User manual WindSim

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2 Revision history

Rev	Prog Ver.	Date	Description	By
4.7	4.7	2020/01/31	Added command line argument for silent mode	KAA
4.6	4.6	2019/10/04	Added possibility to specify simulation control parameters (optional)	KAA
4.5	4.5	2019/05/06	Fixed issue which some cases gave large standard deviation	
4.4	4.4	2019/03/08	Added flexible input for lengthscale for N400 wind spectrum	KAA
4.3	4.3	2019/02/12	Fixed issue with turbulence intensity. Manual not released	KAA
4.2	4.2	2019/01/16	Added possibility to scale mean wind and turbulence intensity for individual COORD entries	KAA
4.1	4.1	2019/01/10	Updated text for Scale parameter for WindU,V,W, Type=8	KAA
4.0	4.0	2018/10/26	Added mean wind profile, wind spectre and coherence according to N400:2015 / NS-EN 1991-1-4:2005 + NA:2009. Added more examples.	KAA
3.5	3.5	2015/01/13	Corrected text in Eurcode/NS spectrum.	KAA
3.1	3.1	2011/08/19	Added new spectra and coherence fucntions	KAA
3.0	3.0	2011/06/10	Added command line arguments. Major code cleanup	KAA
2.2	2.2	2011/04/01	Minor cosmetic improvements	KAA
2.1	2.1	2009/10/07	Updated wind spectra	KAA
2.0	2.0	2009/02/25	General improvement	KAA
1.6	1.6	2009/10/07	Added option on NS3491 wind spectrum	KAA
1.5	1.5	2008/11/14	Included DnV-OS-J101 formulation.	KAA
1.4	1.4	2008/11/01	Linux compatible version	KAA
1.3	1.3	2007/12/12	Included old DS spectra (used in FLEX). General update	KAA
1.2	1.2	2007/04/26	Statfjord Metocean added	KAA
1.1	1.1	2006/2007	Sporadic updates.	KAA
1.0	1.0	2006/0705	For release version 1.0	KAA
0.0	0.7	2006/06/29	Initial Version	KAA

3 Notations

Notation	Description
[•]	Square brackets indicate a unit.

4 Program background and purpose

This wind simulation program is tailor made to fit with SwaySim. SwaySim is a nonlinear, time domain design tool for wind turbines located offshore, and thus, exposed to wind and waves.

The wind simulations assumes that the instantaneous wind speed can be split into a mean wind part and a fluctuating part, see Figure 1. The mean wind is given by a mean wind profile. The fluctuating part is simulated from winds spectra and coherence functions, such that the spatial statistical properties and are maintained in the simulated time series.

The output file can be used directly in SwaySim.

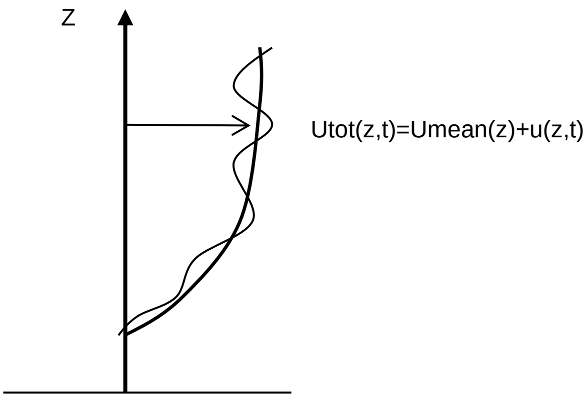


Figure 1 Typical wind profile. Mean wind and fluctuating part.

5 Practical considerations

5.1 Installing the program

The program windsim.exe is a standalone windows exe file. Update the PATH parameter in windows to reflect placement.

5.2 Running the program

Two options for running the program exists. Interactive run and batch run. In the interactive run the program will prompt for the input file, while in the batch run the input file is given as a command line argument.

<u>Interactive run</u>
1. Type *WindSim* in a dos command prompt will bring up the input screen (Figure 2)
2. Type in the input filename with extension (Assumed located in the directory you typed *WindSim*)
3. The program will run and provide feedback similar to what shown in Figure 4

<u>Batch run</u>
The input file is given in the command line: "windsim inp.txt". This feature can be used in a batch file to simulate several different wind files at once, see Figure 3.

The run-time of the program increase exponentially with number of points and length of time series. Particularly the “Cholesky decomposition” May take time. It is suggested to start out with a conservative number of grid points to get a feeling for the runtime.

WindSim creates two output files on the directory where WindSim was started from:

Wind_nameofinputfile.txt contains the simulated time series formatted to be used with SwaySim
HELP.txt : contains info about data read from the input file, as well as notes, warnings and error messages. This information may be helpful for changing the input file.

In addition the VERIFY card creates output to verification files. Se below for details.

Figure 2 Interactive run: Typical input prompt in WindSim.

```
rem
rem Filename: 00runAll.bat
rem This script runs WindSim in batch for all listed files
rem


CALL :sim inp_U05_000
CALL :sim inp_U10_000
CALL :sim inp_U15_000
CALL :sim inp_U20_000
CALL :sim inp_U25_000

GOTO : EOF

:sim

   windsim %1.txt

GOTO :EOF
```

Figure 3 Sample windsim batch file.

```
   W     W I N      N DD    SSS  I M     M
   W     W I NN     N D D  S     I MM   MM
   W     W I N N    N D  D S     I M M M M
   W     W I N  N   N D   D  S   I M  M  M
   W  W  W I N   N  N D   D   S  I M     M
   W W W W I N    N N D  D     S I M     M
   WW   WW I N     NN D D     S  I M     M
   W     W I N      N DD   SSS   I M     M


   ver=2.2  Release date:2011.04.01
   Developed by Ketil Aas-Jakobsen. kaa@aaj.no


   Input data File for wind simulation:  inp5.txt



 Establishing Data Matrix, counting down (this may take some time):...
Comp:   1. Left:   24. Coord(X,Y,Z):(    0.00  -35.00   95.00). Umean(Z):    10.00
Comp:   1. Left:   23. Coord(X,Y,Z):(    0.00  -17.50   95.00). Umean(Z):    10.00
Comp:   1. Left:   22. Coord(X,Y,Z):(    0.00    0.00   95.00). Umean(Z):    10.00
Comp:   1. Left:   21. Coord(X,Y,Z):(    0.00   17.50   95.00). Umean(Z):    10.00
Comp:   1. Left:   20. Coord(X,Y,Z):(    0.00   35.00   95.00). Umean(Z):    10.00
Comp:   1. Left:   19. Coord(X,Y,Z):(    0.00  -35.00   78.75). Umean(Z):    10.00
Comp:   1. Left:   18. Coord(X,Y,Z):(    0.00  -17.50   78.75). Umean(Z):    10.00
Comp:   1. Left:   17. Coord(X,Y,Z):(    0.00    0.00   78.75). Umean(Z):    10.00
Comp:   1. Left:   16. Coord(X,Y,Z):(    0.00   17.50   78.75). Umean(Z):    10.00
Comp:   1. Left:   15. Coord(X,Y,Z):(    0.00   35.00   78.75). Umean(Z):    10.00
Comp:   1. Left:   14. Coord(X,Y,Z):(    0.00  -35.00   62.50). Umean(Z):    10.00
Comp:   1. Left:   13. Coord(X,Y,Z):(    0.00  -17.50   62.50). Umean(Z):    10.00
Comp:   1. Left:   12. Coord(X,Y,Z):(    0.00    0.00   62.50). Umean(Z):    10.00
Comp:   1. Left:   11. Coord(X,Y,Z):(    0.00   17.50   62.50). Umean(Z):    10.00
Comp:   1. Left:   10. Coord(X,Y,Z):(    0.00   35.00   62.50). Umean(Z):    10.00
Comp:   1. Left:    9. Coord(X,Y,Z):(    0.00  -35.00   46.25). Umean(Z):    10.00
Comp:   1. Left:    8. Coord(X,Y,Z):(    0.00  -17.50   46.25). Umean(Z):    10.00
Comp:   1. Left:    7. Coord(X,Y,Z):(    0.00    0.00   46.25). Umean(Z):    10.00
Comp:   1. Left:    6. Coord(X,Y,Z):(    0.00   17.50   46.25). Umean(Z):    10.00
Comp:   1. Left:    5. Coord(X,Y,Z):(    0.00   35.00   46.25). Umean(Z):    10.00
Comp:   1. Left:    4. Coord(X,Y,Z):(    0.00  -35.00   30.00). Umean(Z):    10.00
Comp:   1. Left:    3. Coord(X,Y,Z):(    0.00  -17.50   30.00). Umean(Z):    10.00
Comp:   1. Left:    2. Coord(X,Y,Z):(    0.00    0.00   30.00). Umean(Z):    10.00
Comp:   1. Left:    1. Coord(X,Y,Z):(    0.00   17.50   30.00). Umean(Z):    10.00
Comp:   1. Left:    0. Coord(X,Y,Z):(    0.00   35.00   30.00). Umean(Z):    10.00
 Cholesky decomposition (be patient)...
 Creating U-component
 Simulating stochastic in each node...
TS_N:   1. Coord(X,Y,Z):(    0.00  -35.00   95.00). Umean(Z):    10.00. Std:     1.75
TS_N:   2. Coord(X,Y,Z):(    0.00  -17.50   95.00). Umean(Z):    10.00. Std:     1.70
TS_N:   3. Coord(X,Y,Z):(    0.00    0.00   95.00). Umean(Z):    10.00. Std:     1.70
TS_N:   4. Coord(X,Y,Z):(    0.00   17.50   95.00). Umean(Z):    10.00. Std:     1.59
TS_N:   5. Coord(X,Y,Z):(    0.00   35.00   95.00). Umean(Z):    10.00. Std:     1.74
TS_N:   6. Coord(X,Y,Z):(    0.00  -35.00   78.75). Umean(Z):    10.00. Std:     1.75
TS_N:   7. Coord(X,Y,Z):(    0.00  -17.50   78.75). Umean(Z):    10.00. Std:     1.82
TS_N:   8. Coord(X,Y,Z):(    0.00    0.00   78.75). Umean(Z):    10.00. Std:     1.72
TS_N:   9. Coord(X,Y,Z):(    0.00   17.50   78.75). Umean(Z):    10.00. Std:     1.64
TS_N:  10. Coord(X,Y,Z):(    0.00   35.00   78.75). Umean(Z):    10.00. Std:     1.79
TS_N:  11. Coord(X,Y,Z):(    0.00  -35.00   62.50). Umean(Z):    10.00. Std:     1.69
TS_N:  12. Coord(X,Y,Z):(    0.00  -17.50   62.50). Umean(Z):    10.00. Std:     1.83
TS_N:  13. Coord(X,Y,Z):(    0.00    0.00   62.50). Umean(Z):    10.00. Std:     1.71
TS_N:  14. Coord(X,Y,Z):(    0.00   17.50   62.50). Umean(Z):    10.00. Std:     1.62
TS_N:  15. Coord(X,Y,Z):(    0.00   35.00   62.50). Umean(Z):    10.00. Std:     1.75
TS_N:  16. Coord(X,Y,Z):(    0.00  -35.00   46.25). Umean(Z):    10.00. Std:     1.82
TS_N:  17. Coord(X,Y,Z):(    0.00  -17.50   46.25). Umean(Z):    10.00. Std:     1.79
TS_N:  18. Coord(X,Y,Z):(    0.00    0.00   46.25). Umean(Z):    10.00. Std:     1.63
TS_N:  19. Coord(X,Y,Z):(    0.00   17.50   46.25). Umean(Z):    10.00. Std:     1.61
TS_N:  20. Coord(X,Y,Z):(    0.00   35.00   46.25). Umean(Z):    10.00. Std:     1.72
TS_N:  21. Coord(X,Y,Z):(    0.00  -35.00   30.00). Umean(Z):    10.00. Std:     1.72
TS_N:  22. Coord(X,Y,Z):(    0.00  -17.50   30.00). Umean(Z):    10.00. Std:     1.71
TS_N:  23. Coord(X,Y,Z):(    0.00    0.00   30.00). Umean(Z):    10.00. Std:     1.63
TS_N:  24. Coord(X,Y,Z):(    0.00   17.50   30.00). Umean(Z):    10.00. Std:     1.72
TS_N:  25. Coord(X,Y,Z):(    0.00   35.00   30.00). Umean(Z):    10.00. Std:     1.67
 Inverse Fourier Transforms finished
 Saving simulated wind to file.
```

