`windsimu` a program for simulation of turbulence in complex terrain

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1 Introduction

The program `windsimu` simulates wind fluctuations in flat or complex terrain. Much of the code as well as the input is similar to that of `comspec` (see the description of that program). However, the output is fields of turbulence that can be used as input for structural mechanics calculations in the time domain.

All inputs are given in a file, and the name of this file is given as command line argument to the program `windsimu`.

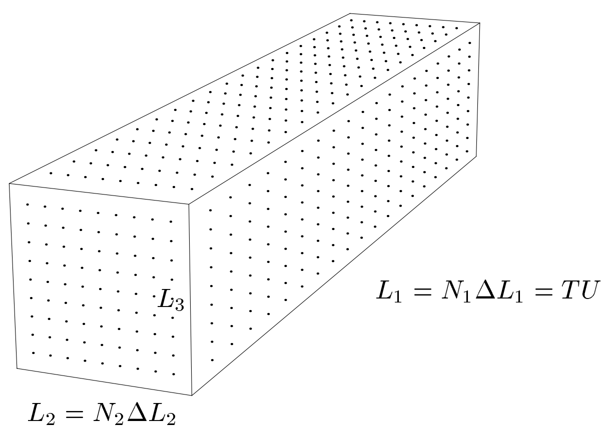

Figure 1: The box consists of $N_1 \times N_2 \times N_3$ points and has side lengths L_i, $i = 1, 2, 3$, so the separation between the points in the i-direction is $\Delta L_i = L_i / N_i$. U is the mean wind speed and T is the simulation time.

2 The input file

In the following the x-direction is the direction of the mean wind. The y-direction is horizontal and perpendicular to that, and the z-direction is vertical, positive upward and perpendicular to the two first. The x direction is equivalent to a time axis (via Taylor's hypothesis).

2.1 Description of the geometry of the simulated fields

The first number in the input file is the number of dimensions in the field(s) to be simulated, $fieldDim$. This is either 1, 2 or 3. The next is the number of components of the wind field that should be simulated $NComp$, again 1, 2 or 3.

If $NComp < 3$ the next $NComp$ number describes which components to simulate. E.g. if $NComp = 2$ the next two numbers could be 1 and 3, if only the u- and w-components are going to be simulated.

If $fieldDim = 2$ the next number $AbsentDim$ is the spatial dimension in which the simulated field does *not* extent into. F.ex. if $AbsentDim = 3$ the two-dimensional fields extend in the x- and y-directions, which could be used for load simulation on a bridge deck. If $AbsentDim = 2$ the two-dimensional fields extend in the x- and z-directions, suitable of load calculations on a tower or mast. For wind turbine purposes $fieldDim = 3$.

The next $fieldDim$ numbers are N_i, which should be powers of 2 (see figure 1), and the next $fieldDim$ numbers are L_i, the dimensions of the box in meters. This concludes the description of the geometry of the simulated fields.

2.2 Turbulence description

The next line in the input file is a word describing the general situation. It can either be `basic`, `sea`, `land`, or `terrain`. The following table, which is exactly the same as in the note on `comspec` gives the additional input in each of the four cases:

	Description
`basic`	The parameters $\alpha\varepsilon^{2/3}$, L and Γ, which describes the three-dimensional spectrum (the so-called spectral tensor) for flat terrain, are given directly. This is only valuable if the parameters for some reason are know in advance, or if isotropic ($\Gamma = 0$) statistics is wanted.
`sea`	Open sea. Mean wind speed U, the height above the sea surface z, and the spectrum type (see note on `comspec`) are given.
`land`	Flat, homogeneous land. Mean wind speed U, the height above the surface z, the roughness length z_0, and the spectrum type are given.
`terrain`	Complex terrain. The name of the file containing output from LINCOM is given. The output from LINCOM is the flow characteristics along an upstream line. The next input is an integer specifying the height of interest in the LINCOM file. If there is only one this number should be 1. Thereafter two booleans are given (either `True` or `False`) determining whether the roughness perturbations and the orography perturbations have to be taken into account. The spectrum type is finally given.

