. Links to e-mail addresses will start your e-mail application when invoked.

Topics and entire books can be printed when choosing the **P**rint menu point.

3.4 What's new in this edition?

The WAsP help facility is continuously under development, so changes and additions to its structure and contents should be expected. Major changes compared to the second general release (WAsP 6.0, June 1999) are:

- A *WAsP Installation* book has been added.
- A *Modelling with WAsP* book has been added. This describes the topographical concepts used in WAsP modelling, as well as the different models of WAsP: the roughness model, the flow model, the shelter model and the wake model.
- A *WAsP Tools and more...* book has been added. In this, we have collected information on the OWC Wizard, the MapEdit utility, the Air Density Calculator, the RIX program and the DXF translator, as well as lists of

other software and hardware that may be useful when working with WAsP in practice.

- The *Park program* section does not exist anymore since the functionality of the Park program is now included in WAsP.
- Some sample WAsP forms are now described in the *Appendices* section.
- A description of the wind-climatological fingerprint has been added to the *Appendices* section.

Note also, that the terminology used in WAsP has been changed slightly: we have tried to avoid any sloppy uses of the terms 'energy' and 'power' as well as some related terms.

Major changes in the second release (June 1999) compared to the first general release (March 1999) are described here.

3.5 Plan for the next edition

The contents of the next edition will to some extent depend on the user response to the present version. However, we do plan to add more information on the following subjects:

- Wind power meteorology in general
- Site calibration and customisation
- Limitations of the wind atlas methodology
- Wind resource assessment in specific situations: offshore, near-shore, complex terrain and wind resource mapping.

We also aim at providing more sample data and example projects with the WAsP package.



3.6 Bibliographical reference

Title: Wind Atlas Analysis and Application Program: WAsP 7 Help Facility

Authors: Niels G. Mortensen†, Duncan N. Heathfield*, Lars Landberg†, Ole Rathmann†, Ib Troen† and Erik L. Petersen†

†Risø National Laboratory and *World in a Box Ltd

ISBN: 87-550-2941-8

Department: Wind Energy Department, Risø National Laboratory

Date: September 2001

Topics: 291

Tables: 11

Illustrations: 229

References: 26

Abstract: The Wind Atlas Analysis and Application Program (WAsP) is a PC-program for horizontal and vertical extrapolation of wind data. The program contains a complete set of models to calculate the effects on the wind of sheltering obstacles, surface roughness changes and terrain height variations. The analysis part consists of a transformation of an observed wind climate (speed and direction distributions) to a wind atlas data set. The wind atlas data set can subsequently be applied for estimation of the wind climate and wind power potential, as well as for siting of specific wind turbines. The WAsP 7 Help Facility includes a Quick Start Tutorial, a User's Guide and a Technical Reference. It further includes descriptions of the Observed Wind Climate Wizard, the WAsP map editor tool, the Air Density Calculator, the RIX program for calculating the ruggedness index of a site in complex terrain and the DXF Translator.

Descriptors (INIS/EDB): COMPUTER PROGRAM DOCUMENTATION; DATA ANALYSIS; MAPS; RESOURCE ASSESSMENT; SITE CHARACTERIZATION; W CODES; WIND; WIND POWER.

Please refer to: Mortensen, N.G., D.N. Heathfield, L. Landberg, O. Rathmann, I. Troen and E.L. Petersen (2001). *Wind Atlas Analysis and Application Program: WAsP 7 Help Facility*. Risø National Laboratory, Roskilde, Denmark. 291 topics. ISBN 87-550-2941-8.

4 Quick Start Tutorial

This section of the WAsP help facility is intended to provide a very brief introduction to the essential features and uses of WAsP.

A concise explanation of the most basic techniques is followed by a simple step-by-step example.

New users will get an idea of what WAsP is for and how to use it. Existing users of older versions of WAsP will be introduced to the new ways of working.

4.1 The GUI essentials

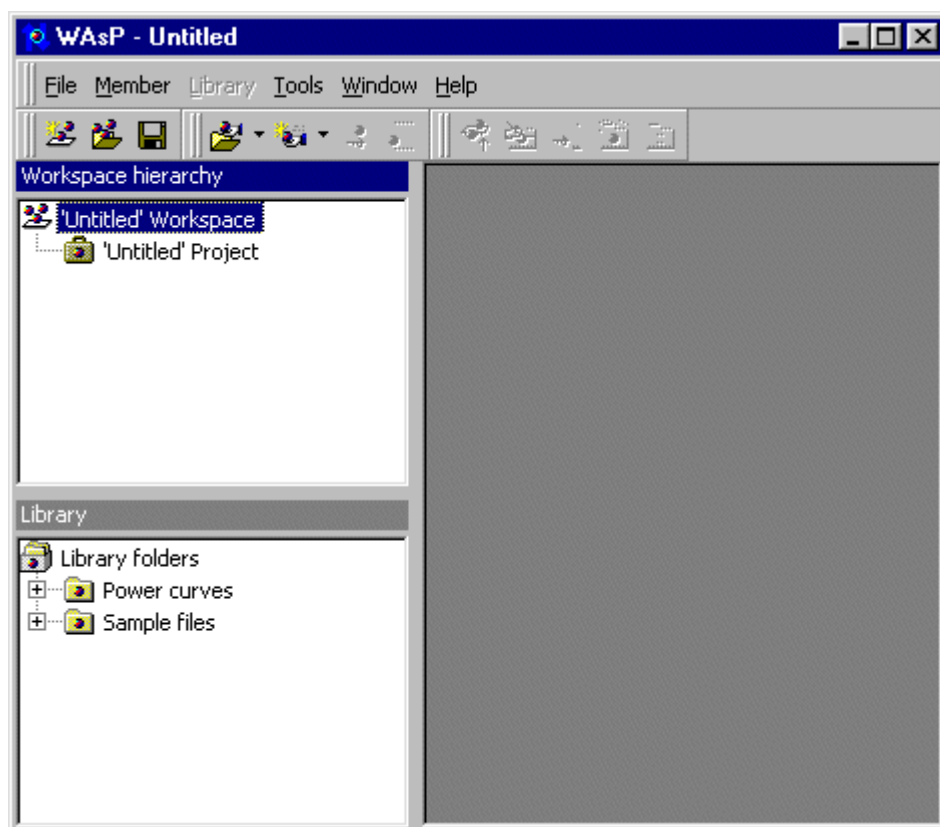
This section is not intended to be a complete guide to using WAsP. Instead, you are introduced to just enough of the basics to let you work through the simple step-by-step example. Read through the following sections in order

1. WAsP workspaces
2. Working with the workspace hierarchy
3. Saving the workspace members

This brief introduction is followed by the step-by-step example.

Opening a new WAsP workspace

When you first open WAsP, you are presented with an empty window. To start work, you need to open a workspace. In WAsP, all work is performed within the context of a workspace. Workspaces can be created, saved and re-opened. To open a new workspace, select **New workspace** from the **File** menu.



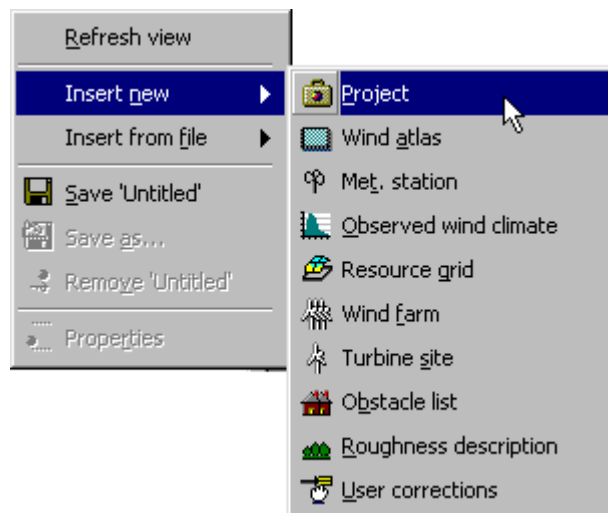
Two white window 'panes' have appeared on the left-hand side of the main window: the workspace hierarchy and the library. The library pane simply makes it faster to find files. It is explained elsewhere in the documentation. For now, ignore the library pane and concentrate on the workspace hierarchy, which is the most important area of the program.

Working with the workspace hierarchy

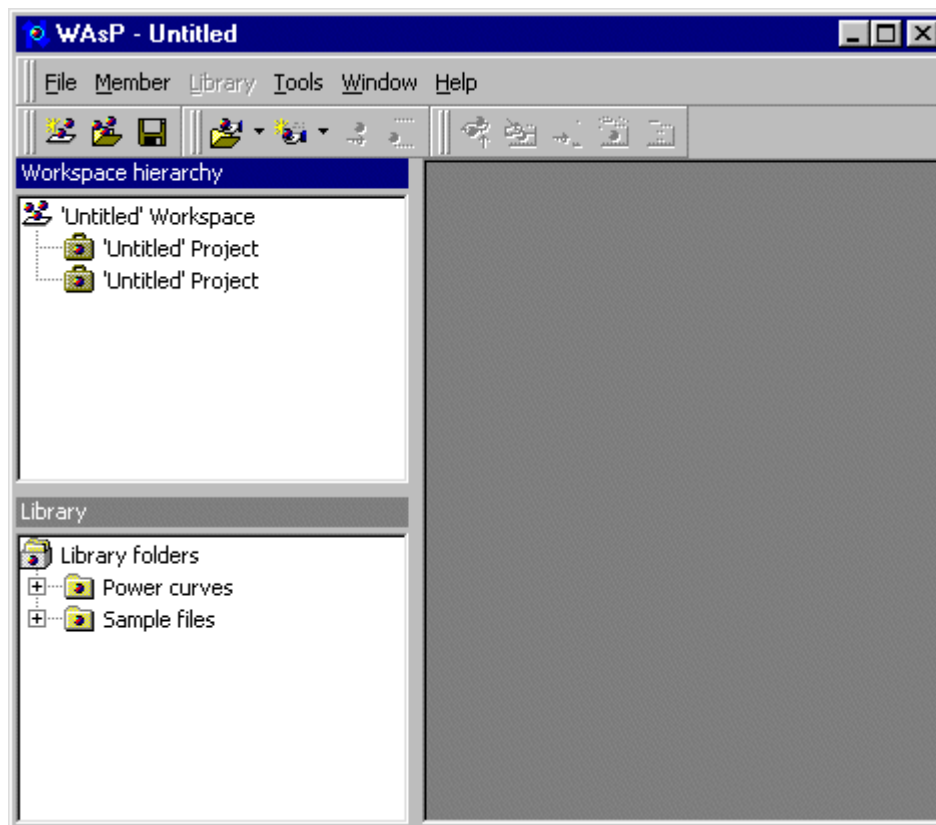
The workspace hierarchy contains one single icon, representing the 'root' of the workspace. This workspace further contains one 'Untitled' project. To work with WAsP, you need to add new items to the workspace. These items are arranged in a hierarchy and are called hierarchy members or just 'members', for short. The workspace root is always at the very top of the hierarchy. All of the members of the workspace are children of the workspace root.

To insert a new member to the hierarchy, do the following:

- Click with the right hand mouse button on the workspace icon.
- A small 'pop-up' menu appears. Select **I**nsert **n**ew.
- Another menu appears. Select **P**roject.



A project hierarchy member is inserted as a child of the workspace root.



Every member of the hierarchy has a right-click menu. Most members' right-click menus include insertion sub-menus.