Figure 4 Typical run feedback.

5.3 *Examining the output file*

The output file contains information about the dataset used as input. Of particular importance is the summary of the standard deviation of the simulated time series, shown in Figure 5. The “Target” line shows the standard deviation for the whole wind field. The “Extracted” shows the extracted part (i.e. the part that is between the fmin and fmax parameters defined in FAXIS, or values derived from the TIME card). The “Simulated” is the standard deviation of the simulated time series. These numbers should be relatively equal. The simulated time series may occasionally be larger than the extracted due to the random nature of the simulation.

```
' -----------------------------------------------
' Key data for first simulated point:
' -----------------------------------------------
' U-component StDev:
'             Target:     1.705
'             Extracted:  1.692
'             Simulated:  1.551
```

Figure 5 Summary output data for wind component.

5.4 Verification of simulated time series.

A more in-depth verification of the simulated time series can be done using the VERIFY input card. Based on the simulated time series, wind spectrum and root-coherence functions are recreated and compared to the input values. The heading of the file contains key parameter used in the verification, see Figure 6. The verification procedure creates one file for each fluctuating wind component. The files are named VERIFY_u/v/w_inputfilename.txt.

A perfect match between the target and the simulated spectra is not to be expected. Some information leak to other frequencies during simulation during recreation of the spectra from the simulated time series. This is due to random phase angles in the simulation, block division, detrending and Hanning windowing in the verification part. However, reasonably equal values, as shown below, is to be expected.

```
' --------------------------------------------------------------
' V E R I F I C A T I O N   F I L E   F O R   * S W A Y S I M *
' ---------------------------------------------------------------
' This file was created: Wed Jul  5 14:57:06 2006
' By WindSim - the numerical wind simulator: ver=1.0  Release date:2006.07.05
' Developed by Ketil Aas-Jakobsen: kaa@aaj.no
'
' Verification key parameters:
' Blocksize: 2048
' ---------------------------------------------------------------
'Values used in verification:
'Point 1. Ext.NodeNo:   2. X=    0.00. Y=  -45.00. Z=   15.00
'Point 2. Ext.NodeNo:   4. X=    0.00. Y=  -45.00. Z=   35.00
'For Root Coherence: Separation: 20.00. Decay parameter: 7.50. Avg. Winds: 27.29
'Umean:           25.871    25.871    28.712    28.712
'xLu:            248.800   248.800   248.800   248.800
'std Target:       2.820     2.820     3.130     3.130
'std Specter:      2.723     2.554     3.027     2.738
' -----------------------------------------------------------------------
'           f  TargetS1        S1  TargetS2        S2  TrootCoh   rootCoh
' -----------------------------------------------------------------------
       0.0000     0.000    68.739     0.000   105.256     1.000     0.877
       0.0024   296.279   143.225   330.774   183.440     0.987     0.864
       0.0049   271.032   272.455   307.329   255.916     0.974     0.904
       0.0073   237.972   297.966   275.391   221.592     0.961     0.927
       0.0098   204.098   158.763   241.150   110.696     0.948     0.865
       0.0122   173.361   149.944   208.702   115.620     0.935     0.873
       0.0147   147.148    98.885   179.960    83.011     0.923     0.732
       0.0171   125.445    72.954   155.402   132.013     0.910     0.641
       0.0195   107.682    94.601   134.784   163.054     0.898     0.742
       0.0220    93.168    81.781   117.588   140.213     0.886     0.655
       0.0244    81.265    39.380   103.252    63.767     0.874     0.509
       0.0269    71.441    62.384    91.262    51.081     0.863     0.733
       0.0293    63.271    69.140    81.182    46.551     0.851     0.645
       0.0318    56.421    73.791    72.655    68.235     0.840     0.605
       0.0342    50.631    46.048    65.396    50.834     0.829     0.697
```

Figure 6 Typical verification output.

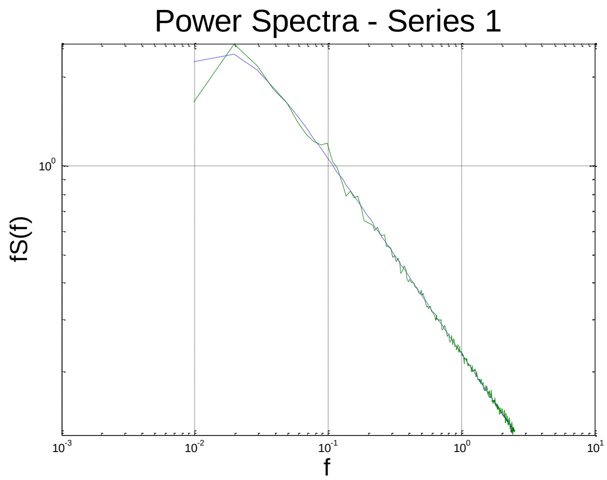


Figure 7 Comparison of target (broken line) and simulated (full line) spectrum.

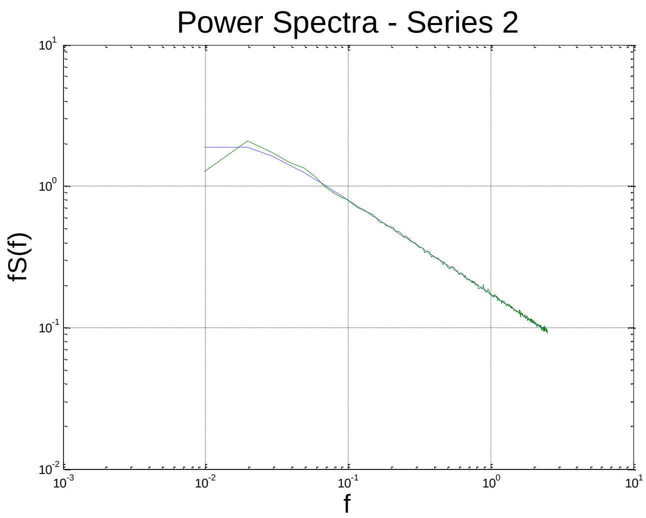


Figure 8 Comparison of target (broken line) and simulated (full line) spectrum.

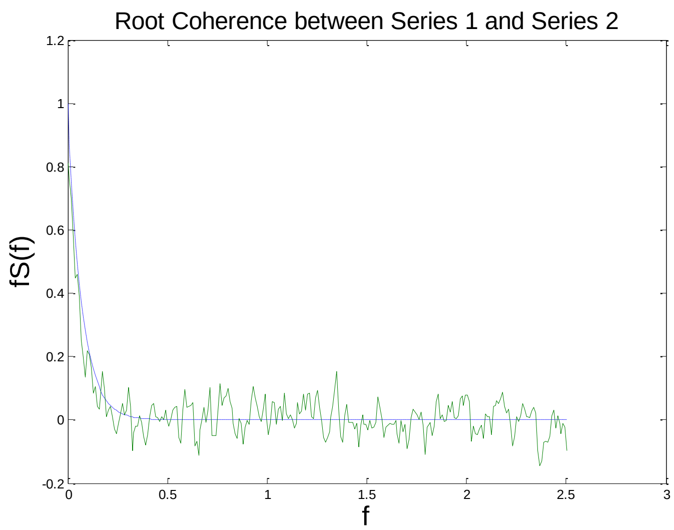


Figure 9 Root coherence between simulated time series.

