

SNWIND USER'S GUIDE

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INTRODUCTION

Back in the deep, dark past, Paul Veers of Sandia National Laboratories wrote a handy program called SNLWIND. It could generate full- field turbulent wind for the u component only. Years later, Neil Kelley of the National Renewable Energy Laboratory (NREL) took Paul's code, added several spectral models, and modified it to generate the v and w components. SNLWIND-3D was the result. Over the years, Neil's program was modified; some of the modifications included adding the Kaimal and von Karman spectral models specified by the International Electrotechnical Commission (IEC). Gary Desroachers of NREL modified it to run on many different platforms by including C-Preprocessor directives for conditional compilation. In 1997, I added the ability to generate binary files that are compatible with Garrad Hassan's *BLADED* turbine design code.

These programs were written in FORTRAN 77 and required recompilation for different grid densities and run lengths. This made using and supporting it difficult.

In January 2000, I decided it was time to modernize the program. Neil took out all the spectral models but the two defined by the IEC and turned the code over to me. Except for the Fast Fourier Transform (FFT) routines, I completely rewrote the code in Fortran 95 and eliminated the C-Preprocessor directives. This included using dynamic-memory allocation for the big arrays. I found and fixed a few bugs, modified the input and output file format, streamlined things, and added the ability to generate hub-height files in Aero-Dyn format. I renamed the program SNwind (Sandia/NREL Wind) because NREL had made major contributions to the code. I have since made further refinements (see the change log). One major change was replacing the random number generator Neil used with the standard Fortran intrinsic function, which nearly doubled the speed of the program.

RETRIEVING FILES FROM THE ARCHIVE

Download the SNwind archive from our web server page <http://wind2.nrel.gov/designcodes/>. The file will have a name like "SNwind_v110.exe." Create an SNwind folder somewhere on your file system and put this file there. You can double click on it from Windows Explorer or by entering "SNwind_v101" at a command prompt with the SNwind folder as the current directory. This will create some files and folders. Please see my paper *Installing NWTC Design Codes* for information on how to set up SNwind to run in any folder.

DISTRIBUTED FILES

See Table 1 for a list of the files included in the SNwind archive.

Table 1. Files in the SNwind Archive.

File(s)	Description
ArcFiles.txt	The list of files that are written to the archive.
Archive.bat	The batch file that creates the archive.
Change.log	The list of changes to SNwind.
SNwind.doc	This user's guide in Word format.
SNwind.exe	The SNwind program for 32-bit Windows platforms.
SNwind.inp	A sample input file.
SNwind.pdf	This user's guide in PDF format.
Source*.*	The Fortran source code for SNwind.
Test*.*	Files used to run and manage the certification tests.
Test\TstFiles*.*	My results for the certification tests.

CERTIFICATION TEST

Before using SNwind, run the certification-testing program. It is a batch file called "CertTest.bat" and is located in the "Test" folder. To test the installation, edit "CertTest.bat" and set the environment variables found near the top of the file to settings that are compatible with your system. You will probably have to change only the "Editor" variable. Then, open up a command window, go to the Test folder, and enter "CertTest".

SNwind will run twice. The test procedure will compare the new results to those stored in the "Test\TstFiles" folder. The procedure will write the differences between the output files to a file called "CertTest.out." The test procedure will automatically open this file with the editor you specified with the "Editor" variable. Scan through the file; the only differences should be the date and time stamps in the headers of the files. If you recompiled SNwind with another compiler, there may be some slight differences in the last digit of many of the numbers.

COMPILING SNWIND

You should not need to compile SNwind unless you want to make changes to the code. The archive contains code primarily for the Compaq Visual Fortran compiler. All of the compiler-specific code should reside in files called "SysCVF.f90" and "ModCVF.f90." If you want to port SNwind to another platform or compiler, you should have to change only these two files. All source code resides in SNwind's "Source" folder.

USING SNWIND

To run SNwind, enter "snwind [<RootName>]", where the <RootName> is optional.