To insert another member to the hierarchy:

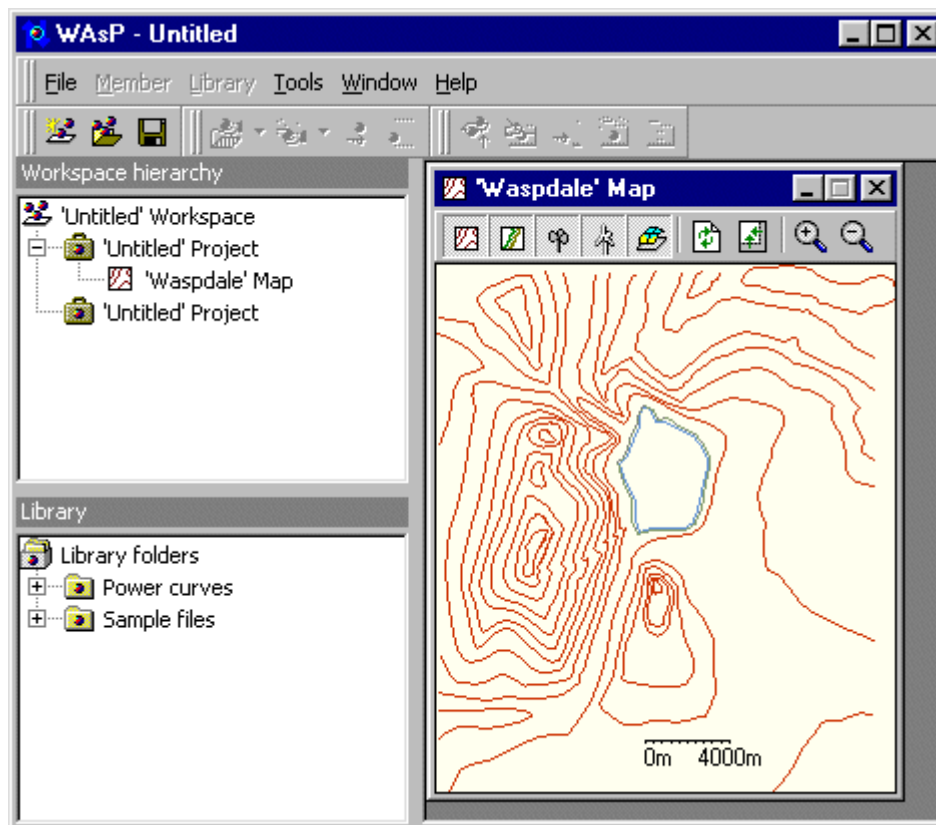
- Select **Insert from file** from the first projects pop-up menu
- Select **Map** from the insertion sub-menu
- A file-choice dialog box appears. Select the file called 'Waspdale.map'

You may have to navigate to the folder containing the sample data, which was created when you installed WAsP. The map is now a member of the hierarchy, as a child of the first project.

To view the map:

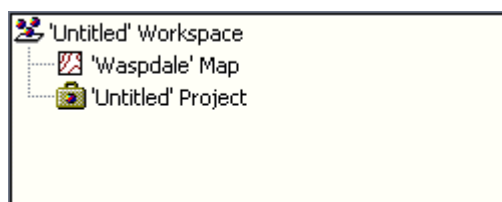
- Select **View** from the map icon's right-click menu.

The map window appears in the right-hand side of the main window.



Most members in the hierarchy have an associated window in addition to the simple icon, which is displayed in the hierarchy itself.

All members of the hierarchy (except the hierarchy root) can be inserted, moved around or deleted. You can re-organise the existing hierarchy members by dragging them around with the mouse. To move the map so that it is a child of the workspace root, simply drag the map icon onto the workspace icon.



The map and the project are now both children of the workspace root. There are constraints on where different types of hierarchy member can be placed in the hierarchy, but most types of member (including maps) are allowed to be children of the workspace root.

You have already learned the most important techniques for working with WAsP!

It is largely a matter of manipulating the members of the workspace hierarchy using the mouse. Learning to use WAsP is now simply a question of getting to know the various members of the workspace hierarchy and understanding how to use them.

Saving the workspace and members

Each member of the workspace has an associated data file. When you work with a hierarchy member in WASP, you are dealing with a copy of the data and you can make changes to anything. The changes to the data are not written to the file unless you save them.

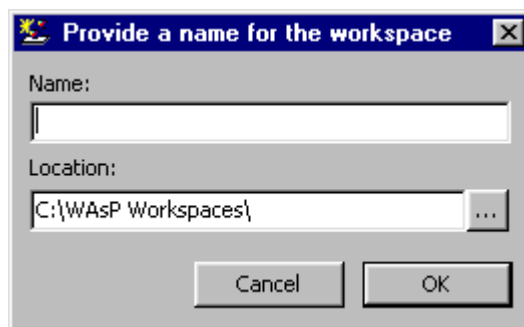
You can save changes to most individual hierarchy members by using their right-click menu:

- Select **Save** from the member icon's right-click menu.

To save a copy of a member:

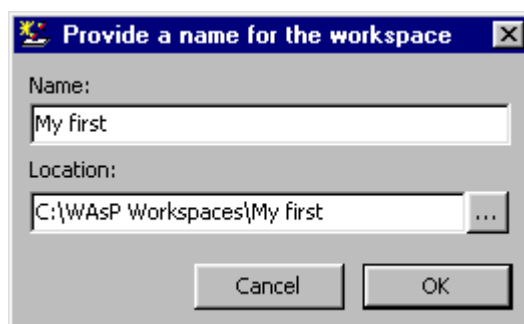
- Select **Save as...** from the member icon's right-click menu.
- Provide a name and path for the file in the file dialog box, which appears.

Every WASP workspace and every WASP project is stored in its own folder on your computer. So, when you first save a project or workspace you need to provide the name of a new folder rather than a file name. A special dialog box appears to help you do this:



To save the workspace:

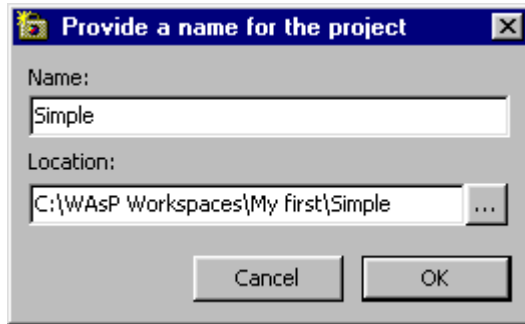
- Select **Save** from the workspace icon's right-click menu.
- Type a name in the box, which appears.
- Notice that the new folder name is being added automatically to the location.




When you press OK, a new folder with that name is automatically created, and a new workspace file with the same name is placed into the folder. You are now invited to save the project too.

To save the project:

- Type a name in the box, which appears.
- Notice that the project folder is being created as a sub-folder of the workspace folder.



You can save whole branches of the workspace hierarchy in a single operation. For example, if you save a project, any changes to any of the children of the project are automatically saved too. (That's why, in the example above, you were invited to save the project, even though you had only asked to save the workspace.

 At any time, you can save the whole workspace by clicking on the **Save workspace** icon in the main toolbar. Any new files, which you create in the context of a project or a workspace, are (by default) saved to the project or workspace folder.

Now you should be ready for a step-by-step example...

4.2 A step-by-step example

Introduction

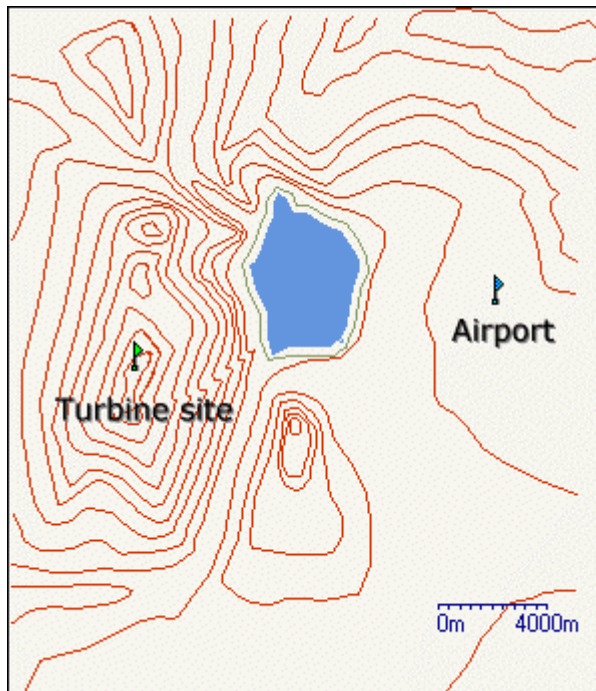
The example works through a complete wind turbine siting operation, starting with some measured wind data and ending up with a prediction of the power yield from erecting a turbine at a specific site.

You can find the data used for the example in the folder containing the sample data, which was created when you installed WAsP, e.g. '`\WAsP Workspaces\Samples\Sample data`'.

The situation

The company *Friends of Wind Energy, Waspdale Ltd.* has asked you to provide a prediction of the power yield from locating a wind turbine in Waspdale. They propose to erect a single 600-kW wind turbine at the summit of Waspdale hill (they have modest energy requirements).

No wind measurements have been taken at the turbine site itself, but data have been collected from a meteorological station at nearby Waspdale airport. A map of Waspdale is shown below.



You are equipped with:

- a contour map of the area
- the wind data from the airport
- a simple description of the land use in the area
- an annotated sketch of the airport buildings near the met. station
- a description of the power-generating characteristics of the turbine

These have been converted into digital files, as follows:

- a digital map of topography and roughness
- a data file containing wind data
- a data file describing the buildings at the airport
- a data file containing a power production curve for the turbine

Working with WAsP to provide a prediction

From engineering data, you know how much power will be generated by the turbine at a given wind speed. If the plan was to erect the turbine at exactly the same place where the meteorological data had been collected, then it would be a really simple task to work out how much power to expect.

However, just from looking at the map it is obvious that the proposed turbine site is completely different from the meteorological station at the airport: the properties of the meteorological station itself will affect the wind data recorded there. In addition, the properties of the turbine site will have an effect on the way that the wind behaves near the turbine. It is also unlikely that the hub height of the turbine would be the same as the height of the anemometer.

What you need is a way to take the wind climate recorded at the meteorological station, and use it to predict the wind climate at the turbine site. That's what WAsP does.

Using WAsP, you can analyze the recorded data, correcting for the recording site effects to produce a site-independent characterisation of the local wind climate. This site-independent characterisation of the local wind climate is called a wind

atlas or *regional wind climate*. You can also use WAsP to apply site effects to wind atlas data to produce a site-specific interpretation of the local wind climate.

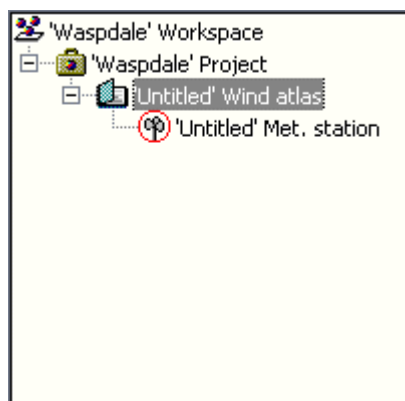
Providing a prediction in the Waspdale case will therefore be a two-stage process. First, the data from the meteorological station need to be analysed to produce a wind atlas, and then the resulting wind atlas needs to be applied to the proposed turbine site to estimate the wind power.

4.3 Calculating the wind atlas

Setting up a met. station

To begin, you need to open a new workspace in WAsP. A new, 'Untitled' project is automatically inserted in this workspace. Save the workspace and project, calling them both 'Waspdale'. Return to the GUI essentials if you don't know how to do this.

