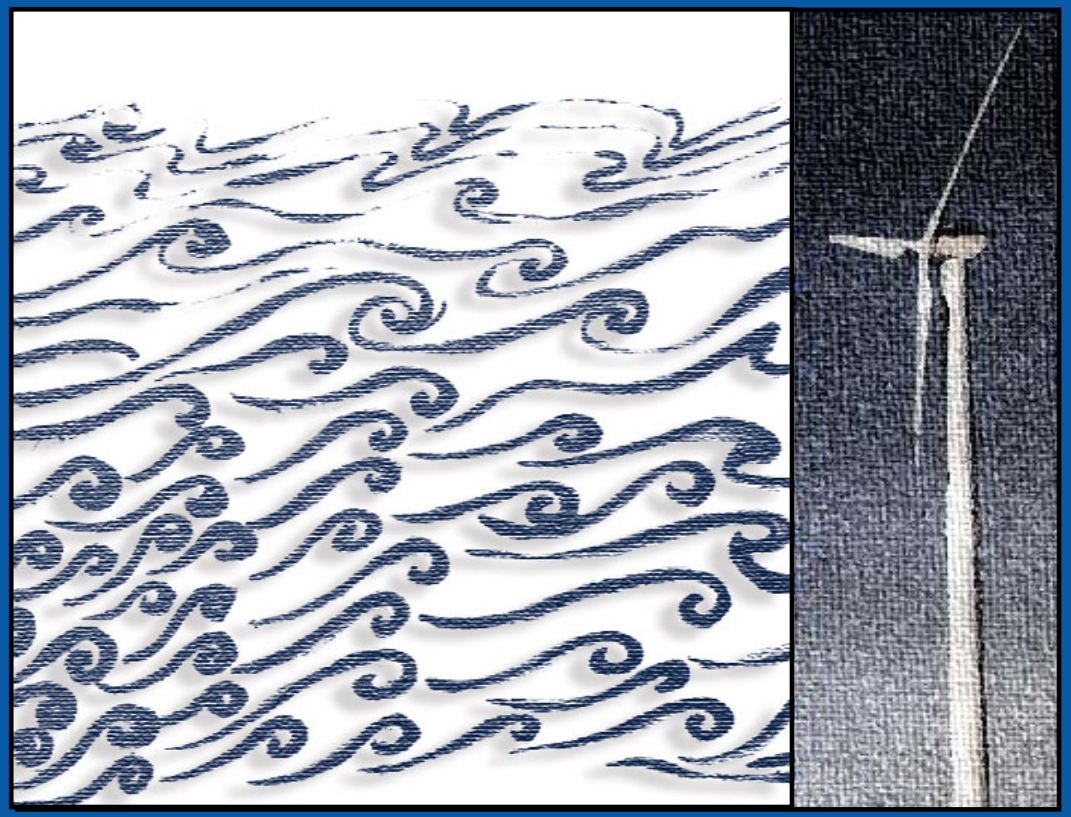
National Renewable Energy Laboratory
*Innovation for Our Energy Future*

# Using TurbSim:
## The Non-Meteorological Input Parameters



**TurbSim Workshop**
**National Wind Technology Center**

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**September 23, 2008**

# Outline of Presentation

- TurbSim Input File
  - Runtime Options
  - Turbine/Model Specifications
  - Coherent Turbulence Scaling Parameters
  - Input Parameters
    - Definitions
    - What they do
- Running the Code
- Creating and Using Coherent Turbulence Files

# The TurbSim Input File

- The TurbSim Input File for version 1.40: TurbSim.inp
  - All values needed to run TurbSim are contained in a single text file
  - Parameters are assumed to be on specific lines
  - Character strings are not case sensitive