Examples:

```
snwind
```

This will start SNwind and open "snwind.inp." This is equivalent to entering "snwind snwind".

```
snwind myroot
```

This will start SNwind and open "myroot.inp."

All output files will have the specified root file name with different extensions.

Wind components are as follows:

```
u  downwind
v  to the left when looking downwind
w  up
```

INPUT FILES

Do not add or remove lines from the sample input files. SNwind assumes that parameters are located on specific lines.

Runtime Options

The first input value is the random seed. It must be an integer between -2147483648 and 2147483647 (inclusive).

The next five fields tell SNwind what you want for output. You can use any combination of output types. Valid entries for these flags are the strings "true" and "false." It is not case sensitive. The first output option is to generate hub-height (HH) time series in GenPro-binary form. It is probably useful only to Neil Kelley. The second file type is a time series of HH wind data and turbulence parameters in formatted (human-readable) form. The third is HH time series in AeroDyn format. The fourth is binary, full-field (FF) time series in AeroDyn and *BLADED* format. The last is FF time series in SNLWIND-3D human-readable format.

The last parameter in this section is a flag to tell whether the turbine rotates in the clockwise direction when looking downwind.

Turbine/Model Specifications

The first parameter is the number of grid points to generate in the horizontal or vertical direction. It must be an even number.

The next parameter is the time step. We set it to 0.05 seconds and recommend that you do not change it.

The usable length of the data in seconds comes next. This differs from the actual amount of data that SNwind will generate. Because AeroDyn requires that there be data both upwind and downwind of the tower in case the turbine is yawed, it insists that there be extra data in the file to shift the data enough to ensure that the turbine will reside entirely within the wind-data domain.

The hub height of the turbine comes next. SNwind works in the metric system, so enter the value in meters.

The height and width of the grid must be large enough to ensure that no part of the blade can lie outside the grid. AeroDyn will test to make sure that the rotor radius plus the shaft length (distance from yaw axis to hub) is less than half the grid width.

The vertical mean-flow angle allows you to simulate wind blowing uphill or downhill. Enter the angle in degrees and do not exceed 45 degrees in magnitude. A positive value means the wind is blowing uphill.

The horizontal mean-flow angle is the wind direction. Positive angles (enter them in degrees) shift the wind to the right.

Meteorological Boundary Conditions

The first parameter tells SNwind which turbulence model it should use. Valid values are "IECKAI" for the Kaimal model and "IECVKM" for the Von Karman model. The values are not case sensitive.

The second parameter tells SNwind what turbulence intensity (TI) you want to use. Input values of "A" or "B" correspond to the standard IEC turbulence characteristics, with "A" being the more turbulent. You can also specify the TI in percent instead of choosing the standard turbulence characteristics.

The third parameter in this section specifies the height of the reference wind speed (in meters). This allows you to specify the mean wind speed at a height other than the hub height. SNwind will shear it from there to generate the mean HH wind speed.

The last parameter in the file is for the mean, u-component wind speed. It will be less than the mean, horizontal wind speed, which is the vector sum of the u and v components. Its value must be in meters per second.

SPECTRAL MODELS

SNwind currently offers only the Kaimal and von Karman spectral models as defined in the IEC standard. Please refer to "IEC 61400-1, Ed. 2: Wind Turbine Generator Systems - Part 1: Safety Requirements" for details on these models.

OUTPUT FILES

SNwind can generate five different sets of output files. They take the root name of the SNwind input file and add extensions that indicate what type of files they are. See the Runtime Options section above to learn how to tell SNwind which sets to output. SNwind always generates a summary file.

Summary Files

SNwind generates the summary file for all runs. It has a ".sum" extension. The first part of the file tells you what you specified in the input file. After that, SNwind prints out many statistics for the run. If you request FF AeroDyn files, SNwind will add another section that tells AeroDyn how to convert the normalized data to floating-point form.