Now insert a new wind atlas as a child of the project. The wind atlas will be generated from a meteorological station. Insert a new met. station hierarchy member as a child of the wind atlas. The workspace should now look like this:



Provide names for the wind atlas and met. station by saving them. To do this, simply save the whole workspace: you will be prompted for the file names for the newly created hierarchy members. Call the wind atlas 'Waspdale' and call the met. station 'Airport'.

WAsP now requires:

- a description of the data-recording site
- a summary of the wind data recorded at the site

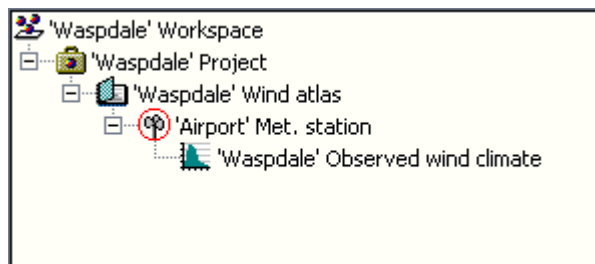
Adding wind observations

You now need to insert some wind data to the hierarchy.

Select the met. station and use **Insert from file** to insert an **Observed wind climate** member. You will be asked to provide the name of a file to use. Navigate to the folder containing the sample data, which was created when you installed WAsP, and select the file called 'Waspdale.tab'.

You can read more about how to create observed wind climate files from raw data measurements elsewhere in the documentation.

The workspace should now look like this:

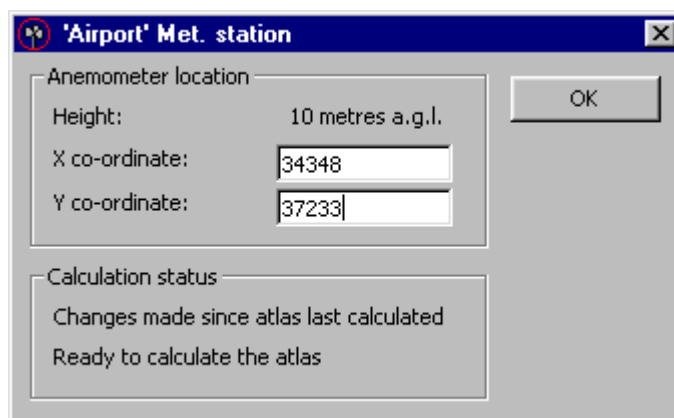


Describing the site

Now WASP needs to know about the site where the data were collected. First, introduce a map as a child of the project. You should use the project's **Insert from file** method and select the file called 'Waspdale.map'. Now you need to locate the met. station in the map.

To locate the met. station:

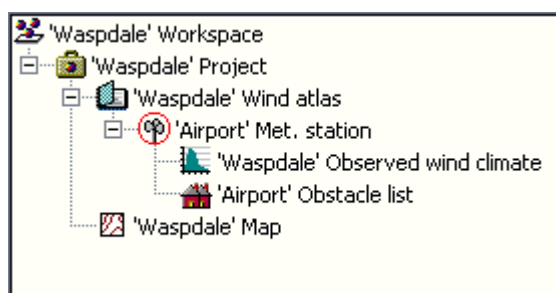
- From the met. station's right-click menu, select **Edit location**.
- When a dialog appears, set the location to (34348,37233).
- Press OK.



At the met. station site, several buildings and shelterbelts of trees were found in the vicinity of the anemometer mast. WASP needs to know about these.

Insert a list describing the obstacles, use the **Insert from file** method of the met. station to add an **Obstacle list**. When the choose file dialog box appears, select the file 'Airport.obs'.

The workspace hierarchy should now look something like this:



The atlas calculation

WASP is now ready to calculate the wind atlas for Waspdale, but before proceeding, pause to examine the members of the hierarchy which are contributing to the analysis. The map, the observed wind climate and the obstacle list all contain data and can be viewed. Each has a command called **View** on its right-click menu, which will open the window associated with the member. Open each one and have a look. To see where the met. station is in the map, select the **Highlight location in map** command from the met. station's right-click menu, or click on the little anemometer icon in the map's toolbar.

Now get WASP to generate the wind atlas. From the met. station's right-click menu, select the **Calculate atlas** command. When the calculation is finished, the small red ring which surrounded the met. station icon has gone. This indicates that the calculations for the met. station are up to date.

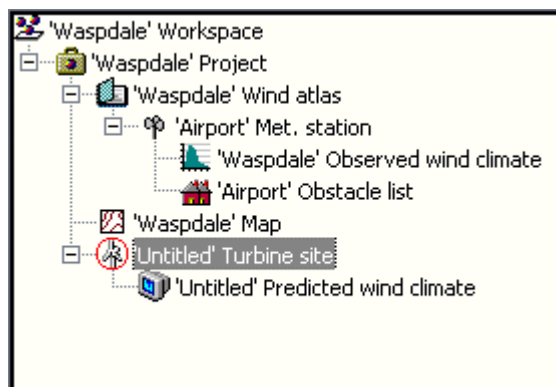
To see the results of the calculation, select the **View** command from the Wind atlas' right-click menu. The wind atlas is displayed. This is a site-independent characterization of the wind climate for the Waspdale area; you may also think of it as the *regional wind climate* of Waspdale.

4.4 Estimating wind power

Setting up a turbine site

Now that the project contains a wind atlas with site-independent wind climate data, we can apply those data to the proposed turbine site. WASP will adjust the data for the situation found at the turbine site, and will produce a prediction of the wind climate for the site itself.

You need to add a turbine site hierarchy member to the workspace. Insert a new turbine site as a child of the project. The workspace now looks like this:



WASP has automatically added a new hierarchy member called a predicted wind climate as a child of the turbine site. This member will be used to contain all of the predictions, which WASP generates for the turbine site. It cannot be separated from its turbine site parent.

Save the workspace. You will be prompted to provide a name for the turbine site. Call it 'Hilltop', since the plan is to erect the turbine on a hill.

WASP now requires:

- the location of the site in the map
- a description of the type of wind turbine that you propose to use.

There are no obstacles near the hilltop, so there is no need to add an obstacle list to this site.

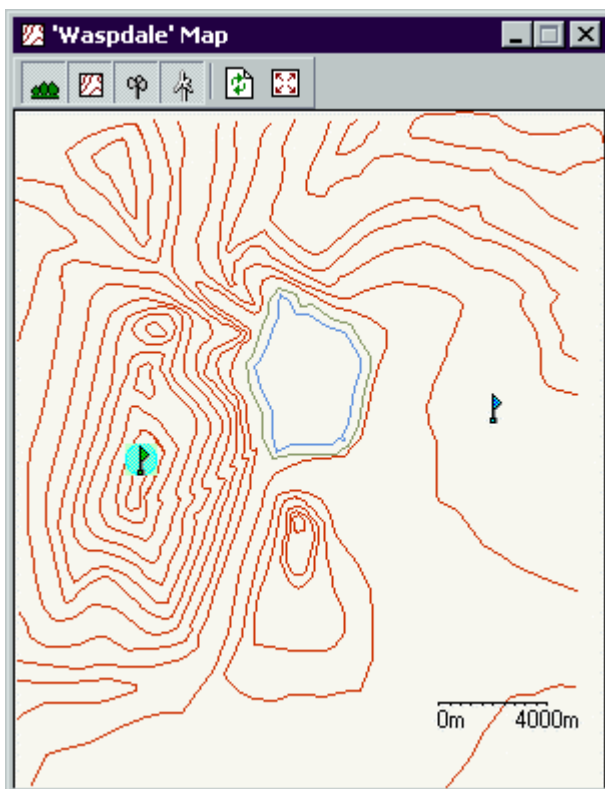
Locating the turbine site

First, locate the turbine site in the map. Because the map and the turbine site are in the same project, WASP automatically knows that the site lies in the area covered by the map. All that you need to do is provide the co-ordinates. This could be done by following the same procedure as used for siting the met. station (type the co-ordinates into the site dialog box). However, since the location of the turbine site has not been exactly decided, we do not need to be so precise at this stage. We can use a different method.

From the turbine site's right-click menu, select **Locate in map**. The map window will appear, and the turbine site will be highlighted in the middle of the map area. If the turbine site disappears as you are working with it, check that the turbine site button in the toolbar is in the down position, like this:



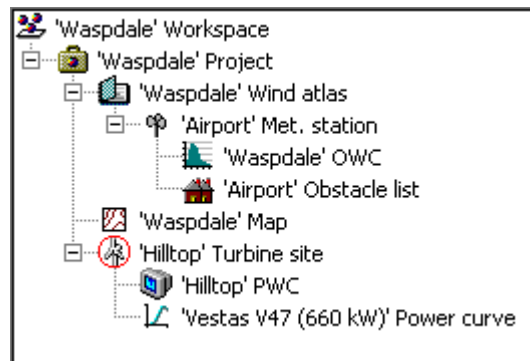
It is now possible to drag the turbine site in the map to the location you want. Put it on top of the hill in the west of the area, like this:



If you want to adjust the location of the site to an exactly specified position, then use the site dialog box, which can be reached at any time from the right-click menu of the turbine site icon in the workspace hierarchy. You can also call up the dialog box by right-clicking on the flag icon in the map.

Assigning the power curve

In order to predict how much power will be produced by the turbine, WAsP needs to know the power production characteristics of the turbine. You provide this information to WAsP by associating a power curve hierarchy member with the turbine site. From the turbine site's right-click menu, select **Insert from file**, and then choose 'Vestas V47 (660 kW).pow' when prompted. The hierarchy should now look like this:

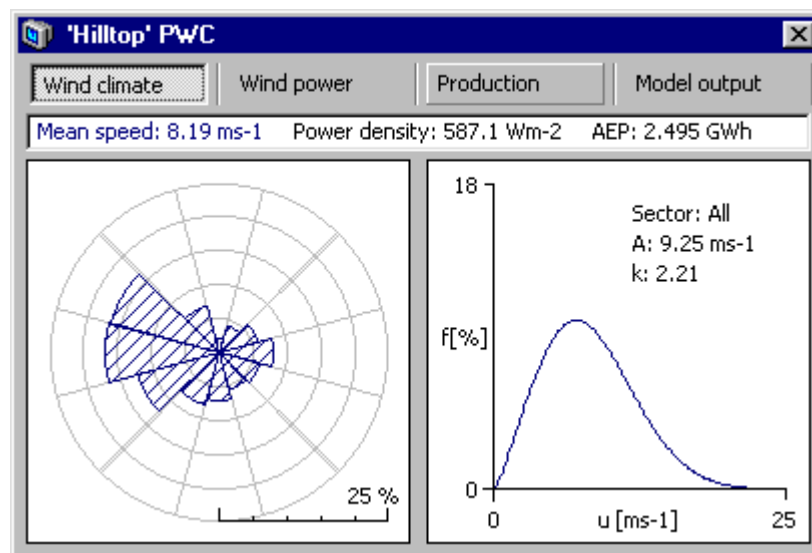


It is not yet possible to view the predicted wind climate, but you can open the power curve window and view the generating characteristics of the turbine.

Predicting the wind climate

WAsP is now ready to predict the wind climate for the turbine site. From the turbine site's right-click menu, select Calculate wind climate. As with the met. station, the small red ring surrounding the turbine site icon disappears as soon as the calculation is performed.