5.5 Known issues

- **z-values:** It is not possible to have negative z-values for the wind simulation. It is not verified that offset of zero level of wind speed is behaving correctly. It so strongly suggested that zero level, is zero level.
- **Trailing spaces.** Trailing spacec in inputfile may cause termination of the program.
- **Time axis drifting.** There is some drifting of the time axis. This is believed to be a round-off error which is sums up to a drift on the time axis.

6 Commands

This section contains a summary of the commands available to WindSim.

The comment indicator is exclamation mark: !. Any reminder of the line will be treated as a comment.

6.1 Command line arguments

Windsim can be run with command line arguments.

SYNTAX	`WINDSIM filename silentMode`
Description	Runs Windsim with command line arguments. All arguments are optional.
See Also	YGRID ZGRID COORD
filename silentMode	Inputfile to windsim If no filename is given Windsim will run in interactive mode 0 : Normal feedback from Windsim (as shown in this manual) 1 : Activate silent mode. Only minimum output to screen.

Example	`Windsim input.txt   => runs Windsim with values in input.txt`
	`Windsim input.txt 0 => as above`
	`Windsim input.txt 1 => as above, but with minimum screen output`

6.2 Wind grid geometry

The wind is simulated at specified points in space. They can either be defined by a grid (XGRID,YGRID,ZGRID) or actual free coordinates (COORD). The program is optimized for the GRID style input. A mixed input will favour the GRID style.

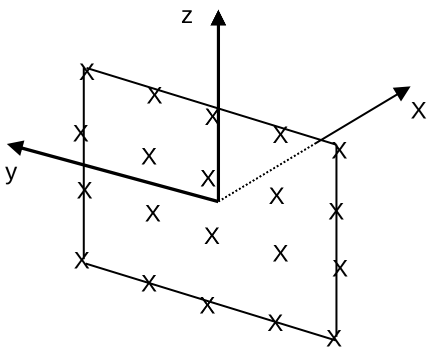


Figure 10 Grid style input.

6.2.1 XGRID

SYNTAX	`XGRID min max no`
Description	Defines number of points for the wind simulation grid in the global x-direction
See Also	YGRID ZGRID COORD
min max no	Minimum x-location [Unit: m] Maximum x-location [m] Number of division between min and max. dX=(Max-Min)/(No-1)
Example	`‘      Min Max No` `XGRID   0    0   1`

6.2.2 YGRID

SYNTAX	`YGRID min max no`
Description	Defines number of points for the wind simulation grid in the global y-direction
See Also	XGRID ZGRID COORD
min max no	Minimum y-location [m] Maximum y-location [m] Number of division between min and max. dY=(Max-Min)/(No-1)
Example	`!      Min Max No` `YGRID  -45  45 10`

6.2.3 ZGRID

SYNTAX	`ZGRID min max no`
Description	Defines number of points for the wind simulation grid in the global z-direction
See Also	XGRID ZGRID COORD
min max no	Minimum z-location [m] Maximum z-location [m] Number of division between min and max. dZ=(Max-Min)/(No-1)
Example	`!      Min Max No` `ZGRID    5   95  10`

6.2.4 COORD

SYNTAX	`COORD no x y z U_Sc Iu_Sc Iv_Sc Iw_Sc`
Description	Defines a point in space where time series will be calculated with optional parameters which scale mean wind and turbulence intensity. These scalings are only available for the COORD command NOTE: Effects are cumulative. Since e.g Iu=sigma_u/Umean Mean wind scaling will the value of sigma_u. Turbulence intensity scaling will not work for: Type = 2, Statfjord Metocean Type = 6 Harris (NORSOK N-003): Type = 7 Panofsky (NORSOK N-003):
See Also	XGRID YGRID ZGRID
no X Y Z U_Sc Iu_Sc Iv_Sc Iw_Sc	Point Number X – coordinate [m] in global coordinate system Y-coordinate [m] in global coordinate system Z-coordinate [m] in global coordinate system Scale U-component. Default=1.0 Scale Turbulence Intensity Iu. Default=1.0 Scale Turbulence Intensity Iv. Default=1.0 Scale Turbulence Intensity Iw. Default=1.0

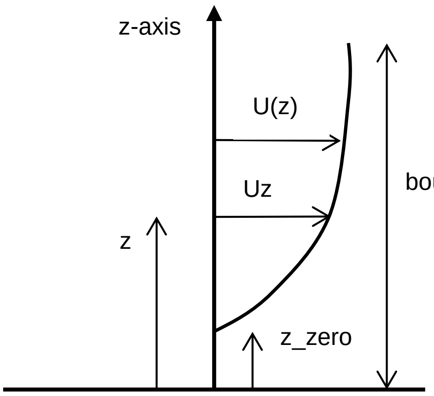
Example	`!        No X  Y   Z U_Sc Iu_Sc Iv_Sc Iw_Sc`
	`COORD    10 0 15 87`
	`COORD    11 0 25 87 1.15 1.01  1.05  1.10`

6.2.5 ACTRL

SYNTAX	`ACTRL output`
Description	Specifies simulation parameters (Optional card)
See Also	
output	0: normal output (Default)
Example	`'      Out` `ACTRL    1`

6.3 Wind data

6.3.1 WPROFILE



SYNTAX	`WPROFILE Type Param_1 Param_2 Param_3 …`
Description	Mean wind profile
See Also	
Type=1	Definition of mean wind profile: $$U(z) = U_{ref} \cdot \left(\frac{z}{z_{ref}} \right)^{\alpha}$$ Input back-calculates an Uref at zref=10m, that fits this model.
Type Uz z Z_zero Alpha boundh Dir	1 :Type of mean wind profile Wind speed [m/s] at height z [m]. z is defined in the global coordinate system Height, in global coordinate system where Uz is defined. Zero level of wind profile [m]. Global coordinate system. Shape parameter of wind profile. Typically about 0.2.[Non-dimensional] Boundary layer height [m]. Typically about 2000m, but depends on terrain type. NOT IMPLEMENTED BUT MUST BE GIVEN! Direction of mean wind. 1=parallel to X-axis 2=parallel to Y-axis 3=parallel to Z-axis
Example	`! Type Uz z z_zero alpha boundh Dir` `WPROFILE 1 15 20.0 0 0.2 2000 1`
Type=2	Statfjord Metocean wind profile $$U(z,t) = U(z) \cdot \left[1 - 0.41 \cdot I_u(z) \cdot \ln\left(\frac{t}{t_0} \right) \right]$$ $$U(z) = U_0 \cdot \left[1 + C \cdot \ln\left(\frac{z}{10} \right) \right]$$, where $C = 5.73 \cdot 10^{-2} \cdot [1 + 0.15 \cdot U_0]^{1/2}$ $$I_u = 0.06 \cdot [1 + 0.043 \cdot U_0] \cdot \left(\frac{z}{10} \right)^{-0.22}$$
Type U0 Z_zero t	2: Type of mean wind profile 1 hour mean wind speed at z=10m Zero level of wind profile [m]. Global coordinate system. Averaging time in seconds. Max 3600sec.
Example	`! Type U0 z_zero t` `WPROFILE 2 20.3 0.0 3600`
Type=3	Wind profile from NS-EN 1991-1-4:2005 + NA:2009 $V_m(z) = c_r(z) * v_b$

	Where: $c_r(z) = k_r * \ln(z/z_0)$ if $z>=z_{min}$ $c_r(z) = k_r * \ln(z_{min}/z_0)$ if $z<z_{min}$ and $k_r = 0.19 *(z_0/0.05m)\text{^}0.07$
Type	3: Type of mean wind profile
vb	Basic wind speed with necessary corrections according to §4.2. (10min average wind speed at 10m height) [m/s]
Z_zero	Zero level of wind profile [m]. Global coordinate system.
z_0	Roughness length according [m]
Z_min	Starting level of logarithmic wind profile [m].
Example	`! Type vb z_zero z_0 z_min` `WPROFILE 3 29.1 0.0 0.047 2.0`

6.3.2 WINDU

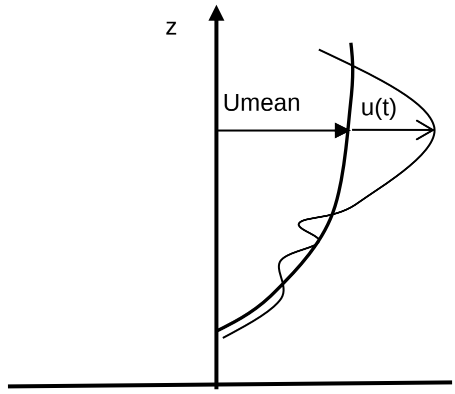


Figure 11 Fluctuating wind component.