GenPro Binary Files

These files are readable by Neil's GenPro postprocessor and are in machine-readable form. SNwind gives them a ".bin" extension. See Table 2 for the file format.

Hub-Height Formatted Files

These files are essentially the same as the GenPro binary files, but they are in human-readable form. They carry a ".dat" extension.

Table 2. Format of GenPro Binary Files.

Time	time
u	downwind wind speed
u _h	horizontal wind speed (u+v)
u _t	total wind speed (u+v+w)
v	sideways wind speed
w	vertical wind speed
u'	u fluctuating-velocity component
v'	v fluctuating-velocity component
w'	w fluctuating-velocity component
u'w'	u-w Reynolds stress component
u'v'	u-v Reynolds stress component
v'w'	v-w Reynolds stress component

Hub-Height AeroDyn Formatted Files

These human-readable files are in a format compatible with AeroDyn. They carry the ".hh" extension. See Table 3 for the file format.

Full-Field AeroDyn Binary Files

This is a set of two files. One is a binary file designed to be read by AeroDyn and *BLADED*. It has a ".wnd" extension. SNwind normalizes the data and encodes them in two-byte integers. The first part of the file is a header that provides information about the grid

Table 3. Format of Hub-Height AeroDyn Files.

Time
Horizontal wind speed
Wind direction
Vertical wind speed
Horizontal wind-shear, linear parameter
Vertical power-law, wind-shear exponent
Vertical wind-shear, linear parameter
Gust speed (not sheared by AeroDyn)

and tells AeroDyn and *BLADED* how to convert the integers to floating-point values. The wind speeds for the grids follow that.

The second file is a human-readable file that gives *BLADED* additional information on the setup of the binary file. It has a “.ddd” extension.

When generating this set of files, SNwind adds a section to the end of the summary file that tells AeroDyn how to convert the data to floating-point form.

Full-Field Formatted Files

This is the traditional format of SNLWIND-3D FF output files. These three files are human readable, but consume five times more storage than the binary files. They are no longer readable by AeroDyn. There is one file for each component. They have “.u,” “.v,” and “.w” extensions.

The tops of the files have headers with some basic information about the simulation. Blocks of data follow. The first line in each block has the time and the hub-height wind speed. Following that line is a table with the number of rows and columns being the number of grid points specified in the input file. The tables contain the wind speeds for the different grid points. Their orientation appears as if you are looking downwind.

WARNINGS

- HH wind files and FF wind files do not have events happening at the same time because AeroDyn shifts the FF files.
- Because of the way the FFT routine works, we must add extra time to the run to get the FFT to run correctly (it needs the number of points to factor to small primes). This means that the mean wind speed for the portion of the run you will actually use may be different from what you specified in the input file.

LIMITATIONS

- You must use an even number of grid points (e.g., 2x2, 6x6, 8x8).
- I have not been able to generate a grid larger than 14x14 for a 10-minute run. A 16x16 grid requires more than 2GB of virtual memory, which Windows NT does not permit.

POSSIBLE FUTURE ENHANCEMENTS

- Add the ability to use stochastic, Gaussian turbulence intensities (TI). If the IEC turbulence characteristic is not set to “A” or “B,” assume

the input line contains the mean and standard deviation of the TI.

- Add the spectral models taken out of the code once they are validated.
- Replace the FFT routines with modern Fortran 95 routines.
- Add the 300m von Karman model.
- Eliminate the requirement for an even number of grid points.
- For the Kaimal and von Karman models, do the components serially to reduce the size of the spectrum array.

KNOWN BUGS

- None.

CAVEATS

NREL makes no promises about the usability or accuracy of SNwind, which is essentially a beta code. NREL does not have the resources to provide full support for this program. *You may use SNwind for evaluation purposes only.*

ACKNOWLEDGEMENTS

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FEEDBACK

If you have problems with SNwind, please contact Marshall Buhl. If he has time to respond to your needs, he will do so, but please do not expect an immediate response. Send your comments or bug reports to:

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