You can now open the predicted wind climate window to view the results:



The numbers shown above might differ slightly from those returned to you, because the location of the sites might not be exactly the same. WAsP has estimated that about 2.5 GWh per year would be generated by erecting a turbine on the hilltop. This number is referred to as the Annual Energy Production (AEP) in the predicted wind climate (PWC) window.

You can now return to the *Friends of Wind Energy, Waspdale Ltd.* and make your report!

There's a lot more to learn...

There's still a lot more to learn about the user interface of WASP, but as you have seen, you don't need to know about that in order to get work done. For first-time WASP users, it's important to understand more about what WASP is actually doing behind the scenes. WASP results are not useful unless the models' limitations are understood. Before using WASP for any real world applications, it's important to study the material, which explains WASP modelling in more detail.

The Modelling with WASP book of this help facility offers brief explanations to many aspects of the wind atlas methodology. For more comprehensive descriptions you should consult the Risø readings on wind power meteorology, in particular the European Wind Atlas. Details on specific topics may also be found in the publications in the References section.

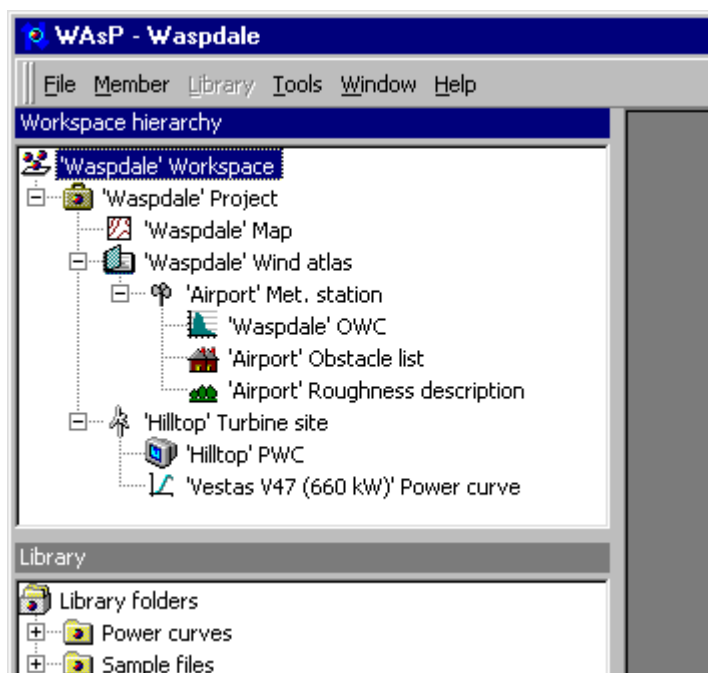
4.5 Sample data and workspaces

In addition to the sample data used for the Quick Start Tutorial, three sample workspaces are installed in the folder '\\WASP Workspaces\\Samples' during the installation: 'WASPdale', 'Wind farmer' and 'Resource grid'. You may **Open** any of these workspaces and study how typical WASP applications are set up in the workspace hierarchy.

A collection of sample wind turbine power curves are installed in the folder '\\Program Files\\WASP\\Power curves'. These are also available directly from the WASP Library.

Sample workspace #1: WASPdale

The 'WASPdale' workspace is an example of the classic WASP session: analysing the wind data from a met. station to obtain the regional wind climate (wind atlas) and then using the same wind atlas data set to predict the wind climate and power production at a nearby turbine site:



Note, that both the met. station and the turbine site are located in the same map; this is typical, but not necessary. The regional wind climate is assumed to be the same at both sites.

Sample workspace #2: Wind farmer

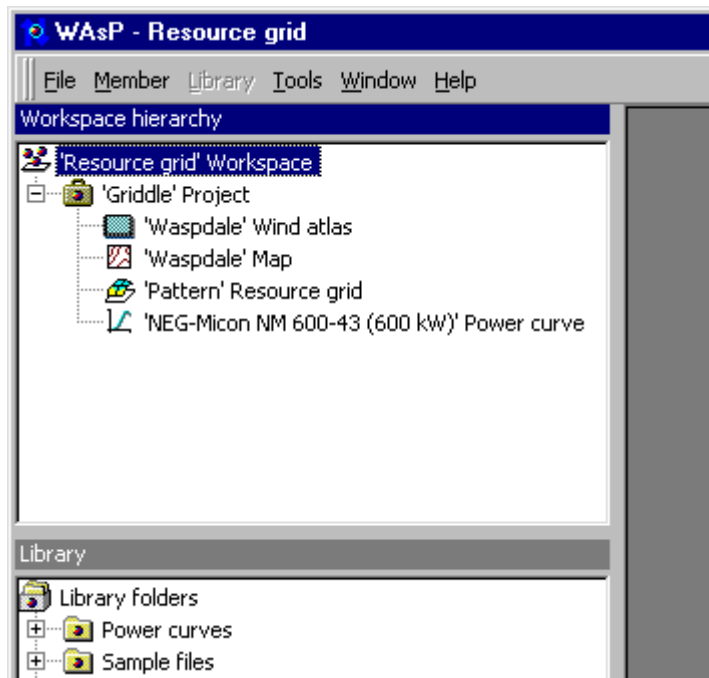
The 'Wind farmer' workspace is an example of another typical application: an existing wind atlas data set is used to predict the power production of several wind farms (or different layouts) in a given area:



Note, that the wind atlas, map and power curve are common to both wind farms.

Sample workspace #3: Resource grid

The 'Resource grid' workspace is an example of how to investigate the variation in the wind resource over an area: an existing wind atlas data set is used to predict the wind climate and power production of several wind turbine sites in a given area:



Again, the wind atlas, map and power curve are common to all the modelled wind turbine sites. The turbine sites are arranged in a regular grid and the resource grid can be used to establish a wind speed or power production map of the area – suitable for micro-siting of the actual turbine sites in a wind farm.

4.6 Auxiliary software tools...

WASP is a complete software package for wind data analysis, map editing, wind atlas generation, wind resource assessment and siting of wind turbines. Working with wind resource assessment and WASP in practice, however, requires other software as well. In addition to a general-purpose office package containing a word-processor, a spreadsheet and a database, the software mentioned below may come in handy if you use WASP on a regular basis.

Text editor

In order to create, view and edit the contents of text files you need a text editor. You can use **Notepad** to create or edit text files that do not require formatting and are smaller than 64K. Notepad opens and saves text in ASCII (text-only) format only. To create or edit files that require formatting or are larger than 64K, use **WordPad**. Both of these text editors are part of your Windows distribution.

File compression software

Some data and WASP files – in particular the time-series wind data, the terrain map and the resource grid files – can get rather large in size. Software for file compression and archiving is therefore important, especially if you transfer the files over the Internet or mail them on floppy disks. The **WinZip** package runs on Windows 95/98/NT4; an evaluation version is available from www.winzip.com.

Digitising software

The creation of a new map by digitisation of paper maps is not possible any more from within the WASP program. Three possible workarounds are described here. We recommend the **Didger** program from Golden Software for digitisation of maps. The BNA output format from this simple and cheap digitising package can be imported directly by WASP and the new map editor utility. More information

about this program is available from Golden Software. A demo version of the software is available [here](#).

Graphics and plotting software (2D)

The graphic displays of WAsP data, e.g. of the wind rose, speed distributions or the power curve, can be copied to the Windows clipboard and pasted into your printouts and reports. For even better quality graphics and publication-ready figures, however, you will need dedicated plotting and graphics software: the plotting routines of a spreadsheet program or, better yet, a scientific graphics software package like **Grapher** from Golden Software. A demo version of this software is available [here](#).

Graphics and plotting software (3D)

Many WAsP input data and results are *spatial* data: the contour and roughness maps, the wind farm layout and the wind resources over an area are important examples. It is of vital importance to be able to display these data and results in the best possible way, so it may be worthwhile to consider a plotting and graphics package specifically designed to illustrate spatial data. The **Surfer** package from Golden Software can make both 2D maps and 3D renderings of your WAsP data. A demo version of the software is available [here](#).

WAsP Utility Programs

The WAsP **Utility Programs** is a collection of DOS (16/32-bit) and Windows (W95/98/NT4) programs to calculate, analyze, convert, transform, translate, plot, and print WAsP-related data. A brief description of the main features of each utility program is given [here](#). Note, that a few utilities have been included in the present WAsP package.

4.7 And a 'real' toolbox

Site visits to met. stations and wind turbine / wind farm sites are a valuable, and often absolutely necessary, part of wind resource assessment and siting work. For this, you need a 'real' toolbox...

In the field

For site visits you will at least need the following:

- **Topographical maps** (1:25,000 to 1:100,000). Maps should preferably show the topography at the time of the collection of the met. data, or be as new as possible if you explore the wind resource for wind turbine site assessments. The contour line interval should be 20 m or smaller.
- **Compass** (360-degree). A good-quality, hand-held compass where the divisions are to the nearest degree. A sighting-type model is preferred for taking accurate bearings to nearby obstacles.
- **GPS receiver** (Global Positioning System). A battery-operated, hand-help GPS receiver should be preferred. Remember to use the datum setting corresponding to the map datum.
- **Camera** for taking photographs of the surroundings of the met. station and/or WTG position(s). Take sector-wise photographs from the site for each of twelve 30-degree sectors, as well as of the mast set-up and instruments.
- **Measuring tape**. A measuring tape of about 25 m or more, to measure the distances to nearby obstacles and, preferably, the actual height of the wind measuring equipment (however, never enter a mast or tower without the proper safety equipment!)
- **Summaries of wind measurements**. Summaries of the wind speed and

direction data from the met. station. Also, graphical presentations of the same: wind rose plot, wind speed histograms for each sector, etc. Similar information for predicted wind climates.

- **WAsP forms and checklist.** A number of sample forms are provided with the WAsP program. These may be used to record characteristics of the wind data, anemometer or wind turbine site, near-by obstacles and surrounding roughness.
- **Pocket calculator**, notebook, pencil and eraser.

In addition, the following items may come in very handy, though they are not absolutely essential:

- Binoculars
- Odometer or range-finder
- Aerial photographs or satellite imagery

In office

In addition to your PC and a high-quality printer, you may consider:

- **Digitising tablet** (A3 or larger) for digitising the height contour and roughness change lines from standard paper map sheets. The tablet will require software to run it, e.g. Didger from Golden Software.
- **Scanner** (flat-bed, A4 or larger) for scanning of background map images to be employed by the MapEdit program.

5 For users of the DOS versions

5.1 Welcome to the new WAsP

WAsP is 100% 32-bit Windows software, which runs under Windows 95, Windows 98, Windows NT 4.0 and Windows 2000. It conforms to standard windows software user-interface conventions, making it easy to learn and easy to use. A brief introduction to the program is given below.

New, faster ways of getting work done

WAsP allows you to organize your work in completely new ways. Operations that used to require batch files can now be accomplished by dragging and dropping with the mouse. A new hierarchical 'workspace' paradigm makes it possible to work with many sites at the same time, sharing wind atlases and maps between them. Proposals for large wind farms can be quickly created and investigated, with changes to contributing data being instantly reflected in all the affected results. Changes to the situation under investigation are made by simple, fast, drag-and-drop operations. By organising their work into exportable 'projects', users can easily share information with others. When projects are exported, all of the files necessary to re-open the same project on another computer are automatically copied into the new location. This also makes it easy to back up work in progress.

Backward-compatibility for existing users

Existing users of WAsP for DOS will be able to use most of their files without adjustments. A few new file formats have been defined, but most files, which worked under WAsP 4 and 5, will work perfectly well with WAsP. Despite the new user interface, it will be possible for 'old hands' to continue to use the same mental model of the WAsP system, while gradually starting to explore and make use of the new features.