SYNTAX	`WINDU Type Param1 Param2 Param3 …`
Description	Definition of fluctuating component.
See Also	WINDV WINDW COHERENCE
Type=0	Mean wind profile only
type	0=mean wind profile only (i.e. fluctuating comp. will not be added)
Example	`! Type` `WINDU 0`
Type=1	Fluctuating component added. vonKarman spectrum $\frac{fS_{uu}}{\sigma_u^2} = \frac{4 f_u}{(1+70.8 f_u^2)^{5/6}}$ where $f_i = \frac{f\,{}^xL_i}{U}$ where i=u,v,w
type Iu xLu yLu zLu	1 = Fluctuating wind component to be included Turbulence intensity. Given as a decimal number, i.e. 17% is entered as 0.17. Length scale [m]. Mandatory input. Other lengthscales will be scaled according to ESDU if they are not given. Length scale [m]. Use 0 to get ESDU estimates Length scale [m]. Use 0 to get ESDU estimates
Example	`! Type I# xL# yL# zL#` WINDU 1 0.15 191.5 0.0 0.0
Type=2	Fluctuating component according to Statfjord Metocean $S(f) = \frac{320 \cdot \left(\frac{U_0}{10}\right)^2 \cdot \left(\frac{z}{10}\right)^{0.45}}{\left(1+\tilde{f}^{\,n}\right)^{\frac{5}{3n}}}$ where $\tilde{f} = 172 \cdot f \cdot \left(\frac{z}{10}\right)^{\frac{2}{3}} \cdot \left(\frac{U_0}{10}\right)^{-0.75}$ where n=0.468
type	2
Example	`! Type` `WINDU 2`
Type=3	Fluctuating component according to NS3491-3:2002 $\frac{fS_{ii}}{\sigma_i^2} = \frac{A_i f_i}{(1+1.5 \cdot A_i \cdot f_i)^{5/3}}$ where $f_i = \frac{f\,{}^xL_i}{U}$ where i=u,v,w
type	3
sigma A zo Zref	Standard deviation of wind fluctuations (same standard dev., mean speed changes) Au=6.8 Av=Aw=9.4 Surface roughness according to Table 1 in NS3491-4:2002 Reference height. Length scales are calculated at this height. If zero, uses height at each gridpoint. (Zref must be greater than 16m)
Example	`! Type sigma A zo Zref` `WINDU 3 2.51 6.8 0.01 55.0`

Type=4	Fluctuating component according to FLEX (old DS 472). Kaimal spectrum. $$S_{ii} = \frac{I_i^2 V_{10\min} L_i}{\left(1 + 1.5 \cdot \frac{f \cdot L_i}{V_{10\min}}\right)^{5/3}}$$ where L_1=600m where i=u,v,w This is similar to Type=3, but with different input values tuned to the FLEX model. V_{10min} is the mean wind at Hub height.
type	4
V10min I1 L1	Mean wind speed at hub height. Used for all heights. Turbulence intensity in along wind direction. Const. for all gridpoints. Implies change in std with mean wind profile Length scale in along wind direction. For DS472 L=600m. Used for all heights.
Example	`! Type V10min I L` `WINDU 4 12 0.18 600`
Type=5	Fluctuating component according to DnV-OS-J101 and IEC61400-1:2007/6.3 and Annex B: $$S_{ii} = \sigma_u^2 \frac{4 \cdot \frac{L_k(z)}{U(z)}}{\left(1 + 6.0 \cdot \frac{f \cdot L_k(z)}{U(z)}\right)^{5/3}}$$ where i=u,v,w The standard deviation of the wind fluctuation is constant across the rotor plane and taken as: σ(z)=I_u*U(z), where I_u is the turbulence intensity at hub height and U(z) is taken from the mean wind profile. L_k is implemented in as L_k=5.67z for z<60m and L_k=340.2 for z>60 (According to DnV-OS-J101/403) This is similar to Type=3 and 4, but with input values tuned to the DnV-OS-J101 input data.
type	5
I	Turbulence intensity in along wind direction. Const. for all gridpoints. Implies change in std with mean wind profile
Example	`! Type I` `WINDU 5 0.12`
Type=6	Fluctuating component according to Harris (NORSOK N-003): $$S_{uu} = \frac{4 \cdot k \cdot V_{10\min}^2 \cdot \frac{f \cdot L_u}{V_{10\min}}}{f \cdot \left(2.0 + \left(\frac{f \cdot L_u}{V_{10\min}}\right)^2\right)^{5/6}}$$ The standard deviation of the wind fluctuation is constant and based on the mean wind speed at 10m above surface and the surface drag coefficient. V10m is the surface wind speed at10m. Taken from the mean wind profile.
type	6
Lu k	turbulence lengtscale surface drag coefficient.
Example	`! Type Lu k` `WINDU 6 150 0.03`
Type=7	Fluctuating component according to Panofsky (NORSOK N-003): $$S_{vv} = \frac{15 \cdot k \cdot V_{10\min}^2 \cdot \frac{f \cdot L_u}{V_{10\min}}}{f \cdot \left(1.0 + 9.5 \cdot \left(\frac{f \cdot L_u}{V_{10\min}}\right)\right)^{5/3}}$$ **Normally used in the across wind direction**.

	The standard deviation of the wind fluctuation is constant and based on the mean wind speed at 10m above surface and the surface drag coefficient. V10m is the surface wind speed at10m. Taken from the mean wind profile.
type	7
Lu k	turbulence lengtscale surface drag coefficient.
Example	`!          Type    Lu      k` `WINDU         7   150   0.03`
Type=8	Fluctuating component according to N400 Bruprosjektering (2015) and Eurocode NS-EN 1991-1-4:2005: $\frac{fS_{ii}}{\sigma_i^2} = \frac{A_i f_i}{(1+1.5\cdot A_i \cdot f_i)^{5/3}}$ where $f_i = \frac{f\,{}^xL_i}{U}$ where i=u,v,w Length scales are calculated from the input like this: For $z>=z_{min}$: ${}^xL_u(z) = {}^xL_{u10}*(z/10m)^{0.3}$ For $z< z_{min}$: ${}^xL_u(z) = {}^xL_{u10}*(z_{min}/10m)^{0.3}$ The default for ${}^xL_{u10}$ is the N400 value: ${}^xL_{u10}$ = 100m. The other length scales are derived from ${}^xL_u$: v-component: ${}^xL_v$ =1/4 ${}^xL_u$ w-component: ${}^xL_w$ =1/12 ${}^xL_u$
type	8 (Note: similar to type=3, but lengthscales are calculated differently, see above)
Scale	Scale factor to adjust the turbulence intensity to something other than given in HB-N400/2015. Scale=1.00 gives default values in HB-N400 which are based on the calculations below: $I_u = I_u$ $I_v = 0.75 * I_u$ $I_w = 0.50 * I_u$ The scale value is applied as follows: $\sigma_u(z)$ = scale * U(z) * $I_u(z)$ $\sigma_v(z)$ = scale * U(z) * $I_v(z)$ $\sigma_w(z)$ = scale * U(z) * $I_w(z)$ Thus, if I_v is specified to be I_v=0.8, the scale value is 0.84/0.75 = 1.12 $I_u(z)$ is calculated as in NS-EN-1991-1-4:, but without the topography factors: If z >= z_{min} : $I_u(z) = k_r/c_r(z)$ If z < z_{min} : $I_u(z) = k_r/c_r(z_{min})$ Where $c_r(z)$ is the terrain roughness factor: $c_r(z) = k_r * \ln(z/z_0)$ if $z>=z_{min}$ $c_r(z) = k_r * \ln(z_{min}/z_0)$ if $z<z_{min}$ and k_r = 0.19 *(z_0/0.05m)^0.07
A	Spectral factor. According to NS-EN 1991-1-4:2005: Au=6.8 Av=Aw=9.4
zo	Surface roughness according to NS-EN 1991-1-4:2005
zmin	Minimum height of wind profile.
${}^xL_{u10}$	(OPTIONAL)Length scale given at elevation z=10m. The default is the N400 value: ${}^xL_{u10}$ = 100m.

Example	`!          Type   scale    A     zo    Zmin    xLv`
	`WINDU         8     1.00  6.8   0.01     2.0  ! Default value used`
	`WINDV         8     1.12  9.4   0.01     2.0  ! Iv scaled down by 12%`
	`WINDW         8     0.93  9.4   0.01     2.0  ! Iw scaled down by 7%`
	`WINDU         8     1.00  6.8   0.01     2.0   142! Adjusted lengthscale`

6.3.3 WINDV

SYNTAX	`WINDV Type Param1 Param2 Param3 …`
Description	Definition of fluctuating component.
See Also	WINDU WINDW COHERENCE
Type=0	Mean wind profile only
type	0=mean wind profile only (i.e. fluctuating comp. will not be added)
Example	`! Type` WINDV 0
Type=1	Fluctuating component added. vonKarman spectrum $\frac{fS_{ii}}{\sigma_i^2} = \frac{4 f_i \left(1+755.2 f_i^2\right)}{\left(1+283.2 f_i^2\right)^{11/6}}$ where $f_i = \frac{f\,{}^xL_i}{U}$ where i=u,v,w
type Iv xLv yLv zLv	1 = Fluctuating wind component to be included Turbulence intensity. Given as a decimal number, i.e. 17% is entered as 0.17. Length scale [m]. Mandatory input. Other lengthscales will be scaled according to ESDU if they are not given. Length scale [m]. Use 0 to get ESDU estimates Length scale [m]. Use 0 to get ESDU estimates
Example	`! Type I# xL# yL# zL#` `WINDV 1 0.0 0.0 0.0 0.0`
Type=2	Fluctuating component according to Statfjord Metocean – only defined for u-comp.
Type	2
Example	`! Type` `WINDV 2`
Type=3	Fluctuating component according to Eurocode NS-EN 1991-1-4:2005 / NS3491-4:2002 $\frac{fS_{ii}}{\sigma_i^2} = \frac{A_i f_i}{\left(1+1.5\cdot A_i \cdot f_i\right)^{5/3}}$ where $f_i = \frac{f\,{}^xL_i}{U}$ where i=u,v,w
Type Sigma A zo	3 Standard deviation of wind fluctuations (same standard dev., mean speed changes) Au=6.8 Av=Aw=9.4 Surface roughness according to Table 1 in NS3491-4:2002
Zref	Reference height. Length scales are calculated at this height. If zero: Uses Zref for U-component.
Example	`! Type sigma A zo` `WINDV 3 1.92 9.4 0.01`
Type=4 Type V10min I1	Fluctuating component according to FLEX (old DS 472). Kaimal spectrum. $S_{ii} = \frac{I_i^2 V_{10\min} L_i}{\left(1+1.5\cdot\frac{f\cdot L_i}{V_{10\min}}\right)^{5/3}}$ where L_1=600m where i=u,v,w This is similar to Type=3, but with different input values tuned to the FLEX model. V_{10min} is the mean wind at Hub height. 4 Mean wind speed at hub height. Used for all heights. Turbulence intensity in along wind direction. Const. for all gridpoints. Implies change in std with mean wind profile. Internally program calculates Iv=0.8*I1.
L1	Length scale in along wind direction. For DS472 L=600m. Used for all heights. Internally program calculates Lv=0.3*L1.
Example	`! Type V10min I L` `WINDV 4 12 0.18 600`
Type=5	Fluctuating component according to DnV-OS-J101 and IEC61400-1:2007/6.3 and Annex B: $S_{ii} = \sigma_u^2 \frac{4\cdot\frac{L_k(z)}{U(z)}}{\left(1+6.0\cdot\frac{f\cdot L_k(z)}{U(z)}\right)^{5/3}}$ where i=u,v,w