## Sample TurbSim Input File

```
TurbSim Input File. Valid for TurbSim v1.40, 12-Sep-2008

---------Runtime Options-----------------------------------
2318573             RandSeed1       - First random seed  (-2147483648 to 2147483647)
RANLUX              RandSeed2       - Second random seed (-2147483648 to 2147483647) for intrinsic pRNG, or a
False               WrBHHTP         - Output binary hub-height turbulence parameters?  (Generates RootName.bi
False               WrFHHTP         - Output formatted hub-height turbulence parameters?  (Generates RootName
False               WrADHH          - Output formatted AeroDyn hub-height time-series data?  (Generates RootN
False               WrADFF          - Output binary TurbSim/AeroDyn full-field time-series data? (Generates R
True                WrBLFF          - Output binary BLADED/AeroDyn full-field time-series data?  (Generates R
False               WrADTWR         - Output binary tower time-series data? (Generates RootName.twr)
False               WrFMTFF         - Output formatted full-field time-series data?  (Generates RootName.u, R
True                WrACT           - Output formatted AeroDyn coherent turbulence time steps? (Generates Roo
True                Clockwise       - Clockwise rotation looking downwind? (used only for full-field binary f
True                ScaleIEC        - Scale hub-height IEC turbulence to target TI?

--------Turbine/Model Specifications-----------------------
13                  NumGrid_Z       - Vertical grid-point matrix dimension
13                  NumGrid_Y       - Horizontal grid-point matrix dimension
0.05                TimeStep        - Time step [seconds]
600                 AnalysisTime    - Length of analysis time series [seconds] (program will add time if nece
40                  UsableTime      - Usable length of output time series [seconds] (program will add GridWid
84.2876             HubHt           - Hub height [m] (should be > 0.5*GridHeight)
80.00               GridHeight      - Grid height [m]
80.00               GridWidth       - Grid width [m] (should be >= 2*(RotorRadius+ShaftLength))
0                   VFlowAng        - Vertical mean flow (uptilt) angle [degrees]
0                   HFlowAng        - Horizontal mean flow (skew) angle [degrees]

--------Meteorological Boundary Conditions-------------------
"SMOOTH"            TurbModel       - Turbulence model ("IECKAI"=Kaimal, "IECVKM"=von Karman, "GP_LLJ", "NWTC
"1-ED3"             IECstandard     - Number of IEC 61400-x standard (x=1,2, or 3 with optional 61400-1 editi
"A"                 IECturbc        - IEC turbulence characteristic ("A", "B", "C" or the turbulence intensit
"NTM"               IEC_WindType    - IEC turbulence type ("NTM"=normal, "xETM"=extreme turbulence, "xEWM1"=e
default             ETMc            - IEC Extreme Turbulence Model "c" parameter [m/s]
default             WindProfileType - Wind profile type ("JET","LOG"=logarithmic,"PL"=power law,"IEC"=PL on r
84.2876             RefHt           - Height of the reference wind speed [m]
18.2                URef            - Mean (total) wind speed at the reference height [m/s] (or "default" for
default             ZJetMax         - Jet height [m] (used only for JET wind profile, valid 70-490 m)
default             PLExp           - Power law exponent [-] (or "default")
default             Z0              - Surface roughness length [m] (or "default")

--------Non-IEC Meteorological Boundary Conditions-----------
default             Latitude        - Site latitude [degrees] (or "default")
0.05                RICH_NO         - Gradient Richardson number
default             UStar           - Friction or shear velocity [m/s] (or "default")
default             ZI              - Mixing layer depth [m] (or "default")
default             PC_UW           - Hub mean u'w' Reynolds stress (or "default")
default             PC_UV           - Hub mean u'v' Reynolds stress (or "default")
default             PC_VW           - Hub mean v'w' Reynolds stress (or "default")
default             IncDec1         - u-component coherence parameters (e.g. "10.0  0.3e-3" in quotes) (or "d
default             IncDec2         - v-component coherence parameters (e.g. "10.0  0.3e-3" in quotes) (or "d
default             IncDec3         - w-component coherence parameters (e.g. "10.0  0.3e-3" in quotes) (or "d
default             CohExp          - Coherence exponent (or "default")

--------Coherent Turbulence Scaling Parameters-------------------
"M:\coh_events\eventdata"  CTEventPath     - Name of the path where event data files are located
"Random"            CTEventFile     - Type of event files ("LES", "DNS", or "RANDOM")
true                Randomize       - Randomize the disturbance scale and locations? (true/false)
 1.0                DistScl         - Disturbance scale (ratio of billow height to rotor disk). (Ignored when
 0.5                CTLy            - Fractional location of tower centerline from right (looking downwind) t
 0.5                CTLz            - Fractional location of hub height from the bottom of the dataset. (Igno
30.0                CTStartTime     - Minimum start time for coherent structures in RootName.cts [seconds]

===============================================
NOTE: Do not add or remove any lines in this file!
===============================================
```

# The TurbSim Input File

- Overview of Sections in the Input File
  - Runtime Options
    - Sets random seed(s)
    - Determines type(s) of files to generate
  - Turbine/Model Specifications
    - Sets grid size and location
    - Determines time/frequency content
  - Meteorological Boundary Conditions
    - Sets spectral model
    - Determines wind speeds
    - Sets IEC-specific boundary conditions
  - Non-IEC Meteorological Boundary Conditions
    - Sets stability and shear velocity
    - Determines coherence
  - Coherent Turbulence Scaling Parameters
    - Locates LES and/or DNS files
    - Determines spatial scales for coherent structures

# Runtime Options

TurbSim's
**Runtime Options**
Input Parameters

```
---------Runtime Options-----------------------------------
2318573    RandSeed1    - First random seed  (-2147483648 to
RANLUX     RandSeed2    - Second random seed (-2147483648 to
False      WrBHHTP      - Output binary hub-height turbulence
False      WrFHHTP      - Output formatted hub-height turbule
False      WrADHH       - Output formatted AeroDyn hub-height
False      WrADFF       - Output binary TurbSim/AeroDyn full-
True       WrBLFF       - Output binary BLADED/AeroDyn full-f
False      WrADTWR      - Output binary tower time-series dat
False      WrFMTFF      - Output formatted full-field time-se
True       WrACT        - Output formatted AeroDyn coherent t
True       Clockwise    - Clockwise rotation looking downwind
True       ScaleIEC     - Scale hub-height IEC turbulence to
```