A tried-and-tested wind resource calculation engine

Perhaps the most important feature of the new WAsP is an old feature! The WAsP calculation engine is the standard for wind resource calculations, and represents years of experience, refinement and testing. Some enhancements to the core calculation routines have been made for the new WAsP, but you can rest assured that the same algorithms that have made previous versions of the program so successful are working away at the heart of the new program.

5.2 Getting started...

We recommend that you work through the new version of Getting Started – the Quick Start Tutorial – to see for yourself what the new WAsP is all about. We hope that you come to like the new way of WAsP'ing even though it may take a little while before you are 'up-to-speed' again.

We have tried to provide the same – or better – functionality in the new version of WAsP. However, there might be some specific features you miss, or features of the old DOS versions you have come to like (!?). If this is the case we have some good news for you.

You can help us make a better WAsP!

Existing users of WAsP have a wealth of experience in wind resource assessment

and siting using the old WAsP programs. We therefore invite you to provide us with your feedback. Which old features do you miss the most? Which files have you got which you can only use with the old version? Which new features would you like to have built into WAsP? Your suggestions will – like our own ideas, the frequently asked questions and known issues – be recorded by the WAsP team and displayed on the WAsP home page.

5.3 Whatever happened to...

Where have all the good old WAsP features gone? This page provides a list of old features, which have been repackaged or renamed. There are explanations about what's changed and links to information about the new features.

RAWDATA – the meteorological data input routines

This function is now provided by a utility program called the OWC Wizard. This Wizard accepts raw data files and produces *.tab files. Table (or histogram) files are now called observed wind climate files, or OWC files. Hence the name OWC Wizard.

The output format is the same, so you can use *.tab files created with the old WAsP and the new Wizard interchangeably. The new Wizard does not yet accept binary files as raw data input, so you might need to use the old WAsP if you only have binary raw data files.

MAPDATA – the map input, display and editing routines

This function is now shared between WAsP, the new WAsP map editor utility and other software. The WAsP program accepts and can display map files containing height contour lines and roughness change lines. The editing of maps is taken care of by the WAsP map editor utility, from within which you can retrieve, edit, check and store maps. It is also possible to digitise scanned maps on screen using the mouse.

The creation of a new map file by digitisation of paper maps is not possible any more from within the WAsP program. Three possible workarounds are described here. We recommend the Didger program from Golden Software for digitisation of maps. The *.bna output format from this simple and cheap digitising package can be imported directly by WAsP and the new map editor utility.

Batch files - automating the program

You cannot use batch files with the new WAsP. We hope that the new workspace hierarchy structure will provide a flexible alternative way of performing multiple operations.

5.4 What on earth is...?

This page provides a list of features which are new, renamed or have been repackaged. There are explanations about what's changed and links to information about the new features.

OWC and the OWC Wizard

OWC stands for observed wind climate. This is just the good old *.tab file. The OWC Wizard is a utility program which builds a tab file from one or more raw data files. In the old WAsP, this was the RAWDATA feature.

User corrections

Corrections specified by the user were stored in the roughness description file (*.rds) in previous versions of WAsP. These corrections are now stored in a new user correction file (*.ucf). The site-specific roughness description (roughness rose) is now stored in a reformatted roughness description file (*.rrd).

5.5 Good news for DOS die-hards

Yes, we're still shipping the old ones...

It takes time to get acquainted to new software and changing your work routines; and even more time to get productive – or so it seems, at least. Therefore, we're still maintaining and supporting the DOS versions of WAsP: WAsP 4 (16-bit) and WAsP 5 (32-bit). These packages are included on the WAsP installation CD.

So, if you're comfortable with digitising maps 'the old way' or find it fast and efficient to use the old WAsP map editor, please go ahead: the new WAsP and WAsP map editor utility **MapEdit** both accept the map file formats from previous versions of WAsP.

5.6 File format changes

With only one exception, we have left the file formats unchanged for WAsP; the old roughness description file (*.rds) has been divided into a reformatted roughness description file (*.rrd) and a new user correction file (*.ucf). This change of files is described in more detail here.

In addition, an alternative extension has been defined for resource grids (*.wrg), i.e. resource files established with the grid option. The old *.rsf extension can still be used, but in some circumstances, WAsP will be unable to distinguish between a resource grid file with the *.rsf extension and a wind farm file with the *.rsf extension.

Note, that WAsP handles only a subset of the file formats handled by previous versions of WAsP. In addition, some file formats may be updated or changed completely with time. Descriptions of the different file formats recognised by WAsP are given in the Technical Reference section.

6 Feedback and support

6.1 Reporting problems

If you have any problems using the WAsP software, please send an e-mail to wasp.support@risoe.dk. If you do not have e-mail, you may send a fax to the number given here.

Don't hesitate

Don't hesitate to send some feedback, even if you are not sure whether it is a bug, a suggestion or just a question. Information about any user difficulty is really valuable, even if they are not caused by program errors. Some users are shy making of bug reports because they wrongly assume that the error it is somehow 'their fault', because they don't fully understand the program. Please, don't hesitate to report a problem to us.

Check the bugs list and FAQ

A list of known issues will be maintained at www.wasp.dk. You may also want to check the list of Frequently Asked Questions (FAQ) which will be maintained at the same address.

Check that you have the latest version

The latest version of the WAsP program can be downloaded from www.wasp.dk in the form of an update file to the main installation on the CD-ROM.

Provide the version number

Let us know which version of WAsP you are using (please provide the full version number). Please also mention which operating system you are running.

Tell us how to reproduce the error

Before you report the problem, try to make it happen again. Include a description of how to reproduce the bug when you send the bug report.

Provide the program's own error description

When WAsP shows you an error message, you can request details. When the details are showing, you can press the 'Copy' button to put a complete exception report onto the Windows system clipboard. Paste this into the e-mail you send.

Provide the file

If the software is having problems with a particular file, then please send it (zipped) along with the description. If the file is bigger than 50 kb, then e-mail first so that we can arrange a more appropriate way of transferring the file.

Provide the whole project

To fix a bug, it is sometimes helpful to be able to reproduce the situation you're describing. The easiest thing is to have the whole project. You can export the whole project to a directory on your computer, then zip it up and send it along with the feedback message. Again, if the resulting file is bigger than 50 kb, then send an e-mail first and we can arrange another way of transferring the file.

6.2 Making suggestions

The future development of WAsP could depend on you! Even though we have

many ideas ourselves for the future development of the WAsP program, its user interface and built-in models, we welcome very much your suggestions and requests for new features.

Which features to include and how to implement them depend strongly on the response we get from the WAsP users. Please e-mail or fax your comments and suggestions to the addresses given here.

Beginning with the release of WAsP 6 we will maintain a list of the WAsP team's own ideas and the suggestions already received from the users at the WAsP home page.

6.3 Frequently Asked Questions (FAQ)

Beginning with the release of WAsP 6 we have established and will maintain this list of Frequently Asked Questions; regarding the use of WAsP and WAsP-related software. Unless otherwise stated, the Q&A's refer to the latest version of WAsP, even though most of the information may be valid for previous versions as well.

How can I use Surfer to make a wind resource map of an area?

Golden Software's Surfer program can read and utilize WAsP's wind farm (RSF) and resource grid files (WRG) directly. In the **Grid** menu of Surfer, choose **Data** and enter the name of the wind farm or resource grid file. You will then get the message "File type not recognised!". Choose 'ASCII Data (.TXT)' and press the 'Ok' button. You may then get the message "Surfer error: Current data columns do not contain 3 or more distinct XYZ points". Disregard this message and carry on, specifying the **Data Columns** used for the X and Y coordinates and the wind power density/power production: column B contains the X coordinate, column C the Y coordinate and column H the power density or power production. Surfer can now make a grid from the data in the usual way – and a map of the wind resource can be made.

You can also make Surfer recognize these file types by adding the following two lines to the file Surfer32.ini – in the [GS Worksheet Import Filters] section – using a text editor like Notepad:

```
WAsP Wind Farm=WSIDAT32.DLL;RSF;GSdata
WAsP Resource Grid=WSIDAT32.DLL;WRG;GSdata
```

How can I generate a WAsP map from gridded data or spot heights?

The Surfer program can make a contour map of an area from spot heights given in a regular grid; a so-called digital elevation model. The grid data may be input directly or it can be generated by Surfer from irregularly spaced spot heights. The Surfer program can further be employed to edit the map contents, e.g. the map limits and contour interval. The height contours of the map can be exported as a 3-D DXF-file from Surfer's **Map** menu (**Contour Map/Export Contours**). This DXF-file can be converted into a WAsP MAP-file by the WAsP Utility Program dxf2map.exe.

Gridded height data can also be transformed directly into a WAsP MAP-file using the WAsP Utility Program grd2map.exe. This program reads Surfer ASCII GRD-files and writes WAsP MAP-files. The vertical contour interval and elevation range for extracted contours may be specified by the user.

6.4 WAsP courses and training

The Wind Power Meteorology Program at Risø offers courses and training in wind resource assessment, site characterization, use of the WAsP software and application of the wind atlas methodology.

Standard WAsP course

Realistic assessment of the wind resource is a key parameter in any wind energy project – large or small. The course aims at providing practical experience and confidence in wind data analysis, wind climate estimation and power production calculations – using the WAsP program, a state-of-the art collection of PC tools developed specifically for these purposes.

The standard WAsP course is scheduled for 2½ days and is held every year, at Risø or abroad. The number of participants is usually about 10 to 15 and we aim at providing one teacher for every five participants. An outline of the contents of the course is given here and more detailed information here.

Specific WAsP courses and training

In addition to the standard WAsP course, Risø offers courses and training tailored specifically to meet the needs of a particular institution, company or wind energy project. Such training is usually carried out at the premises of the client and may further include training in e.g. siting of wind-monitoring stations, met. station analysis, site characterization, and reporting of the wind resource assessment activities. Please contact Lars Landberg for more information and a quotation.

Project supervision and QA

For the experienced WAsP user, Risø can offer to review the data and results of any wind resource assessment project – whether wind atlas, wind resource map, wind farm production calculation, or tender document – in order to assure the quality of the work. This transfers the latest knowledge and further build the capacity of your company or institution. Please contact Lars Landberg for more information and a quotation.

6.5 WAsP Utility Programs

The WAsP Utility Programs is a collection of DOS (16/32-bit) and Windows (W95/98/NT) programs to calculate, analyze, convert, transform, translate, plot and print WAsP-related data. A brief description of each utility program is given below. Note, that a few utilities are now included in the WAsP package.

Wind-climatological fingerprint

As in the European Wind Atlas. Fingerprint page with graphs (*.ps or *.plt file) and X-tables (*.txt or *.tex) of daily/yearly and monthly/yearly mean wind speeds.

Fitting Weibull distribution functions

Generates measured and fitted data (*.dat) for e.g. plotting the total and sector-wise wind speed distributions from an Observed Wind Climate file (*.tab). Summary table (*.txt or *.tex) in two different layouts. Conversion of any old WAsP-for-DOS *.tab-file format to the new standard WAsP-for-Windows format.

Plotting the histogram and wind rose

Generates data and Grapher files for plotting the wind speed and direction distributions. Data can be used with other plotting programs as well.

Weibull distribution characteristics

Statistics and data files (on screen and *.dat) for a given Weibull distribution (A and k parameters). Total power density and window (e.g. 0-25 ms⁻¹) power density. Power production from specified power curve. Data file suitable for plotting.