2.3 The seed of the output files

The next number is a seed for the random number generator. It is a used supplied negative integer. Finally, $NComp$ file names for the binary output are given, i.e. each wind component of the simulated field is written to a separate file. The numbers are written as four byte floats. This confers to the conventions of HAWC, a program for the calculation of loads on horizontal axis wind turbines.

3 Examples of input and output

3.1 Example 1

Simulate a three-dimensional field of u-fluctuations at a site with complex roughness distribution with the wind coming from the North on a grid-box of $4096 \times 32 \times 32$ points with the dimensions $6144 \times 80 \times 80$ meters. This requires approximately 16 Mb of RAM on the computer.

The input file is (`simEx1.inp`)

`3`	*Three-dimensional field*
`1`	*Only one component to be simulated,*
`1`	*namely the u-component.*
`4096`	N_1
`32`	N_2
`32`	N_3
`6144`	L_1 *in meters*
`80`	L_2
`80`	L_3
`terrain`	*Complex terrain calculation*
`P_01_000.dat`	*LINCOM output file*
`1`	*The first (and only) height in the LINCOM file.*
`False`	*Effects of orography are not taken into account,*
`True`	*but effect of roughness changes are.*
`0`	*Spectrum type*
`-5`	*Random seed*
`sim1`	*Name of the output file*

The output is a binary file. If $u(n_1, n_2, n_3)$ is the fluctuating part of the wind field, the binary file contains u written as four byte reals with the last index running fastest. E.g. the first vertical slice of the data is obtained by reading the first $N_2 \times N_3$ reals from the file.

3.2 Example 2

Simulate a three-dimensional field of u-, v- and w-fluctuations at a site with complex roughness distribution and orography (WAsPvale) with the wind coming from 225 ° on a grid-box of $1024 \times 32 \times 32$ points with the dimensions $2096 \times 96 \times 96$ meters. This requires approximately 12 Mb of RAM on the computer.

The input file is (`simEx2.inp`)

`3`	*Three-dimensional field*
`3`	*All three components to be simulated,*
`1024`	N_1
`32`	N_2
`32`	N_3
`2096`	L_1 *in meters*
`96`	L_2
`96`	L_3
`terrain`	*Complex terrain calculation*
`P_01_225.dat`	*LINCOM output file*
`1`	*The first height in the LINCOM file.*
`True`	*Both effects of orography*
`True`	*and roughness changes are taken into account.*
`0`	*Spectrum type*
`-5`	*Random seed*
`sim1`	*Name of the output files*
`sim2`	
`sim3`	

The output is three binary files.

3.3 Example 3

Simulate a *two*-dimensional field of w-fluctuations at a site with complex roughness distribution and orography (WAsPvale) with the wind coming from 225° on a grid-box of 1024×128 points with the dimensions 10240×1280 meters. This could be a simulation for bridge load calculations.

The input file is (`simEx3.inp`)

`2`	*two-dimensional field*
`3`	*One component is simulated,*
`3`	*namely the* w*-component*
`3`	*The field does not extend into the vertical dimension.*
`1024`	N_1
`128`	N_2
`10240`	L_1 *in meters*
`1280`	L_2
`terrain`	*Complex terrain calculation*
`P_01_225.dat`	*LINCOM output file*
`1`	*The first height in the LINCOM file.*
`True`	*Both effects of orography*
`True`	*and roughness changes are taken into account.*
`2`	*Spectrum type*
`-5`	*Random seed*
`sim2d`	*Name of the output file*

The output is a single binary file.

4 Source files

All source files are described in the note on `comspec` except the following:

`tensimu.cpp`	Function for the simulation of field of various dimensions.
`windsimu.cpp`	Main file handling input and output.
`windsimu.exe`	The executable

References