# Runtime Options: Random Seeds

- Parameter 1 , **RandSeed1**: Random seed 1
  - Definition: A random seed for the pseudorandom number generator (pRNG)
    - Valid values: any integer
- Parameter 2, **RandSeed2**: Random seed 2
  - Definition: A random seed for the intrinsic pRNG or the name of a different pRNG
    - Valid values: any integer or the strings “RANLUX” or “RNSNLW”
- The specified pseudorandom number generator is initialized with this/these seed(s)
  - Two spectral models with the same initial seeds will use the same random phases (one per frequency per grid point)

# Runtime Options: Random Seeds

- Three available pseudorandom number generators:
  - Intrinsic
    - The pRNG in SNwind
    - Requires 2 seeds
    - Two separate congruential generators used together (algorithm by Pierre L'ecuyer)
  - RNSNLW
    - The pRNG in SNLWIND-3D
    - Requires 1 seed
  - RanLux
    - Recommended pRNG
    - Requires 1 seed
    - Lüscher's level 3 "Luxury Pseudorandom Numbers": algorithm throws numbers away to destroy correlations

# Runtime Options: Output files

- Parameter 3, **`WrBHHTP`**: Write binary hub-height turbulence parameters?
  - Definition: Determines if binary HH files should be written
    - Valid values: True or False
    - Generates *RootName*.bin
- Parameter 4, **`WrFHHTP`**: Write formatted hub-height turbulence parameters?
  - Definition: Determines if formatted (text) HH files should be written
    - Valid values: True or False
    - Generates *RootName*.dat

# Runtime Options: Output files

- Parameters 3-4, **`WrBHHTP`** and **`WrFHHTP`**: Write hub-height turbulence parameters? (continued)
  - Both input parameters write the same turbulence information, one as 32-bit binary real numbers, the other in text
  - Files contain turbulence parameters from the hub point

This hub-height turbulence-parameter file was generated by TurbSim (v1.40, 12-Sep-2008) on 10-Sep-2008 at 22:13:04.

| Time | U | Uh | Ut | V | W | u' | v' | w' | u'w' | u'v' | v'w' | TKE | CTKE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 11.673 | 11.706 | 11.911 | -0.875 | 2.201 | 4.322 | -0.875 | 2.201 | 9.513 | -3.783 | -1.927 | 12.146 | 5.209 |
| 0.05 | 11.320 | 11.348 | 11.544 | -0.785 | 2.118 | 3.969 | -0.785 | 2.118 | 8.407 | -3.116 | -1.663 | 10.428 | 4.559 |
| 0.10 | 10.946 | 10.951 | 11.228 | -0.316 | 2.481 | 3.595 | -0.316 | 2.481 | 8.917 | -1.136 | -0.784 | 9.588 | 4.512 |
| 0.15 | 11.520 | 11.523 | 11.737 | -0.228 | 2.235 | 4.169 | -0.228 | 2.235 | 9.318 | -0.950 | -0.510 | 11.215 | 4.690 |
| 0.20 | 11.584 | 11.585 | 11.842 | -0.139 | 2.452 | 4.233 | -0.139 | 2.452 | 10.378 | -0.589 | -0.341 | 11.975 | 5.200 |
| 0.25 | 11.257 | 11.265 | 11.591 | -0.430 | 2.731 | 3.905 | -0.430 | 2.731 | 10.665 | -1.678 | -1.173 | 11.447 | 5.430 |
| 0.30 | 10.878 | 10.924 | 11.139 | -0.994 | 2.180 | 3.527 | -0.994 | 2.180 | 7.687 | -3.507 | -2.167 | 9.089 | 4.362 |
| 0.35 | 10.721 | 10.749 | 10.861 | -0.773 | 1.558 | 3.370 | -0.773 | 1.558 | 5.248 | -2.604 | -1.204 | 7.189 | 2.991 |
| 0.40 | 10.923 | 10.947 | 11.086 | -0.723 | 1.751 | 3.571 | -0.723 | 1.751 | 6.253 | -2.583 | -1.267 | 8.172 | 3.442 |
| 0.45 | 10.821 | 10.824 | 10.929 | -0.262 | 1.512 | 3.470 | -0.262 | 1.512 | 5.245 | -0.911 | -0.397 | 7.196 | 2.669 |
| 0.50 | 10.787 | 10.792 | 10.909 | 0.351 | 1.592 | 3.435 | 0.351 | 1.592 | 5.468 | 1.206 | 0.559 | 7.229 | 2.813 |
| 0.55 | 10.738 | 10.741 | 10.850 | 0.289 | 1.532 | 3.386 | 0.289 | 1.532 | 5.187 | 0.980 | 0.443 | 6.948 | 2.649 |
| 0.60 | 9.967 | 9.971 | 10.139 | 0.299 | 1.837 | 2.616 | 0.299 | 1.837 | 4.805 | 0.781 | 0.548 | 5.153 | 2.449 |
| 0.65 | 9.975 | 10.028 | 10.173 | 1.029 | 1.716 | 2.623 | 1.029 | 1.716 | 4.502 | 2.700 | 1.766 | 5.443 | 2.769 |