Plotting the obstacle set-up

Generates data and DOS Grapher files for plotting an obstacle set-up.

Coordinate transformation

Coordinate transformation (ED50 and WGS84) of single points, lists of points and WASP ASCII *.map files:

- Latitude/longitude to UTM
- UTM to latitude/longitude
- UTM to UTM (zone 32 and 33 only)
- Un-scaling a WASP ASCII map file to absolute coordinates
- Conversion of WASP *.map file to *.bln and *.xyz files as well

Conversion of vector map formats

- AutoCAD *.dxf to WASP *.map file (ASCII *.dxf-file subset only)
- Atlas *.bna to WASP *.map file (Didger *.bna file)
- MapGen *.dat to WASP *.map file (Coastline Extractor *.dat file)

Transformation of map and grid files

- Map to grid transformation: WASP *.map file to Surfer *.grd file
- Grid to map transformation: Surfer *.grd file to WASP *.map file

Ruggedness index (included in WASP)

Calculates the ruggedness index (RIX value) for a single site or for multiple sites given in an RSF-file. Input is a WASP map file. Results for site overall and for each sector.

Map editing (included in WASP)

Map editing features like WASP in a Windows environment (W95/98/NT). Roughness line analysis, e.g. joining these where they meet in node points and pointing out lines where the roughness values are in conflict. On-screen digitisation of scanned maps.

Interpolation of wind atlas data sets

Generation of an 'artificial' WASP wind atlas data set (*.lib file) by spatial interpolation between three other stations/*.lib-files. This is a Windows program.

Plotting the power- and thrust-curves

Generates data and Grapher files for plotting the power-and c_p -curves. Data can be used with other plotting programs as well.

Resource- to grid-file conversion

Calculation of Surfer grid files containing Weibull A , Weibull k , mean wind speed, mean power density, terrain elevation, or power production. Grid may contain absolute or normalised values. Export to (x, y, z) file as well.

Air density calculator

Calculation of air density from the elevation/altitude and mean air temperature at the site.

Printing wind atlas files

Generates text or LaTeX file, resembling the right-hand-side pages of the European Wind Atlas, from a WAsP *.lib file.

PostScript BoundingBox

Finding the BoundingBox of encapsulated PostScript files (*.eps), e.g. Grapher and Surfer for DOS output files.

Sample station description

Proposal for a comprehensive, yet compact, standard description of a wind-measuring station, based on the outputs from WAsP and the Utility Programs.

Further information and ordering

More information can be obtained by contacting the WAsP team at Risø. You can place an order at the WAsP home page. Bug fixes and updates will be available for download from the WAsP home page.

6.6 WAsP Engineering

WAsP Engineering is a computer program for the estimation of extreme wind speeds, wind shears, wind profiles and turbulence in complex terrain. Version 1.0 was launched in July 2001 at the European Wind Energy Conference and Exhibition in Copenhagen.

The purpose of WAsP Engineering is to support the estimation of loads on wind turbines and other civil engineering structures situated in complex terrain. The wind properties that are treated are:

1. **Extreme wind speeds**, e.g. the 50-year wind. If a wind turbine is well situated on a hill the mean wind speed and thereby the power production can be increased significantly compared to that over flat terrain. Unfortunately, the 50-year wind will increase correspondingly, maybe calling for increased strength of the blades or other parts of the turbine.
2. **Wind shears and wind profiles**. Strong mean wind shears (large differences in the mean wind speed over the rotor) give large fluctuating loads and consequently fatigue on the wind turbine blades, because the blades move through areas of varying wind speed.
3. **Turbulence**. Turbulence (gusts of all sizes and shapes) causes dynamic loads on various civil engineering structures, including wind turbines. The strength of the turbulence varies from place to place. Over land the turbulence is more intense than over the sea. Also the hills affect the structure of turbulence. We model various terrain dependent properties of turbulence.

A report on the prototype (which is not the same as the test release) of the program finalised May 2000 may be downloaded here. Please visit the of WAsP Engineering home page for more information.

6.7 The WAsP/KAMM method

The wind is simulated with the Karlsruhe Atmospheric Meso-scale Model KAMM using a large-scale climatology, e.g. from the NCEP/NCAR reanalysis data set. Wind atlas files are generated from the simulated winds. The wind atlas files can be read by WAsP to predict the very local wind climate using the local topography. Please visit www.mesoscale.dk for more information.

6.8 Contacting the WAsP team

For general inquiries, sales support, shipping, invoicing etc. send an e-mail to **wasp@risoe.dk**.

To apply for a licence, send your machine ID number to **waspllicence@risoe.dk**, quoting your user name.

If you have any problems using the WAsP software, please send an e-mail to **waspsupport@risoe.dk**. This way your problem and questions will be registered properly and distributed to the right person in the WAsP team.

E-mail: niels.g.mortensen@risoe.dk
 ole.rathmann@risoe.dk
 lars.landberg@risoe.dk
Web: http://www.wasp.dk
Fax: +45 46 77 59 70
Phone: +45 46 77 50 97 (Ms. Rikke Nielsen)
Post: Wind Energy Department
 Risø National Laboratory, VEA-125
 DK-4000 Roskilde, Denmark

7 Other information sources

7.1 European Wind Atlas

The European Wind Atlas was published in 1989 for the Commission of the European Communities by Risø National Laboratory. It is a hardback book of 656 pages with 16 colour maps and a data disk. The European Wind Atlas is:

- **A data bank** of European wind climate: it contains comprehensive wind statistics from more than 200 stations covering the entire EC (1989), plus colour maps of the wind resources of each EC country.
- **A handbook** for regional wind resource assessment and the local siting of wind turbines, including computational procedures for the effects of shelter, roughness and orography on power production.
- **The basis** for reliable estimates of the wind resources in the EC countries (1989), whether on a regional scale or at a specific site.

Contents of the Atlas

The Atlas is divided into three parts, each intended for readers with different areas of interest – from laymen to professional meteorologists:

Part 1: The Wind Resource provides an overall view of the wind climate and magnitude and distribution of wind resources in the European Community countries. This part of the Atlas is intended to be useful to politicians, planners and laymen in general. The descriptions, figures, tables and colour maps permit a first, rapid identification of regions with favourable wind resources.

Contents of Part 1: The wind climate of Europe • Wind resource maps.

Part 2: Determining the Wind Resource gives explanations and information needed for the purpose of regional wind resource assessments and the local siting of wind turbines. In addition, it contains descriptions, raw statistics, and wind atlas statistics for 220 meteorological stations in the EC. It also includes methods for calculating the influence on the wind resource of various features in the landscape such as coastlines, forests, hills, and buildings.

Contents of Part 2: General concepts • The roughness of a terrain • Shelter behind obstacles • The effect of height variations in the terrain • Regional wind energy potential • Use of the wind resource maps • Siting • Selection of wind climatology for a site • Roughness classification • Calculation of statistics for a site • Calculation of shelter • Orography • Power production • Determination of mean power production • Power density function • Power duration curve • Optimisation of power production • Station statistics and climatologies • Station description • Raw data summary • Regional climatology and mean values • Windclimatological fingerprints • Station statistics and climatologies • Radiosonde statistics.

Part 3: The Models and the Analysis explains in detail the meteorological background for the Wind Atlas. It describes how the analysis was performed from the data and station information, and discusses the physical and statistical basis for the Wind Atlas models. The validity of the models and the analysis is demonstrated through a number of comparisons between measured and modelled wind statistics.

Contents of Part 3: The physical basis • Surface-layer similarity laws • The geostrophic drag law and the geostrophic wind • The stability model • The roughness change model • The shelter model • The orographic model • The statistical basis • The Wind Atlas analysis model • The Wind Atlas application model • Meteorological data and station description • Radiosonde statistics • Limitations of data and models • Verification of the Wind Atlas methodology • Station intercomparisons • Validation against high meteorological masts • References • List of symbols • Auxiliary tables • Selection criteria and questionnaire • The data disk.

Non-English translations

The text of the Atlas has been translated into French, German, Italian, and Spanish. These translations contain the entire text of the Atlas as well as the statistical tables of the French, German, Italian, and Spanish stations, respectively. One non-English edition may be supplied free of charge when purchasing the English reference edition.

Application of the Atlas

The Atlas is the meteorological basis for estimating the wind climate and wind energy resources of any particular site in the EC. The application of the Atlas as a siting handbook is explained in detail in the Atlas.

To facilitate resource calculations and specific siting of wind turbines, the Wind Atlas is furnished with a disk containing all the regional statistics. The disk files can be used directly with the "Wind Atlas Analysis and Application Program" (WASP), which was especially developed for the production of the Wind Atlas and for use in practical siting. The WASP program is not included in the Atlas, but can be obtained from Risø National Laboratory.

Data disk

The observed and model-derived wind statistics from the 220 meteorological stations are furnished on a data disk together with the Atlas – for use with a PC or compatible computer. The data consists of the observed and modelled wind rose and wind speed distributions for each station.

From the Foreword

"The European Wind Atlas is a major outcome of the European Communities' overall effort to promote the market for electricity production from the wind resource in Europe and to develop the technologies and systems associated with it.

This Atlas completes the information previously published in several national wind atlases, and it will doubtless become an essential tool for all planners of wind energy applications in the Community. The data in this new European Atlas are far more comprehensive than those given in previous works. Moreover, this Atlas provides for the first time a coherent overview of all the EC countries, including the large regions with complex terrain. The latter was a major achievement because reliable computer codes had to be developed especially for this task...

I trust that all those interested in the future development of wind energy utilisation in Europe will appreciate this vast work and benefit from the comprehensive information it provides in their future activities."

– Dr. W. Palz, Commission of the European Communities (DGXII)

The reviewers wrote

"This book is a welcome attempt to quantify the meteorological aspects of the wind power available within the parts of Europe belonging to the European Community. The economic viability of generating electricity from the wind is very dependent on not only the mean wind speed but also the distribution of the wind speed at a location. This book addresses this with an examination of 10 years' data from 220 meteorological stations across Europe." – K.L. Simms, *Weather* (1)

"The European Wind Atlas ... uses high quality surface wind observations as its primary data source. The key factor in the development of the atlas has been to transform the measured winds at specific sites into regionally representative values and climatologies. It is this step which sets this work apart from most other wind energy resource studies and has led to a consistent and reliable atlas...

Notwithstanding the weight, I strongly recommend the Atlas to all interested in wind energy and wind climatologies and, for other readers of Boundary-Layer Meteorology, I commend this as an example of the successful, well documented analysis of a complex micro-meteorological issue." – P. Taylor, *Boundary-Layer Meteorology* (2)

"While wind energy research in the United States starved from lack of funding during the last decade, progress continued in Europe. Denmark established a reputation for designing and manufacturing the world's finest modern wind turbines. The publication of the European Wind Atlas by the Risø Laboratory now confirms Denmark as a world leader in wind resource assessment as well... As the twentyfirst century approaches and the environmental wounds of fossil fuel consumption become more severe, wind and solar energy alternatives will certainly become more attractive. The European Wind Atlas is an important contribution toward the utilization of a major renewable energy resource. It is an essential reference for scientists and engineers involved with wind energy work in Europe as well as for serious students of Europe's climate. It can also serve world-wide as a guide for sophisticated wind energy resource assessment." – B. Martner, *Bulletin of the American Meteorological Society* (3)

(1) *Weather* is published by the Royal Meteorological Society. (2) Reprinted by permission of Kluwer Academic Publishers. (3) Reprinted by permission of the American Meteorological Society.