	The standard deviation of the wind fluctuation is constant across the rotor plane and taken as: σ(z)=I_u*U(z), where I_u is the turbulence intensity at hub height and U(z) is taken from the mean wind profile. L_k is implemented in as L_k=5.67z for z<60m and L_k=340.2 for z>60 (According to DnV-OS-J101/403) This is similar to Type=3 and 4, but with input values tuned to the DnV-OS-J101 input data.
type	5
I	Turbulence intensity in along wind direction. Const. for all gridpoints. Implies change in std with mean wind profile
Example	`!            Type      I` `WINDV           5   0.12`
Type=6	Fluctuating component according to Harris (NORSOK N-003): $$S_{uu} = \frac{4 \cdot k \cdot V_{10\,\min}^2 \cdot \frac{f \cdot L_u}{V_{10\,\min}}}{f \cdot \left(2.0 + \left(\frac{f \cdot L_u}{V_{10\,\min}}\right)^2\right)^{5/6}}$$ The standard deviation of the wind fluctuation is constant and based on the mean wind speed at 10m above surface and the surface drag coefficient. **Normally used in the along wind direction** V10m is the surface wind speed at10m. Taken from the mean wind profile.
type	6
Lu k	turbulence lengtscale surface drag coefficient.
Example	`!            Type     Lu       k` `WINDV           6    150   0.03`
Type=7	Fluctuating component according to Panofsky (NORSOK N-003): $$S_{vv} = \frac{15 \cdot k \cdot V_{10\,\min}^2 \cdot \frac{f \cdot L_u}{V_{10\,\min}}}{f \cdot \left(1.0 + 9.5 \cdot \left(\frac{f \cdot L_u}{V_{10\,\min}}\right)\right)^{5/3}}$$ Normally used in the across wind direction. The standard deviation of the wind fluctuation is constant and based on the mean wind speed at 10m above surface and the surface drag coefficient. V10m is the surface wind speed at10m. Taken from the mean wind profile.
type	7
Lu k	turbulence lengthscale surface drag coefficient.
Example	`!            Type    Lu       k` `WINDV           7   150   0.03`
Type=8	Fluctuating component according to N400 Bruprosjektering (2015) and Eurocode NS-EN 1991-1-4:2005: $\frac{fS_{ii}}{\sigma_i^2} = \frac{A_i f_i}{(1+1.5 \cdot A_i \cdot f_i)^{5/3}}$ where $f_i = \frac{f\,{}^xL_i}{U}$ where i=u,v,w Length scales are calculated from the input like this: For z>=z_{min} : ${}^xL_u(z)$ = ${}^xL_{u10}$*(z/10m)$^{0.3}$ For z< z_{min} : ${}^xL_u(z)$ = ${}^xL_{u10}$*(z_{min}/10m)$^{0.3}$ The default for ${}^xL_{u10}$ is the N400 value: ${}^xL_{u10}$ = 100m. The other length scales are derived from ${}^xL_u$: v-component: ${}^xL_v$ =1/4 ${}^xL_u$ w-component: ${}^xL_w$ =1/12 ${}^xL_u$

type	8 (Note: similar to type=3, but lengthscales are calculated differently, see above)
Scale	Scale factor to adjust the turbulence intensity: See description for WindU, Type=8, Scale
A	Spectral factor. According to NS-EN 1991-1-4:2005: Au=6.8 Av=Aw=9.4
zo	Surface roughness according to NS-EN 1991-1-4:2005
zmin	Minimum height of wind profile.
$^{x}L_{v10}$	(OPTIONAL)Length scale given at elevation z=10m. The default is to calculate it from $^{x}L_{u10}$ used for the u-component, as described above. If $^{x}L_{v10}$ is given: $^{x}L_{v}(z) = {}^{x}L_{v10}*(z_{min}/10m)^{0.3}$
Example	`!          Type  scale   A    zo    Zmin  xLv10` `WINDV         8    1.0 9.4  0.01     2.0`

6.3.4 WINDW

SYNTAX	`WINDW Type Param1 Param2 Param3 …`
Description	Definition of fluctuating component.
See Also	WINDU WINDV COHERENCE
Type=0	Mean wind profile only
type	0=mean wind profile only (i.e. fluctuating comp. will not be added)
Example	`! Type` `WINDW 0`
Type=1	Fluctuating component added. vonKarman spectrum $\frac{fS_{ii}}{\sigma_i^2} = \frac{4 f_i \left(1+755.2 f_i^2\right)}{\left(1+283.2 f_i^2\right)^{11/6}}$ where $f_i = \frac{f\,{}^xL_i}{U}$ where i=u,v,w
type Iw xLw yLw zLw	1 = Fluctuating wind component to be included Turbulence intensity. Given as a decimal number, i.e. 17% is entered as 0.17. Length scale [m]. Mandatory input. Other lengthscales will be scaled according to ESDU if they are not given. Length scale [m]. Use 0 to get ESDU estimates Length scale [m]. Use 0 to get ESDU estimates
Example	`! Type I# xL# yL# zL#` WINDW 1 0.11 0.0 0.0 0.0
Type=2	Fluctuating component according to Statfjord Metocean – only defined for u-comp.
Type	2
Example	`! Type` `WINDW 2`
Type=3	Fluctuating component according to Eurocode NS-EN 1991-1-4:2005 / NS3491-4:2002 $\frac{\mathrm{fS_{ii}}}{\sigma_i^2} = \frac{\mathrm{A_i f_i}}{\left(1+1.5\cdot \mathrm{A_i}\cdot \mathrm{f_i}\right)^{5/3}}$ where $f_i = \frac{f\,{}^xL_i}{U}$ where i=u,v,w
Type Sigma A zo Zref	3 Standard deviation of wind fluctuations (same standard dev., mean speed changes) Au=6.8 Av=Aw=9.4 Surface roughness according to Table 1 in NS3491-4:2002 Reference height. Length scales are calculated at this height. If zero: Uses Zref for U-component.
Example	`! Type sigma A zo` `WINDW 3 1.71 9.4 0.01`
Type=4	Fluctuating component according to FLEX (old DS 472). Kaimal spectrum. $S_{ii} = \frac{I_i^2 V_{10\,\mathrm{min}} L_i}{\left(1+1.5\cdot\frac{f\cdot L_i}{V_{10\,\mathrm{min}}}\right)^{5/3}}$ where L_1=600m where i=u,v,w This is similar to Type=3, but with different input values tuned to the FLEX model. V_{10min} is the mean wind at Hub height.
Type V10min I1 L1	4 Mean wind speed at hub height. Used for all heights. Turbulence intensity in along wind direction. Const. for all gridpoints. Implies change in std with mean wind profile. Internally program calculates Iw=0.5*I1. Length scale in along wind direction. For DS472 L=600m. Used for all heights. Internally program calculates Lw=0.1*L1.
Example	`! Type V10min I L` `WINDW 4 12 0.18 600`
Type=5	Fluctuating component according to DnV-OS-J101 and IEC61400-1:2007/6.3 and Annex B: $S_{ii} = \sigma_u^2 \frac{4\cdot\frac{L_k(z)}{U(z)}}{\left(1+6.0\cdot\frac{f\cdot L_k(z)}{U(z)}\right)^{5/3}}$ where i=u,v,w

	The standard deviation of the wind fluctuation is constant across the rotor plane and taken as: σ(z)=I_u*U(z), where I_u is the turbulence intensity at hub height and U(z) is taken from the mean wind profile. L_k is implemented in as L_k=5.67z for z<60m and L_k=340.2 for z>60 (According to DnV-OS-J101/403) This is similar to Type=3 and 4, but with input values tuned to the DnV-OS-J101 input data.
type	5
I	Turbulence intensity in along wind direction. Const. for all gridpoints. Implies change in std with mean wind profile
Example	`!          Type      I` `WINDW         5   0.12`
Type=6	Fluctuating component according to Harris (NORSOK N-003): $$S_{uu} = \frac{4 \cdot k \cdot V_{10\,min}^2 \cdot \frac{f \cdot L_u}{V_{10\,min}}}{f \cdot \left(2.0 + \left(\frac{f \cdot L_u}{V_{10\,min}}\right)^2\right)^{5/6}}$$ The standard deviation of the wind fluctuation is constant and based on the mean wind speed at 10m above surface and the surface drag coefficient. **Normally used in the along wind direction** V10m is the surface wind speed at10m. Taken from the mean wind profile.
type	6
Lu k	turbulence lengtscale surface drag coefficient.
Example	`!          Type     Lu      k` `WINDW         6    150   0.03`
Type=7	Fluctuating component according to Panofsky (NORSOK N-003): $$S_{vv} = \frac{3.36 \cdot k \cdot V_{10\,min}^2 \cdot \frac{f \cdot L_u}{V_{10\,min}}}{f \cdot \left(1.0 + 10.0 \cdot \left(\frac{f \cdot L_u}{V_{10\,min}}\right)\right)^{5/3}}$$ Normally used in the across wind direction. The standard deviation of the wind fluctuation is constant and based on the mean wind speed at 10m above surface and the surface drag coefficient. V10m is the surface wind speed at10m. Taken from the mean wind profile.
type	7
Lu k	turbulence lengtscale surface drag coefficient.
Example	`!          Type     Lu      k` `WINDW         7    150   0.03`
Type=8	Fluctuating component according to N400 Bruprosjektering (2015) and Eurocode NS-EN 1991-1-4:2005: $\frac{fS_{ii}}{\sigma_i^2} = \frac{A_i f_i}{(1 + 1.5 \cdot A_i \cdot f_i)^{5/3}}$ where $f_i = \frac{f\,{}^xL_i}{U}$ where i=u,v,w Length scales are calculated from the input like this: For z>=z_{min} : ${}^xL_u$(z) = ${}^xL_{u10}$*(z/10m)$^{0.3}$ For z< z_{min} : ${}^xL_u$(z) = ${}^xL_{u10}$*(z_{min}/10m)$^{0.3}$ The other length scales are derived from ${}^xL_u$: v-component: ${}^xL_v$ =1/4 ${}^xL_u$ w-component: ${}^xL_w$ =1/12 ${}^xL_u$
type	8