# Runtime Options: Output files

- Parameter 5, **`WrADHH`**: Write formatted AeroDyn hub-height time-series data?
  - Definition: Determines if HH AeroDyn files should be written
    - Valid values: True or False
    - Generates *RootName*.hh

```
! This hub-height wind-speed file was generated by TurbSim (v1.40, 12-
!
! The requested statistics for this data were:
!    Mean Total Wind Speed =    7.351 m/s
!    Turbulence Intensity  =   24.243%
!
!   Time   HorSpd   WndDir   VerSpd   HorShr   VerShr   LnVShr   GstSpd
!  (sec)    (m/s)    (deg)    (m/s)      (-)      (-)      (-)    (m/s)
   0.000    11.71    -4.29     2.20    0.000    0.200    0.000     0.00
   0.050    11.35    -3.97     2.12    0.000    0.200    0.000     0.00
   0.100    10.95    -1.65     2.48    0.000    0.200    0.000     0.00
   0.150    11.52    -1.13     2.24    0.000    0.200    0.000     0.00
```

# Runtime Options: Output files

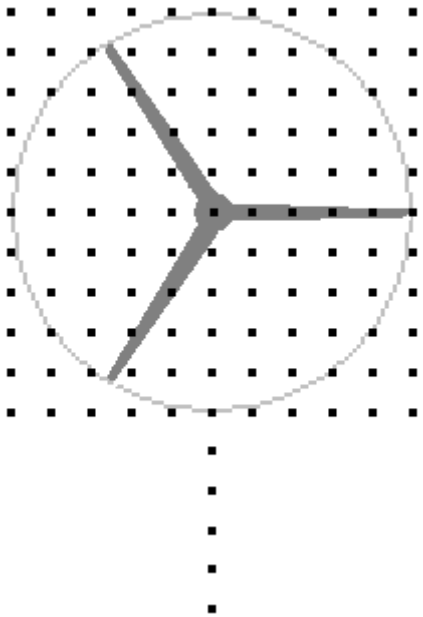
- Parameter 6, **`WrADFF`**: Write binary TurbSim/AeroDyn full-field time-series data?
  - Definition: Determines if binary TurbSim files should be written
    - Valid values: True or False
    - Generates *RootName*.bts
  - Files can't be read by current release of AeroDyn (available in future versions)
  - Stores non-dimensional time series (16-bit integers representing 32-bit reals) of all grid points

# Runtime Options: Output files

- Parameter 7, **`WrBLFF`**: Write binary BLADED/AeroDyn full-field time-series data?
  - Definition: Determines if full-field binary data in a form read by AeroDyn (in GH's BLADED-style) should be written
    - Valid values: True or False
    - Generates *RootName*.wnd
  - Stores non-dimensional time series (16-bit integers representing 32-bit reals) of all grid points
  - Requires data in the TurbSim (text) summary files to rescale the time series

# Runtime Options: Output files

- Parameter 8, **`WrADTWR`**: Write binary AeroDyn tower time-series data?
  - Definition: Determines if binary time-series data for points along the tower centerline and below the grid should be generated
    - Valid values: True or False
    - Generates *RootName*.twr
  - Tower points are calculated only if they are output
  - Files can't be read by current release of AeroDyn (available in future versions)



# Runtime Options: Output files

- Parameter 9, **`WrFMTFF`**: Write formatted full-field time-series data?
  - Definition: Determines if text files of the full-field time-series data should be written
    - Valid values: True or False
    - Generates *RootName*.u, *RootName*.v, and *RootName*.w
  - Files can get very large

# Runtime Options: Output files

Example of *RootName*.u text file of the full-field time-series data

```
This full-field turbulence file was generated by TurbSim (v1.40, 12-Se

 | u-comp |  Y   x   Z   | Grid Resolution (Y x Z) | Time-step | Hub Elev
             5      5       7.500       7.500           0.050       37.00

 Z Coordinates (m):
  -15.000  -7.500   0.000   7.500  15.000

 Y Coordinates (m):
  -15.000  -7.500   0.000   7.500  15.000

    0.000  25.496
   22.250  27.685  22.234  24.957  28.171
   22.889  25.872  22.595  23.257  23.543
   23.352  23.694  25.496  26.629  23.809
   20.857  19.411  21.850  21.863  21.117
   20.367  19.237  20.912  21.181  22.443

    0.050  24.599
   23.347  27.180  22.208  25.135  27.944
   23.257  25.492  22.130  22.601  23.441
```