7.2 Wind Atlases of the World

The wind atlas methodology and the WAsP program has been applied in more than 80 countries and territories around the world for national, regional and local studies. A list of major national and regional studies – several of which contains WAsP data files on disk – is given below. The world according to WAsP is shown below.

Algeria

Hammouche, R. (1991). Atlas Vent de l'Algérie. In French. Office National de la Météorologie, Alger. 150 pp.

Australia

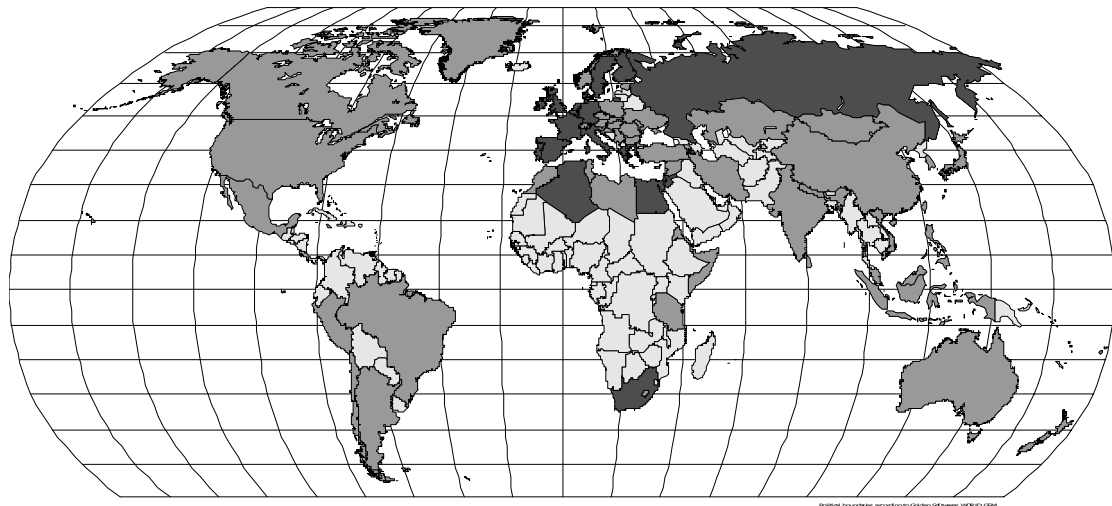
Dear, S.J., M.J. Bell and T.J. Lyons (1990). Western Australian Wind Atlas. Report No. 64, Minerals and Energy Research Institute of Western Australia, Perth. 28 pp. + 14 App.

Belgium

European Wind Atlas (1989), see Europe.

Brazil

Barbezier, G.L., E.A. Feitosa and J.S. Rohatgi (1999). Wind Atlas for the Northeast Region of Brazil. WANE version 1.0. Brazilian Wind Energy Centre, Recife. 46 pp.



Denmark

Petersen, E.L., I. Troen, S. Frandsen and K. Hedegaard (1981). Wind atlas for Denmark. A rational method for wind energy siting. Risø-R-428. Risø National Laboratory, Roskilde. 229 pp.

European Wind Atlas (1989), see Europe.

Mortensen, N.G., L. Landberg, O. Rathmann, G. Jensen and E.L. Petersen (1999). Wind Atlas Analysis of 24 Danish Stations (1987-96). In preparation for publication as Risø-R-1092(EN). Risø National Laboratory, Roskilde.

Egypt

Mortensen, N.G. and Usama Said Said (1996). Wind Atlas for the Gulf of Suez. Measurements and modeling 1991-95. ISBN 87-550-2143-3. Risø National Laboratory, Roskilde; New and Renewable Energy Authority, Cairo. 114 pp.

Europe

Troen, I. and E.L. Petersen (1989). European Wind Atlas. ISBN 87-550-1482-8. Risø National Laboratory, Roskilde. 656 pp.

Finland

Tammelin, B. (1991). Suomen Tuuliatlas. Vind Atlas för Finland (Wind Atlas for Finland). In Finnish/Swedish. Finnish Meteorological Institute, Helsinki. 355 pp.

France

European Wind Atlas (1989), see Europe.

Germany

European Wind Atlas (1989), see Europe.

Traup, S. and B. Kruse (1996). Wind und Wind-energiepotentiale in Deutschland. Winddaten für Windenergienutzer. In German. Selbstverlag des Deutschen Wetterdienstes, Offenbach am Main. 445 pp.

Greece

European Wind Atlas (1989), see Europe.

Greenland

Mortensen, N.G. and L. Landberg (1993). Wind Energy in selected townships of Greenland: Qasigianniguit, Sisimiut and Narsaq. In Danish. Prepared for Nukissiorfiit/Greenland Power Company. Risø-I-718(DA). Risø National Laboratory, Roskilde. 37 pp.

Ireland

European Wind Atlas (1989), see Europe.

Watson, R. and L. Landberg (1999). The Irish Wind Atlas. University College Dublin, Dublin. In preparation.

Italy

European Wind Atlas (1989), see Europe.

Jordan

Højstrup, J. (1989). Wind Atlas for Jordan. Risø National Laboratory, Ministry of Energy and Mineral Resources, Jordan Electrical Authority, and Jordan Meteorological Department. 86 pp.

Luxembourg

European Wind Atlas (1989), see Europe.

The Netherlands

European Wind Atlas (1989), see Europe.

Portugal

European Wind Atlas (1989), see Europe.

Russia

Rathmann, O. (1998). Wind atlas analysis for 12 meteorological stations on the Kola Peninsula. Risø-I-1285(EN). Risø National Laboratory, Roskilde. 36 pp.

Starkov, A.N., L. Landberg, P.P. Bezroukikh and M.M. Borisenko (2000). Russian Wind Atlas. ISBN 5-7542-0067-6. Russian-Danish Institute for Energy Efficiency, Moscow; Risø National Laboratory, Roskilde. 551 pp.

South Africa

Diab, R. (1995). Wind Atlas of South Africa. Department of Mineral and Energy Affairs, Pretoria, 136 pp.

Spain

European Wind Atlas (1989), see Europe.

Sweden

Krieg, R. (1992). Vindatlas för Sverige (Wind Atlas for Sweden). In Swedish.

Slutrapport på projekt 506 269-2 på uppdrag av NUTEK. SMHI, Norrköping. 26 pp.

Krieg, R. (1999). Verifiering af beräknad vind-energiproduktion (Verification of estimated wind power productions). In Swedish. SMHI rapport Nr. 28, SMHI, Norrköping. 25 pp + appendices.

United Kingdom

European Wind Atlas (1989), see Europe.

United States of America

Artig, R. (1999). Minnesota Wind Resource Assessment Program. March 1999 report. Minnesota Department of Public Service, St. Paul. 157 pp.

7.3 Database on Wind Characteristics

This is a database of wind time-series intended primarily for wind (turbine) design purposes. Here you can find high-resolution (1-40 Hz) time-series, measured under different conditions at 32 different locations inside Europe and United States.

The database is compiled and maintained in Denmark by Kurt S. Hansen, Technical University of Denmark (DTU). The operation and maintenance is funded by Sweden, Norway, The Netherlands, United States and Denmark as an IEA Annex (XVII, operating agent Risø National Laboratory).

More than 53.000 hours of wind speed measurements are available in the database right now (as of 21 July 2000) and wind turbine structural measurements together with wind speed measurements will be included very soon. Further information is given in a folder and in the final project report, both of which may be downloaded from the Web-site.

Visitors are invited to browse through the wind statistics and view time-series (login as guest user). Registered users will obtain access to the advanced search facilities, download of wind statistics and time-series. Structural load measurements are also included in the database!

For further information on this database, please contact winddata@et.dtu.dk.

7.4 Risø readings in wind power meteorology

This is a list of selected papers, reports and published conference proceedings authored by or in collaboration with the staff of the Wind Power Meteorology Program of the Wind Energy Department.

Wind power meteorology in general

Petersen, E.L., N.G. Mortensen, L. Landberg, J. Højstrup and H.P. Frank (1998). Wind Power Meteorology. Part I: Climate and turbulence. Wind Energy 1, 2-22.

Petersen, E.L., N.G. Mortensen, L. Landberg, J. Højstrup and H.P. Frank (1998). Wind Power Meteorology. Part II: Siting and Models. Wind Energy 1, 55-72.

Troen, I. and E.L. Petersen (1989). European Wind Atlas. ISBN 87-550-1482-8. Risø National Laboratory, Roskilde. 656 pp.

Wind measurements

Kristensen, L. (1998). Cup anemometer behavior in turbulent environments. *J. Atmos. Ocean. Technol.* 15, 5-17.

Kristensen, L. (1999). The perennial cup anemometer. *Wind Energy* 2, 59-75.

Mortensen, N.G. (1994). Wind measurements for wind energy applications – a review. *Wind Energy Conversion 1994. Proceedings of the 16th British Wind Energy Association Conference, Stirling, June 15-17*, 353-360.

Mortensen, N.G. (1994). Flow-response characteristics of the Kaijo Denki omnidirectional sonic anemometer (DAT 300/TR-61B), Risø-R-704(EN), Risø National Laboratory, Roskilde, Denmark, 32 pp.

Mortensen, N.G., and J. Højstrup (1995). The Solent sonic – response and associated errors. *Ninth Symposium on Meteorological Observations and Instrumentation, Charlotte, NC, March 27-31*, 501-506.

WAsP and wind modelling

Bowen, A.J. and N.G. Mortensen (1996). Exploring the limits of WAsP: the Wind Atlas Analysis and Application Program. *Proceedings of the 1996 European Union Wind Energy Conference and Exhibition, Göteborg, Sweden, May 20-24*, 584-587.

Frank, H.P. and L. Landberg (1997). Modelling the wind climate of Ireland. *Boundary-Layer Meteorol.* 85, 359-378.

Landberg, L. (1997). The mast on the house. In *proceedings from BWEA 19, Edinburgh, 16-18 July*, ed. R Hunter, 167-172.

Mortensen, N.G. and E.L. Petersen (1998). Influence of topographical input data on the accuracy of wind flow modeling in complex terrain. *Proceedings of the 1997 European Wind Energy Conference and Exhibition, Dublin, Ireland, October 6-9*, 317-320.

Walmsley, J.L., I. Troen, D.P. Lalas and P.J. Mason (1990). Surface-layer flow in complex terrain: Comparison of models and full-scale observations. *Boundary-Layer Meteorol.* 52, 259-281.

Wind atlases

Mortensen, N.G. and Usama Said Said (1996). *Wind Atlas for the Gulf of Suez. Measurements and modeling 1991-95*. ISBN 87-550-2143-3. Risø National Laboratory, Roskilde, and New and Renewable Energy Authority, Cairo. 114 pp.

Mortensen, N.G., P. Nielsen, L. Landberg, O. Rathmann and M. Nielsen (1999). A detailed and verified wind resource atlas for Denmark. *Proceedings of the Tenth International Conference on Wind Engineering, Copenhagen, Denmark, 21-24 June. 2013-2018*.

Troen, I. and E.L. Petersen (1989). *European Wind Atlas*. ISBN 87-550-1482-8. Risø National Laboratory, Roskilde. 656 pp.

Petersen, E.L., I. Troen, S. Frandsen and K. Hedegaard (1981). *Windatlas for Denmark. A rational method for wind energy siting*, Risø-R-428, Risø National Laboratory, Roskilde, Denmark. 229 pp.