	(Note: similar to type=3, but lengthscales are calculated differently, see above)
Scale	Scale factor to adjust the turbulence intensity: See description for WindU, Type=8, Scale
A	Spectral factor. According to NS-EN 1991-1-4:2005: Au=6.8 Av=Aw=9.4
zo	Surface roughness according to NS-EN 1991-1-4:2005
zmin	Minimum height of wind profile.
${}^{x}Lw_{10}$	(OPTIONAL)Length scale given at elevation z=10m. The default is to calculate it from ${}^{x}L_{u10}$ used for the u-component, as described above. If ${}^{x}L_{w10}$ is given: ${}^{x}L_{w}(z) = {}^{x}L_{w10}*(z_{min}/10m)^{0.3}$
Example	`! Type scale A zo Zmin xLw10` `WINDW 8 1.0 9.4 0.01 2.0`

6.3.5 COHERENCE

SYNTAX	`COHERENCE type Param1 Param2 Param3 …`
Description	Coherence function
See Also	WINDVU WINDV WINDW
Type=1	Normal, simple coherence function $\sqrt{coh(f,s)} = \exp(-\frac{c_i \cdot f \cdot s}{U})$
Type cu cv cw	1 = Normal decay function (exponential decay) Decay factor for fluctuating wind component u Decay factor for fluctuating wind component v Decay factor for fluctuating wind component w
Example	`! Type cu cv cw` `COHERENCE 1 7.5 8.0 11.0`
Type=2	Statfjord Metocean coherence function $\sqrt{coh(f,s)} = \exp\left(-\frac{1}{U_0} \cdot \left(\sum_{i=1}^{3} A_i^2\right)^{0.5}\right)$ where s=Δ and $A_i = \alpha_i \cdot f^{r_i} \cdot \Delta_i^{q_i} \cdot z_g^{-p_i}$ $z_g = \frac{(z_1 \cdot z_2)^{1/2}}{10}$ and q, p r and α are given for Δ in different directions in:

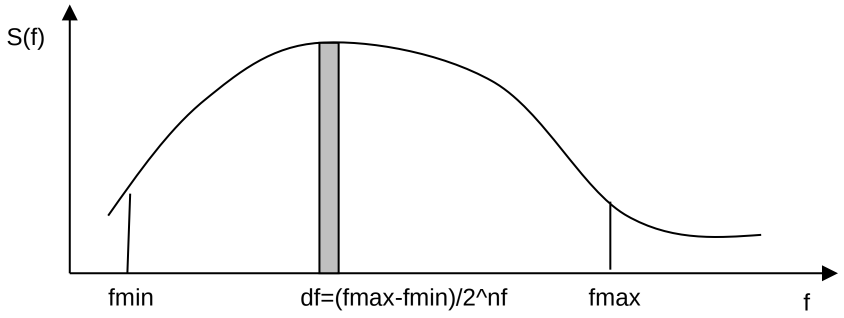
i	Δ	q_i	p_i	r_i	α_i
1	$\lvert x_2 - x_1 \rvert$	1.00	0.4	0.92	2.9
2	$\lvert y_2 - y_1 \rvert$	1.00	0.4	0.92	45.0
3	$\lvert z_2 - z_1 \rvert$	1.25	0.5	0.85	13.0

	All this is implemented in the code, and necessary data is taken from the mean wind profile. U0 is the 1 hour mean wind at 10m above sea level. Mean wind at 10m for the actual simulation is used herein.
Type	2
Example	`! Type` `COHERENCE 2`
Type=3	Coherence function as defined by NS3491-4:2002 $\sqrt{coh(f,s)} = \exp\left(\frac{-f\sqrt{c_y^2 \cdot \Delta y^2 + c_z^2 \cdot \Delta z^2}}{0.5 \cdot (v_s(z_1) + v_s(z_2))}\right)$ where Δy and Δz is the separation in y and z-direction and vs is 10min mean speed. Cy and cz are empirical constants defined below.
Type Cx Cy cz	3 Decay factor in x-direction; cx=0 Decay factor in y-direction; cx=10 Decay factor in z-direction; cx=10
Example	`Type cx cy cz` `COHERENCE 3 0.0 10.0 10.0`
Type=4	Panofsky coherence function $\sqrt{coh(f,s)} = \exp(-\frac{c_i \cdot \left(2 - \frac{\lvert \Delta z \rvert}{R}\right) \cdot R \cdot f}{0.5 \cdot (v_s(z_1) + v_s(z_2))})$ where Δz is the vertical separation and vs is 10min mean speed. c_i are empirical constants defined below and R: $R = \sqrt{\Delta x^2 + \Delta y^2 + \Delta z^2}$
Type	

cu	Decay factor for fluctuating wind component u
cv	Decay factor for fluctuating wind component v
cw	Decay factor for fluctuating wind component w
Example	`Type cu cv cw` `COHERENCE 4 6.0 6.0 3.0`
Type=5	Coherence function as defined in IEC61400-1:2007 Appendix B.2 $\sqrt{Coh(f,s,\alpha)} = \exp\left[-\alpha \cdot \left(\left(\frac{f \cdot s}{U_z}\right)^2 + \left(\frac{0.12 \cdot s}{L_k}\right)^2\right)^{0.5}\right]$ where U_{hub} is the mean wind speed at the given z level and L_k is the length scale at the given z-level. L_k is given in WindU Type 5 in section 6.3.2. In IEC61400-1:2007 α=12.0. f is frequency in Hz and s is separation in m.
Type	5 = coherence function IEC6140-1:2007
au	Decay factor for fluctuating wind component u
av	Decay factor for fluctuating wind component v
aw	Decay factor for fluctuating wind component w
z	Height in m for where U_z and L_k is calculated, often Hub height or another representative elevation.
Example	`! Type au av aw z` `COHERENCE 5 12.0 12.0 12.0 84`
Type=6	Coherence function as defined by N400 NOTE: Modified to take into account simultaneous separation in all directions: $\sqrt{coh_i(f,s)} = \exp\left(\frac{-f \cdot \sqrt{c_{ix}^2 \cdot \Delta x^2 + c_{iy}^2 \cdot \Delta y^2 + c_{iz}^2 \cdot \Delta z^2}}{1/2 \cdot (v_s(z_1) + v_s(z_2))}\right)$ where Δx, Δy and Δz is the separation in x, y and z-direction and v_s is 10min mean speed in the centre between these points. Cx, c_y and c_z are empirical constants defined below.
Type	6
NOTE:	All values below must be given,(use zero values for parameters not needed. Values taken from N400:2015, with fill inn values by ESDU (cxu,cxv and cxw)
cux, cuy, cuz	Decay factor for u-component (x,y,z – direction). Typical values: cux = 10.0, cuy = 10.0, cuz = 10.0
cvx, cvy, cvz	Decay factor for v-component (x,y,z – direction).. Typical values cvx = 10.0, cvy = 6.5, cvz = 6.5
cwx,cwy,cwz	Decay factor for w-component (x,y,z – direction).. Typical values: cwx = 10.0, cwy = 6.5, cwz = 3.0

Example	`Type cux cuy cuz cvx cvy cvz cwx cwy cwz`
	`COHERENCE 6 3.0 10.0 10.0 6.0 6.5 6.5 3.0 6.5 3.0`
	
	`If all x-coordinates are in same plane:`
	`Type cux cuy cuz cvx cvy cvz cwx cwy cwz`
	`COHERENCE 6 0.0 10.0 10.0 0.0 6.5 6.5 0.0 6.5 3.0`

6.3.6 FAXIS



SYNTAX	`FAXIS fmin fmax nf`
Description	Specifies which part of the wind spectrum to be extracted. Time series properties are governed by this choice. Frequency segmentation is df=(fmax-fmin)/2^nf. Length of timeseries=1/df. The timestep=1/fmax. This is an alternative to the TIME
See Also	TIME.
Fmin Fmax nf	Minimum frequency extracted from wind spectrum [Hz]. Maximum frequency extracted from wind spectrum [Hz] Number of frequency segmentations, thus number of time samples: N=2^nf
Example	`!       Fmin Fmax nf` `FAXIS  0.0001  5 12`

6.3.7 TIME

SYNTAX	`TIME tottime dt`
Description	Gives length of timeseries in seconds. This is an alternative to the FAXIS
See Also	FAXIS.
tottime dt	Total time of simulation [s]. Time step between each simulated point [s].
Example	`!        totTime dt` `TIME        1000 0.2`

6.3.8 SEEDIN

SYNTAX	`SEEDIN seedu seedv seedw`
Description	Seeds to the random number generator.
See Also	
seedu seedv seedv	Seed for u-component generation. 0 = a random number is obtained by the integer>0 this is used as a fixed seed (i.e. time series with same number of points and with same number of samples, can be regenerated by using this seed.) See seedu See seedu
Example	`!         Seedu Seedv Seedw` `  SEEDIN      1     0     1`

6.3.9 ROTATE

SYNTAX	`ROTATE øZ dx dy dz`
Description	Generate rotate information for use in USFOS/SWAYSIM. Rotate first, then translate
See Also	
øZ	Rotates wind speed vectors about global z-axis([Deg]).
Dx	Translation of wind field in global-x coordinate system
Dy	Translation of wind field in global-y coordinate system
Dz	Translation of wind field in global-z coordinate system
Example	`! Øz dx dy dz` `ROTATE 30 50 0 0`

6.3.10 VERIFY

The Verify command recreates the wind spectrum and root coherence from the simulated time series and compares it to target values.