# Runtime Options: Output files

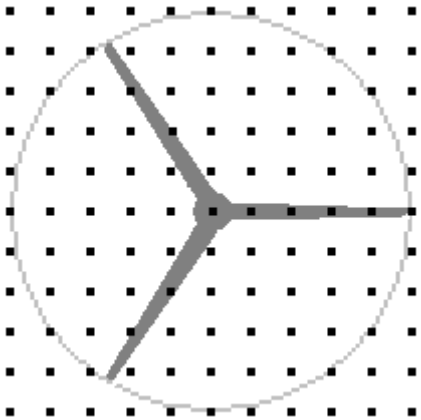
- Parameter 10, **`WrACT`**: Write formatted AeroDyn coherent turbulence time-step data?
  - Definition: Determines whether TurbSim should generate coherent turbulence files to be superimposed on the background wind in AeroDyn
    - Valid values: True or False
    - Generates *RootName*.cts
    - Generates *RootName*.wnd or *RootName*.bts
  - Must use AeroDyn v12.57 or later version to read and superimpose these files on the background *RootName*.wnd files

Example of *RootName*.cts file

```
          LES = FileType
 3.263246     = ScaleVel
 12.16343     = MHHWindSpeed
 52.73271     = Ymax
 80.00000     = Zmax
 1.000000     = DistScl
0.5000000     = CTLy
0.5000000     = CTLz
          110 = NumCTt
 0.000000     00000
 39.14331     00000
 39.28146     03219
 39.42949     03220
```

# Runtime Options: Rotation Direction

- Parameter 11, **`CLOCKWISE`**: Does the turbine rotate clockwise when looking downwind?
  - Definition: Determines the direction of rotation of the turbine the wind field is generated for
    - Valid values: True or False
  - Causes TurbSim to output the full-field grids from right to left instead of left to right
    - AeroDyn reads it the reverse way TurbSim writes it (based on  direction of rotation), so this parameter doesn't change anything with FF files read by AeroDyn
    - Parameter was used to compare results with the same wind field with another program many years ago