Short term prediction

Landberg, L., and S.J. Watson (1994). Short-term prediction of local wind conditions. *Boundary-Layer Meteorol.* 70, 171-195.

Landberg, L. (1999). Short-term prediction of the power production from wind farms. *J. Wind Eng. Ind. Aerodyn.* 80, 207-220.

7.5 On the Web

For general information about wind power, as well as links to other web sites related to wind power, a good place to start is www.windpower.org, the award-winning home page of the Danish Wind Turbine Manufacturers Association. A recent download of this entire home page is provided on the WASP distribution disk.

Wind atlases, wind data and wind characteristics

For information on the wind climate of a particular country or region, you might check the list of wind atlases given here. The national or state meteorological service may also be able to help you; the national weather services are organised in the World Meteorological Organisation. For information on the detailed wind and turbulence characteristics of a given site or type of site, you might check the Database on Wind Characteristics.

Topographical and elevation data

The topographical information needed by WASP consists of a roughness map and a height contour map. These digital maps are usually constructed by digitisation of ordinary, large-scale topographical (paper) maps. However, elevation and/or land-use information may already be available in digital form, in which case this information may be converted into WASP-compatible maps. The national or state survey and cadastre should be able to help you find out whether such data exist.

World coast lines

The coastline is a very important elevation and roughness-change line; you can download the geographical coordinates of coastlines around the world using the Coastline Extractor. You can also download the coordinates of lakes, rivers and political boundaries from this site. An example of a map based on these data is given here.

World elevation data

Global elevation and land-cover data are also available over the Internet, e.g. from the Distributed Active Archive Center of the USGS EROS Data Center. The 'Global 30 Arc-Second Elevation Data Set' contains spot heights of node points in a grid with 30 arc-second resolution (926 m or smaller). These data are not detailed enough for WASP flow modelling, but may be used for overview maps of a region or country; an example of such a map is given here.

Wind turbine and rotor blade manufacturers

For specific information on the characteristics of a particular wind turbine, you should contact the manufacturer directly. A list of major Danish wind turbine and rotor blade manufacturers is given below.

Contact details	Internet home page	E-mail address
Bonus Energy A/S	www.bonus.dk	bonus@bonus.dk
NEG Micon A/S	www.neg-micon.dk	mail@neg-micon.dk
Nordex A/S	www.nordex.dk	nordex@nordex.dk

Norwin A/S	www.norwin.dk	info@norwin.dk
Vestas Wind Systems A/S	www.vestas.dk	vestas@vestas.dk
Wincon West Wind A/S	www.wincon.dk	emn@wincon.dk
LM Glasfiber A/S	www.lm.dk	info@lm.dk

7.6 References

The publications cited in this help facility are listed below.

- Beljaars, A.C.M, J.L. Walmsley and P.A. Taylor (1987). A mixed spectral finite-difference model for neutrally stratified boundary-layer flow over roughness changes and topography. *Boundary-Layer Meteorol.* 38, 273-303.
- Beyer, H.G., T. Pahlke, W. Schmidt, H.-P. Waldl and U. de Witt (1994). Wake effects in a linear wind farm. *J. Wind Eng. Ind. Aerodyn.* 51, 303-318.
- Bowen, A.J. and N.G. Mortensen (1996). Exploring the limits of WAsP: the Wind Atlas Analysis and Application Program. *Proceedings of the 1996 European Union Wind Energy Conference, Göteborg, Sweden, May 20-24*, 584-587.
- Bowen, A.J. and N.G. Mortensen (1999). WAsP prediction errors due to site orography. *Risø-R-995(EN)*. Risø National Laboratory, Roskilde. In preparation.
- Charnock, H. (1955). Wind stress on a water surface. *Quart. J. Roy. Meteor. Soc.* 81, 639-640.
- Jackson, P.S. and J.C.R. Hunt (1975). Turbulent wind flow over a low hill. *Quart. J. Roy. Met. Soc.* 101, 929-955.
- Jensen, N.O. (1984). A Note on Wind Generator Interaction. *Risø-M-2411*, Risø National Laboratory, Roskilde. 16 p.
- Jensen, N.O, E.L. Petersen and I. Troen (1984). Extrapolation of mean wind statistics with special regard to wind energy applications. *World Meteorological Organization, WCP-86*. 85 pp.
- Katic, I. (1986). Wind conditions in wind farms (Vindforhold i mølleparker). In Danish. *Risø-M-2582*. Risø National Laboratory, Roskilde. 38 p.
- Katic, I., J. Højstrup, and N.O. Jensen (1986). A Simple Model for Cluster Efficiency. *Proceedings of EWEC'86 European Wind Energy Association, Conference and Exhibition, Rome, 7-9 October 1986*. Eds. W. Palz and E. Sesto. Published by A. Raguzzi, Rome, Vol. I, 407-410.
- Lettau, H. (1969). Note on aerodynamic roughness-parameter estimation on the basis of roughness-element distribution. *J. Appl. Met.* 8, 828-832.
- Mortensen, N.G. and E.L. Petersen (1997). Influence of topographical input data on the accuracy of wind flow modelling in complex terrain. *Proceedings of the 1997 European Wind Energy Conference, Dublin, Ireland, October 6-9*, 317-320.
- Perera, M.D. (1981). Shelter behind two-dimensional solid and porous fences. *J. Wind Engin. and Industrial Aerodyn.* 8, 93-104.

Petersen, E.L., I. Troen, S. Frandsen and K. Hedegaard (1981). Windatlas for Denmark. A rational method for wind energy siting. Risø-R-428. Risø National Laboratory, Denmark. 229 pp. Risø-R-428, 229 pp.

Petersen, E.L and I. Troen (1986a). Estimation of wind resources. In: Wind Energy in Denmark. Research and technological development. Ed. Fl. Øster. Published by the Danish Ministry of Energy, 29-36.

Petersen, E.L. and I. Troen (1986b). The European Wind Atlas. Proceedings of the European Wind Energy Association Conference and Exhibition, Rome, October 7-9, 1986, 191-200.

Rathmann, O., N.G. Mortensen, L. Landberg and A. Bowen (1996). Assessing the accuracy of WASP in non-simple terrain. Wind Energy Conversion 1996. Proceedings of the 18th British Wind Energy Association Conference, Exeter, England, 25-27 September 1996, 413-418.

Rutkis, J. (1971). Tables on relative relief in middle and western Europe. University of Uppsala, Department of Physical Geography, UNGI Rapport 9. 21 pp.

Salmon J.R., A.J. Bowen, A.M. Hoff, R. Johnson, R.E. Mickle, P.A. Taylor, G. Tetzlaff and J.L. Walmsley (1987). The Askervein Hill Project: Mean wind variations at fixed height above ground. Boundary-Layer Meteorol. 43, 247-271.

Taylor, P.A., J.L. Walmsley and J.R. Salmon (1983). A simple model of neutrally stratified boundary-layer flow over real terrain incorporating wavenumber-dependent scaling. Boundary-Layer Meteorol. 26, 169-189.

Taylor, P.A. and H.W. Teunissen (1987). The Askervein Hill Project: Overview and background data. Boundary-Layer Meteorol. 39, 15-39.

Taylor, P.A. and J.R. Salmon (1993). A model for the correction of surface wind data for sheltering by upwind obstacles. J. Appl. Met. 32, 1683-1694.

Troen, I. (1990). A high resolution spectral model for flow in complex terrain. Ninth Symposium on Turbulence and Diffusion, Roskilde, April 30 - May 3, 1990, 417-420.

Troen, I. and E.L. Petersen (1989). European Wind Atlas. ISBN 87-550-1482-8. Risø National Laboratory, Roskilde. 656 p.

William-Olsson, W. (1974). A map of the relative relief of the western half of Europe, 1:4,000,000. Esselte Map Service, Stockholm.

Wood, N. (1995) The onset of separation in neutral, turbulent flow over hills. Boundary-Layer Meteorology 76, 137-164.

8 Appendices

8.1 WAsP forms

A number of sample forms are provided in the 'Forms' folder of the main WAsP directory. These forms may be used to record characteristics of the wind speed and direction data, the anemometer or wind turbine site, the meteorological station, the near-by obstacles, the surrounding roughness and for exchange of data storing units/cards on a met. station. The forms provided are:

- Data Description Form (Data.doc)
- Site Description Form (Site.doc)
- Station Description Form (Station.doc)
- Obstacle Description Form (Obstacle.doc)
- Roughness Description Form (Roughnes.doc)
- Data Storing Unit Exchange Form (DSU.doc)

The Roughness Description Form is used for the site-specific roughness description or roughness rose. However, most often the roughnesses are specified in the form of roughness change lines in a map; to establish these a copy of the topographical map is most useful.

The Data Storing Unit Exchange Form was developed specifically for Aanderaa systems, but can easily be adapted to other systems/dataloggers.

8.2 Golden Software demos

Golden Software's Windows-based demo software is fully-featured and you can use your own data to experiment with the software. However, the demos do not allow you to print, save, copy, cut, or export. The following demos are available on the WAsP CD-ROM, in the folder 'Golden Software':

- **Surfer 7 Demo** (s7demo.exe, 10.5 MB): Creates contour and 3-D wireframe maps. For Windows 95, 98, Me, NT 4 and 2000.
- **Grapher 3 Demo** (g3demo.exe, 11.6 MB): Creates (x,y) graphs. For Windows 95, 98, Me, NT 4 and 2000.
- **MapView 4 Demo** (mapvdemo.exe, 13.6 MB): Creates thematic maps. For Windows 95, 98, Me, NT 4 and 2000.
- **Didger 2 Demo** (d2demo.exe, 10.4 MB): Creates digital images from paper images. For Windows 95, 98, Me, NT 4 and 2000. Tutorial included in the demo!
-

The demos may also be downloaded free of charge from Golden Software's download page. To view the entire Golden Software site, please visit www.goldensoftware.com.

Installation

To install a demo, click the **Start** button, then choose **Run**. Type the path and file name for the appropriate EXE file, or use the browse button to locate the EXE file. Press OK and setup will begin.

Bibliographic Data Sheet**Risø-I-1532(EN)**

Title and authors

Getting Started with WAsP 7

Niels G. Mortensen, Duncan N. Heathfield, Lars Landberg, Ole Rathmann, Ib Troen and Erik L. Petersen

Department or group

Date

Wind Energy Department

September 2001

Groups own reg. number(s)

Project/contract No(s)

1105 002-01

Pages

Tables

Illustrations

References

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Abstract (max. 2000 characters)

The Wind Atlas Analysis and Application Program (WAsP) is a PC-program for horizontal and vertical extrapolation of wind data. The program contains a complete set of models to calculate the effects on the wind of sheltering obstacles, surface roughness changes and terrain height variations. The analysis part consists of a transformation of an observed wind climate (speed and direction distributions) to a wind atlas data set. The wind atlas data set can subsequently be applied for estimation of the wind climate and wind power potential, as well as for siting of specific wind turbines. The WAsP 7 Help Facility includes a Quick Start Tutorial, a User's Guide and a Technical Reference. It further includes descriptions of the Observed Wind Climate Wizard, the WAsP map editor tool, the Air Density Calculator, the RIX program for calculating the ruggedness index of a site in complex terrain and the DXF Translator. This report consists of excerpts from the electronic version of the WAsP 7 help facility.

Descriptors

COMPUTER PROGRAM DOCUMENTATION; DATA ANALYSIS; MAPS; RESOURCE ASSESSMENT; SITE CHARACTERIZATION; W CODES; WIND; WIND POWER.

Copies to:

Afdelingen for Informationsservice (2)