SYNTAX	`VERIFY point1 point2 blockdiv`
Description	Seeds to the random number generator.
See Also	
point1 point2 blockdiv	External node number of first point of interest. (See listing in HELP file) External node number of first point of interest. (See listing in HELP file) number of divisions of the simulated timeseries. use blockdiv=2^n (i.e. 1,2,4,8…)
Example	`!         Point1 Point2 BlockDiv` `  VERIFY      2      4         4`

7 Example

7.1 *Example 1: Input used for wind turbine analysis*

7.1.1 Sample input file

```
! Sample input to WindSim
!
! Simulation based on Grid
!
!----------------------------------------------
!                   Min Max   No
  XGRID     0    0   1
  YGRID   -45   45  10
  ZGRID     5   95  10
!
!
!----------------------------------------------
!WINDU,V,W Type Comp Parameters
!  Type: 0 : Mean Wind profile only
!  Type: 1 : Buffeting load
!        Parameters:  I# xL# yL# zL#
!
!         Type     I#    xL# yL# zL#
 WINDU       1 0.109 248.8 0.0 0.0
 WINDV       1 0.085   0.0 0.0 0.0
 WINDW       1 0.060   0.0 0.0 0.0
!----------------------------------------------
! Reference height 10m
! Uz=Uref*(z/zref)^alpha (zref=10m above zero level.)
! Uz : Wind at level z
! z  : level for the wind Uz
! z_zero : zero level for wind profile
! boundh : Boundary Layer height. Assume 2000 if not known
! Dir: Wind parallel to: X=1 Y=2 Z=3
!           Uz z    z_zero alpha boundh Dir
 WPROFILE   30 50.0 0      0.123   1700   1
!----------------------------------------------
! Type=1 : Normal decay function
!           Parameters: cu cv cw
!           Type    cu  cv   cw
 COHERENCE     1   7.5 8.0 11.0
!---------------------------------------------
! Time axis. Alternative to FAXIS
! totTime[s] : Total simulation time in seconds
! dt         : Time step
!       totTime dt
  TIME     1000 0.2
!---------------------------------------------
! SEEDIN Input seed for forced simulation. 0=random
!        Seedu Seedv Seedw
! SEEDIN     0     0     0
  SEEDIN     1     1     1
!---------------------------------------------
! VERIFY
! Picking out two points for verification"
! BlockDiv specifies number of divisions of time series
!                              Point1 Point2 BlockDiv
  VERIFY      2      4        4
!---END OF FILE
```

7.1.2 Sample output

```
' ------------------------------------------------
' I N P U T   F I L E   F O R   * S W A Y S I M *
' ------------------------------------------------
' This file was created: Wed Jul  5 14:57:07 2006
' By WindSim - the numerical wind simulator: ver=1.0  Release date:2006.07.05
' Developed by Ketil Aas-Jakobsen: kaa@aaj.no
' ------------------------------------------------
' Summary of wind properties
' ------------------------------------------------
' Wind profile:
'   U(z)= 30.00m/s. z= 50.00. z_zero=  0.00m. alpha=0.12
' Wind spectrum parameters:
'   U-dir: Iu=0.109. xLu=248.800m. yLu= 80.263m. zLu= 59.154m.
'   V-dir: Iv=0.085. xLv= 58.993m. yLv= 76.124m. zLv= 28.052m.
'   W-dir: Iw=0.060. xLw= 20.749m. yLw= 13.387m. zLw= 19.733m.
' Wind coherence parameters:
'   cu= 7.50. cv= 8.00. cw=11.00
' Used seeds:
'       Seedu        Seedv        Seedw
'           1            1            1
' Length of simulation:  1000.20sec. dt= 0.20000sec.
' Frequency axis: Fmin= 0.00010 Fmax= 5.00010 df= 0.0006104
' ------------------------------------------------
' Key data for first simulated point:
' ------------------------------------------------
' U-component StDev:
'             Target:     2.463
'             Extracted:  2.443
'             Simulated:  2.505
' V-component StDev:
'             Target:     1.921
'             Extracted:  1.895
'             Simulated:  1.937
' W-component StDev:
'             Target:     1.356
'             Extracted:  1.320
'             Simulated:  1.328
' ------------------------------------------------
' Input cards for SWAYSIM
' ------------------------------------------------
'            GW_Type
 GWF Type    33
'
'                     nX    nY    nZ      nSteps  ParamCode(Elev,Velo,Acc,Press)
 GWF KeyData Size      1    10    10      5001    11
'
 GWF Keydata CoordSys 1.000 0.000 0.000
                      0.000 1.000 0.000
                      0.000 0.000 1.000
                      0.000 0.000 0.000
'
 GWF Grid     X       Constant       0.000       0.000
 GWF Grid     Y       Constant     -45.000      45.000
 GWF Grid     Z       Constant       5.000      95.000
'
 GWF MeanWind
'            Vx           Vy           Vz
       22.6007       0.0000       0.0000
       25.8706       0.0000       0.0000
       27.5483       0.0000       0.0000
(numbers deleted)
'
 GWF Time       0.0000
'
 GWF WindVector
```

```
'              Vx            Vy            Vz
        27.2725       2.9948        1.4904
        30.3665       2.1184        0.9499
        31.4347       1.7005        0.1647
(numbers deleted)
```

7.2 Example 2: According to N400:2015 / NS-EN 1991-1-4:2005

7.2.1 Input file

The below input is in accordance with N400:2015 and NS-EN 1991-1-4:2005 + NA:2009.

```
!-----------------------------------------------
! Z upwards
!   Min Max  No
 XGRID    0     0   1
 YGRID    0   100  11
 ZGRID   40    60   3
!
!-----------------------------------------------
! WPROFILE
!-----------------------------------------------
!
!Type 3 : N400:2015 / NS-EN 1991-1-4:2009
!         Type   vb  z_zero    z_0 z_min
 WPROFILE     3 29.1     0.0  0.047   2.0
!
!-----------------------------------------------
!WINDU,V,W
!-----------------------------------------------
!Type 3 : N400:2015 / NS-EN 1991-1-4:2009
!         Type Scale     A    z0 Zmin
 WINDU       8  1.00   6.8  0.01  2.0
 WINDV       8  1.00   9.4  0.01  2.0
 WINDW       8  1.00   9.4  0.01  2.0
!
!-----------------------------------------------
!COHERENCE
!-----------------------------------------------
! TYPE 4: N400:2015
!           Type  cux  cuy  cuz  cvx  cvy  cvz  cwx  cwy  cwz
 COHERENCE     6 10.0 10.0 10.0 10.0  6.5  6.5 10.0  6.5  3.0
!
!----------------------------------------------
! 1-hour simulation:
! nf=14 n=16384 T=3600s => dt=3600/16384=0.2197 Fmax=4.55
!         Fmin Fmax  nf
 FAXIS  0.0001 4.55 14
!
!----------------------------------------------
! SEEDIN Input seed for forced simulation. 0=random
!        Seedu Seedv Seedw
! SEEDIN     0     0     0
  SEEDIN   101   201   301
```

7.2.2 Extract of output file

```
' ---------------------------------------------------
' O U T P U T   F I L E   F R O M   * W I N D S I M *
' ---------------------------------------------------
' This file was created: 2018/10/23 16:50:57.598
' Simulation took:     0 min  22 sec.
' By WindSim - the numerical wind simulator: ver=4.0 Release date:2018.10.26
' Developed by Ketil Aas-Jakobsen: kaa@aaj.no


' -----------------------------------------------
' Summary of wind properties
' -----------------------------------------------
' Wind profile:
' Wind profile type: NS-EN 1991-1-4:2005 + NA:2009
'   vb= 29.10m/s. z_0=  0.0470. z_min=  2.00m
' Wind spectrum parameters:
'   U-dir: N400:2015 (NS-EN1991-1-4:2005+NA:2009)
'          scale=  1.000. A=  6.800. z0=  0.010m. Zmin=    2.0m. L=  162.1m (@z=   50.0m)
'   V-dir: N400:2015 (NS-EN1991-1-4:2005+NA:2009)
'          scale=  1.000. A=  9.400. z0=  0.010m. Zmin=    2.0m. L=   40.5m (@z=   50.0m)
'   V-dir: N400:2015 (NS-EN1991-1-4:2005+NA:2009)
'          scale=  1.000. A=  9.400. z0=  0.010m. Zmin=    2.0m. L=   13.5m (@z=   50.0m)
' Wind coherence parameters:
'   Coherence acc. to N400:2015
'   u: cux=10.00. cu=10.00. cuz=10.00
'   v: cvx=10.00. cv= 6.50. cvz= 6.50
'   w: cwx=10.00. cw= 6.50. cwz= 3.00
' Used seeds:
'       Seedu       Seedv       Seedw
'         101         201         301
' Length of simulation:  3600.96sec. dt= 0.21979sec.
' Frequency axis: Fmin= 0.00010 Fmax= 4.55000 df= 0.0002777


' -----------------------------------------------
' Key data for a simulated point:
' -----------------------------------------------
' If Statfjord Metocean is used, Target is not available. (StDev varies with z)
' If Panofsky or Harris is used Metocean is used, Target is not available. (not part of
def.)
' X,Y,Z coordinate of data below:       0.00      0.00     60.00
' Mean windspeed of this point [m/s]:   37.9
' U-component StDev:
'             Target:     4.353
'             Extracted:  4.284
'             Simulated:  4.238
' V-component StDev:
'             Target:     3.265
'             Extracted:  3.168
'             Simulated:  3.111
' W-component StDev:
'             Target:     2.176
'             Extracted:  2.045
'             Simulated:  1.970
```