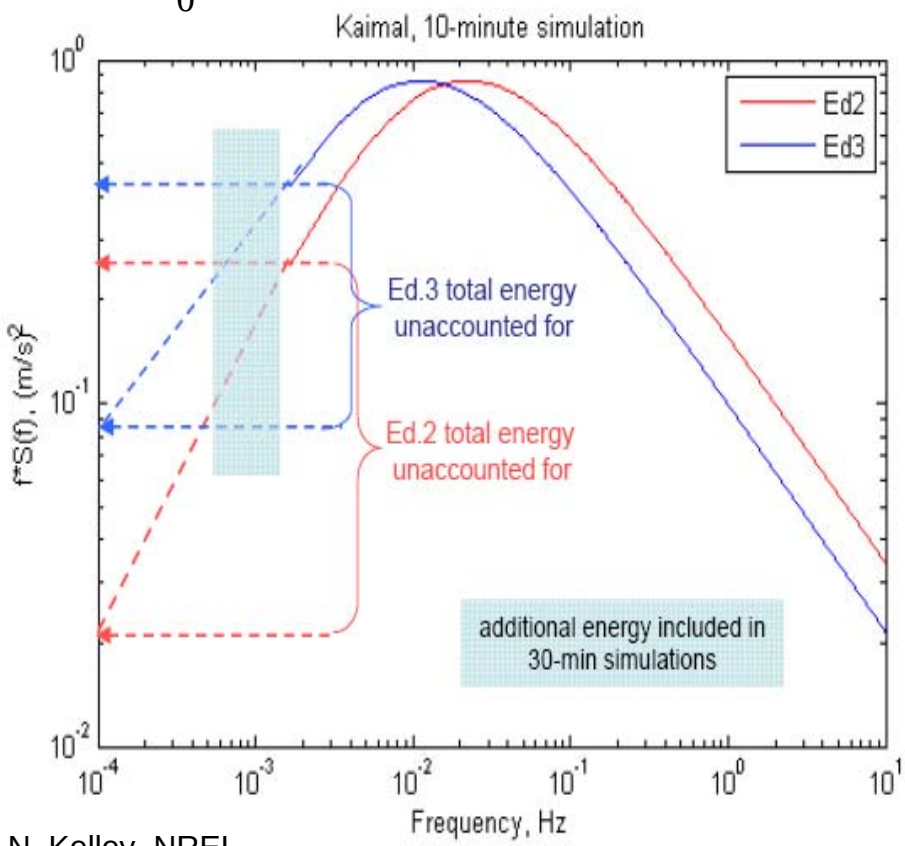
# Runtime Options: Scale IEC models

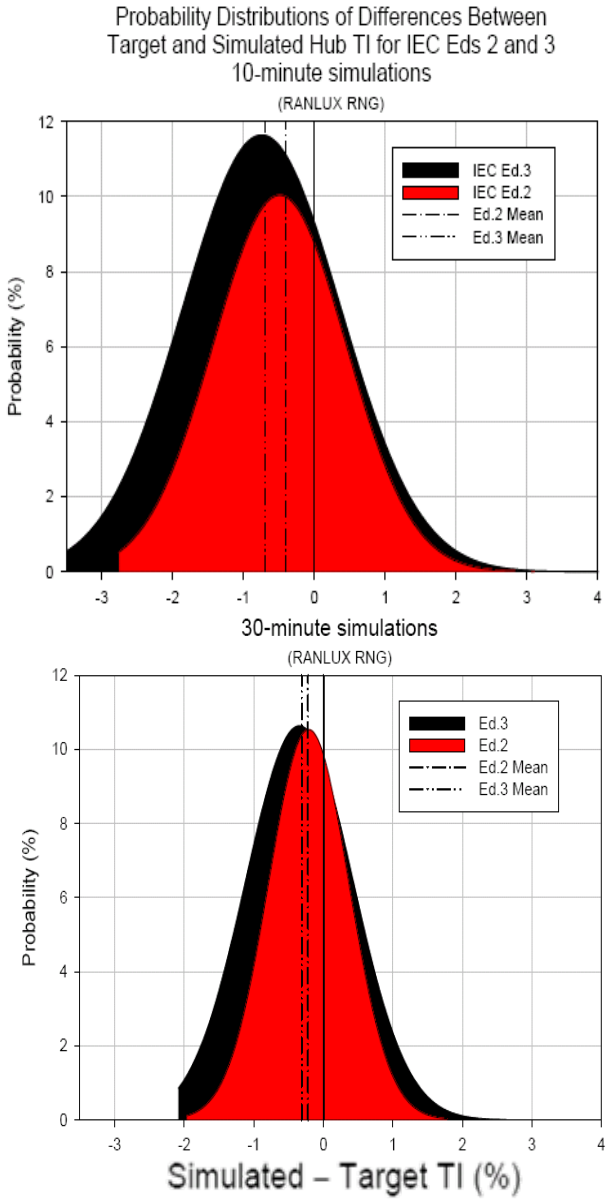
- Parameter 12, **`ScaleIEC`**: Scale IECKAI and IECVKM output to the exact standard deviation requested?
  - Definition: Determines if standard deviation of each wind component should be scaled to be exactly the specified input value
    - Valid values: True or False
  - With scaling, the TI at the hub point does not vary with seed
  - Without scaling, the TI of the simulated time series varies from the target TI
    - Variation depends on random phases (with spatial coherence), time step, length of simulated time series, etc.

# Runtime Options: Scale IEC models

$$TI = \frac{\sigma}{U}$$

$$\sigma^2 = \int_0^\infty S(f)\,df$$




Figures: N. Kelley, NREL

# Turbine/Model Specifications

TurbSim's

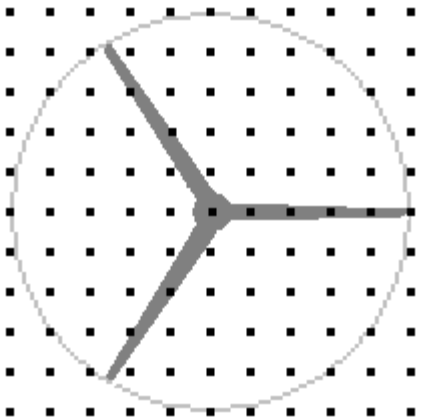
**Turbine/Model Specifications**

Input Parameters

```
--------Turbine/Model Specifications-----------------------
13          NumGrid_Z     - Vertical grid-point matrix dimension
13          NumGrid_Y     - Horizontal grid-point matrix dimensi
0.05        TimeStep      - Time step [seconds]
600         AnalysisTime  - Length of analysis time series [seco
40          UsableTime    - Usable length of output time series
84.288      HubHt         - Hub height [m] (should be > 0.5*Grid
80.00       GridHeight    - Grid height [m]
80.00       GridWidth     - Grid width [m] (should be >= 2*(Roto
0           VFlowAng      - Vertical mean flow (uptilt) angle [d
0           HFlowAng      - Horizontal mean flow (skew) angle [d
```

# Turbine/Model Specifications: Grid Points

- Parameter 1, **`NumGridZ`**: Vertical grid points
  - Definition: The number of grid points in the vertical direction
    - Valid values: integers greater than 1
- Parameter 2, **`NumGridY`**: Horizontal grid points
  - Definition: The number of grid points in the horizontal direction
    - Valid values: integers greater than 1
- These two parameters are independent of each other



# Turbine/Model Specifications: Time Step

- Parameter 3, **`TimeStep`**: The time step
  - Definition: The difference in seconds between consecutive steps in time in the time series generated
    - Valid values:  any positive time
    - Recommended value: 0.05 s
  - Determines maximum frequency in the generated time series

$$f_{\max} = \frac{1}{\Delta t}$$

# Turbine/Model Specifications: Time

- Parameter 4, **`AnalysisTime`**: The analysis time
  - Definition: The length of the time series to generate, in seconds
    - Valid values: positive numbers
    - Recommended value: at least 600 s
  - Must be larger then the length of the time series to output
  - Analysis time is used for
    - Summary file statistics
    - Scaling time series for specific IEC TI values (**`ScaleIEC=true`**)
    - Scaling time series for cross-component correlations (to achieve specified hub Reynolds stresses in non-IEC models)

$$AnalysisTime \geq UsableTime + \frac{GridWidth}{\overline{U_{hub}}} = OutputTime$$

# Turbine/Model Specifications: Time

- The time step and analysis time determine the frequencies in the generated time series
  - TurbSim may increase the analysis time ($t_{max}$) by a few extra time steps ($\Delta t$) so that the number of frequencies is a product of small primes
    - Speeds up the computation of the inverse FFT

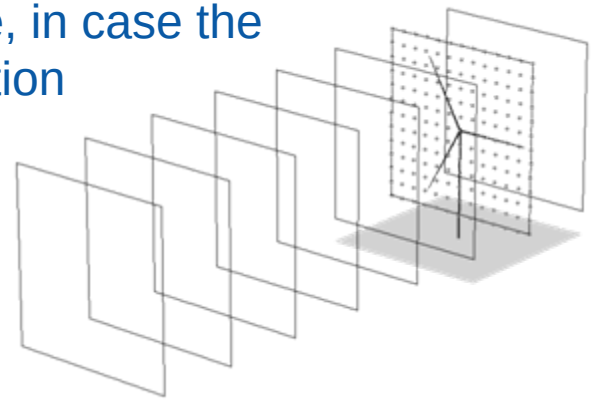
$$f_{\max} = \frac{1}{\Delta t} \qquad \Delta f = \frac{1}{t_{\max}} \qquad NumFreq = \frac{t_{\max}}{\Delta t}$$

  - Generation method converges with “large” number of frequencies
    - Don’t expect great results when generating 30-s time series with 1-s time step!

# Turbine/Model Specifications: Time

- Parameter 5, **`UsableTime`**: The usable time
  - Definition: The length, in seconds, of the "usable" time series to output
    - Valid values: positive values; should not be greater than the analysis time
  - TurbSim will output time-series data from 0 to *UsableTime* + *GridWidth / MeanHHwindSpeed* seconds of the analysis time series
    - The extra time is added because AeroDyn requires data both upwind and downwind of the wind turbine, in case the turbine is yawed at start or end of simulation

$$OutputTime = UsableTime + \frac{GridWidth}{\overline{U}_{hub}}$$



# Turbine/Model Specifications: Hub Height

- Parameter 6, **`HubHt`**: The turbine hub height
  - Definition: The hub height, in meters, of the turbine for which the inflow is being generated
    - Valid values: positive values; should be > *GridHeight* / 2
  - The hub height becomes the reference height in AeroDyn (make sure the hub height in TurbSim is the same as specified in AeroDyn)

# Turbine/Model Specifications: Grid Size

- Parameter 7, **`GridHeight`**: The height of the grid
  - Definition: The height, in meters, of the grid being generated
    - Valid values: positive numbers
- Parameter 8, **`GridWidth`**: The width of the grid
  - Definition: The width, in meters, of the grid being generated
    - Valid values: positive numbers
- Both parameters must be at least twice the rotor radius plus the shaft length

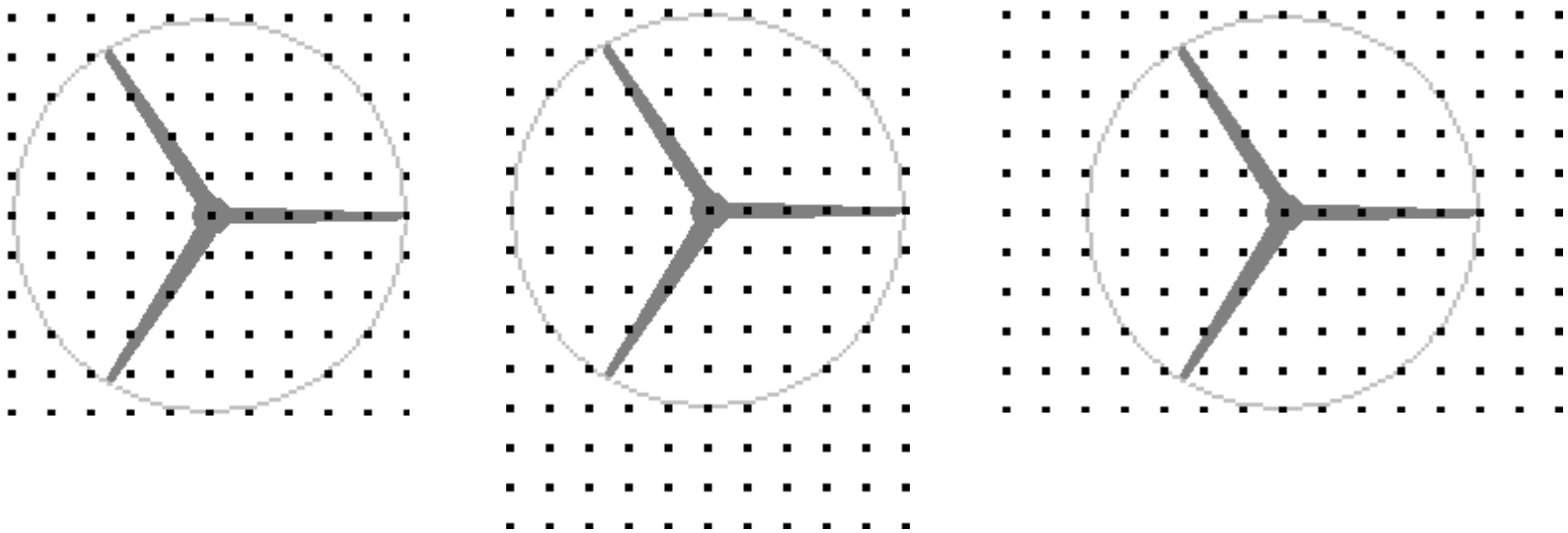
$$GridHeight, GridWidth \geq 2\left(RotorRadius + ShaftLength\right)$$