7.2.3 Verification plots

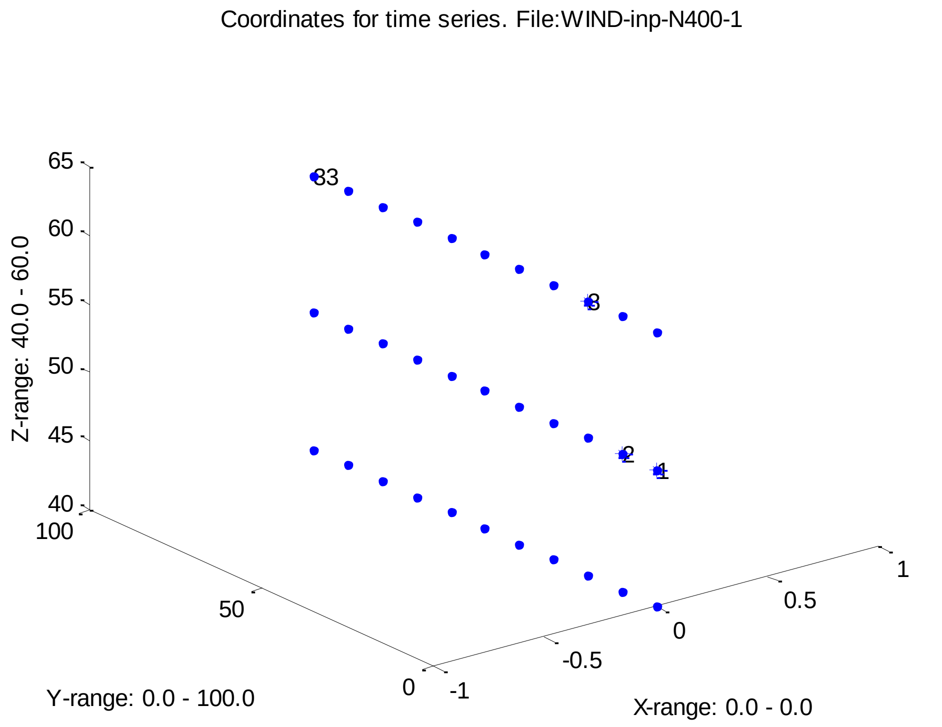


Figure 12 Simulated grid. Verified points indicated with 1,2 and 3.

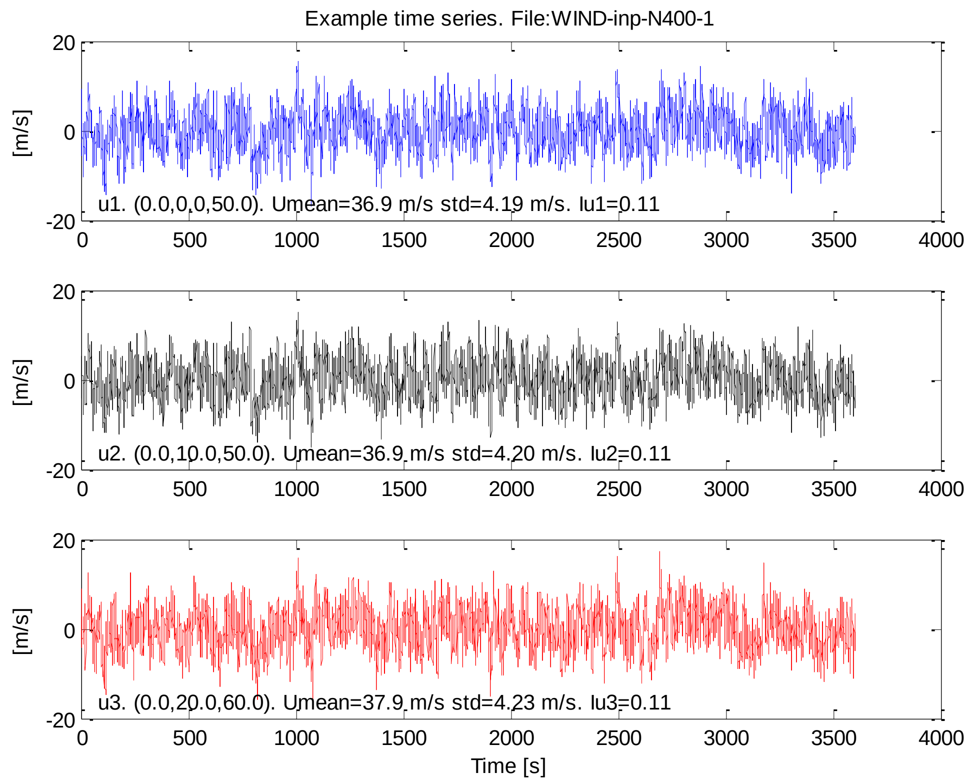


Figure 13 Simulated time histories with key data extracted from the simulated time series.

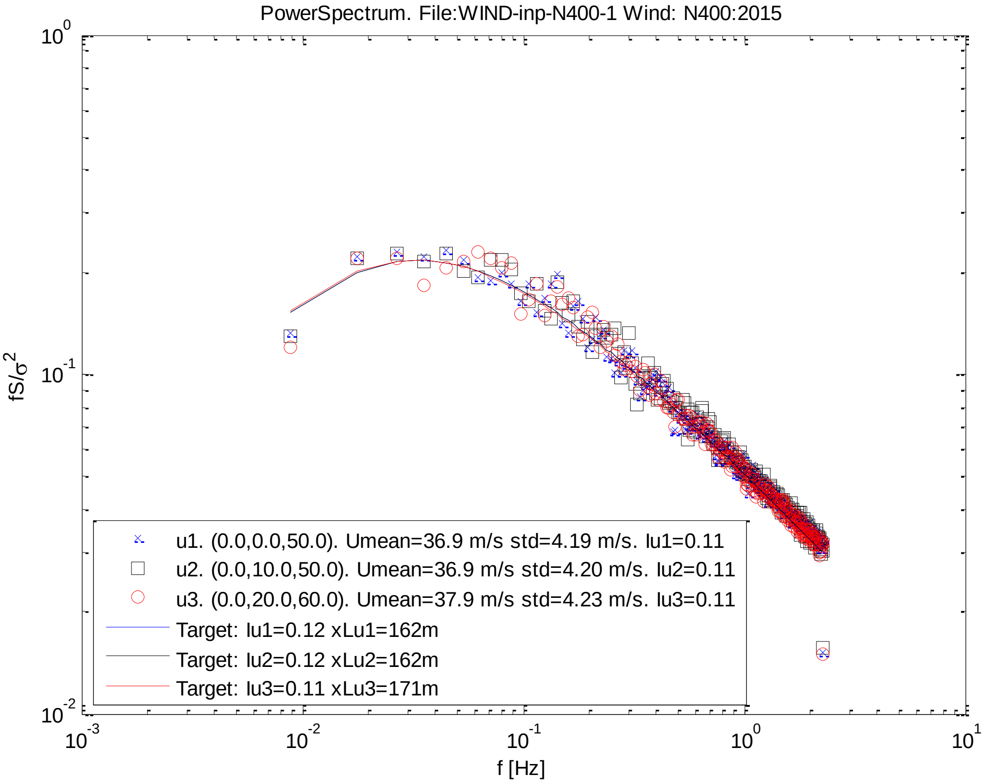


Figure 14 Spectra from simulated time series vs target spectra (full lines)

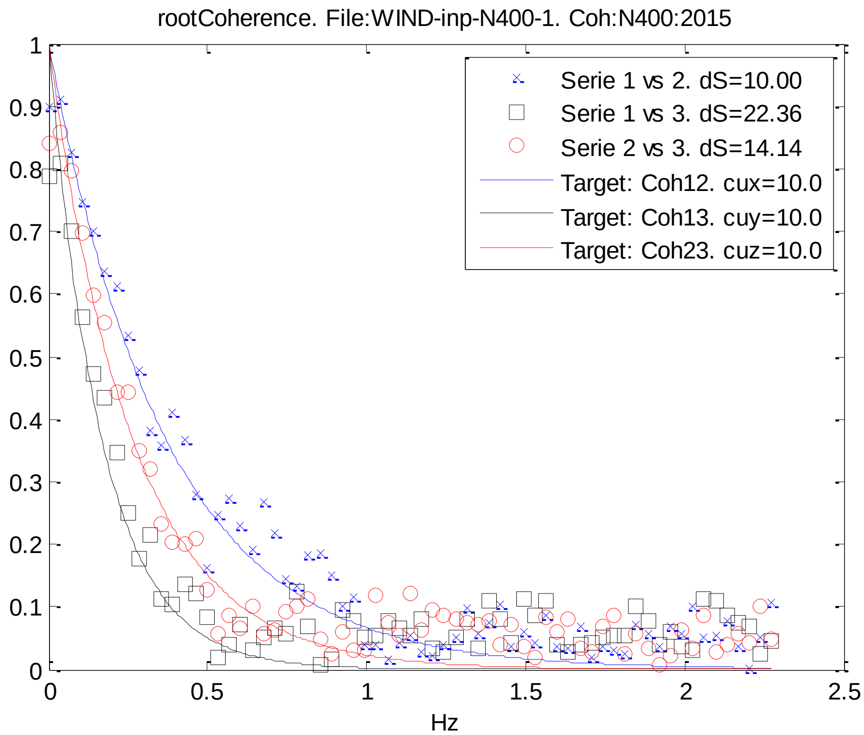


Figure 15 rootCoherence from simulated time series vs target values (full lines)

8 References

/1/ Aas-Jakobsen K. Time domain calculations of buffeting response for wind sensitive structures. 1998. Dr. ing. thesis. Norwegian University of Technology and Science. ISBN 82-471-0189-0

/2/ Engineering Science Date Unit, London, England. WInd Engineering, 5 edition, 1993. Vol 1-4.

/3/ NS3491-2002. Design of structures. Design of actions. Part 4: Wind loads.

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