# Turbine/Model Specifications: Grid Size

- Parameters 7-8, **`GridHeight`** and **`GridWidth`**: The height and width of the grid
  - Must be large enough that AeroDyn can *interpolate* within the grid for any point where it needs the wind speed
    - Turbines that move around a lot will need larger grids
  - TurbSim assumes the rotor diameter is the smaller of these two input parameters
    - The turbine's *actual* rotor diameter will be smaller than this number

# Turbine/Model Specifications: Grid Size

Assumed turbine rotor placement with grid size



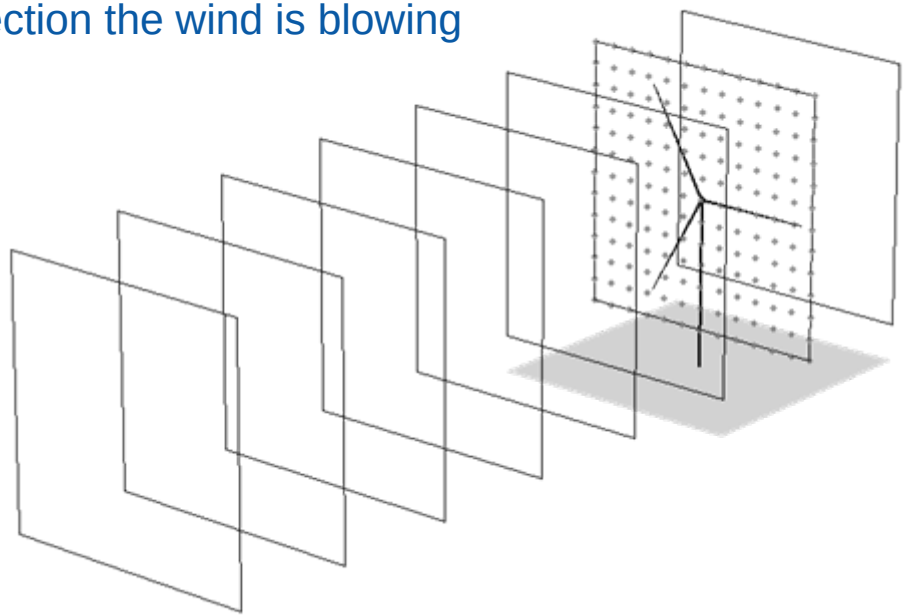
Height = Width  Height > Width  Height < Width

# Turbine/Model Specifications: Flow Angles

- Parameter 9, **`VFlowAng`**: The vertical flow angle
  - Definition: The mean vertical angle, in degrees, of the flow
    - Valid values: angles with magnitudes not to exceed 45°
      - Positive angles represent wind blowing uphill
- Parameter 10, **`HFlowAng`**: The horizontal flow angle
  - Definition: The mean horizontal flow angle (wind direction), in degrees
    - Valid values: any angle possible
    - Not recommended for use with wind used in AeroDyn (use turbine yaw error instead)
- These angles will be used to rotate the wind from its alignment with the mean flow to the inertial reference frame

# Turbine/Model Specifications: Flow Angles

- Parameters 9-10, **`VFlowAng`** and **`HFlowAng`:** The flow angles
  - AeroDyn always “marches” wind grids through the turbine in positive x direction, regardless of mean flow angles
    - If flow angles are not small, strange results can occur:
      - e.g., If horizontal flow angle is 180° the grids will move through the turbine in the opposite direction the wind is blowing



# Coherent Turbulence Scaling

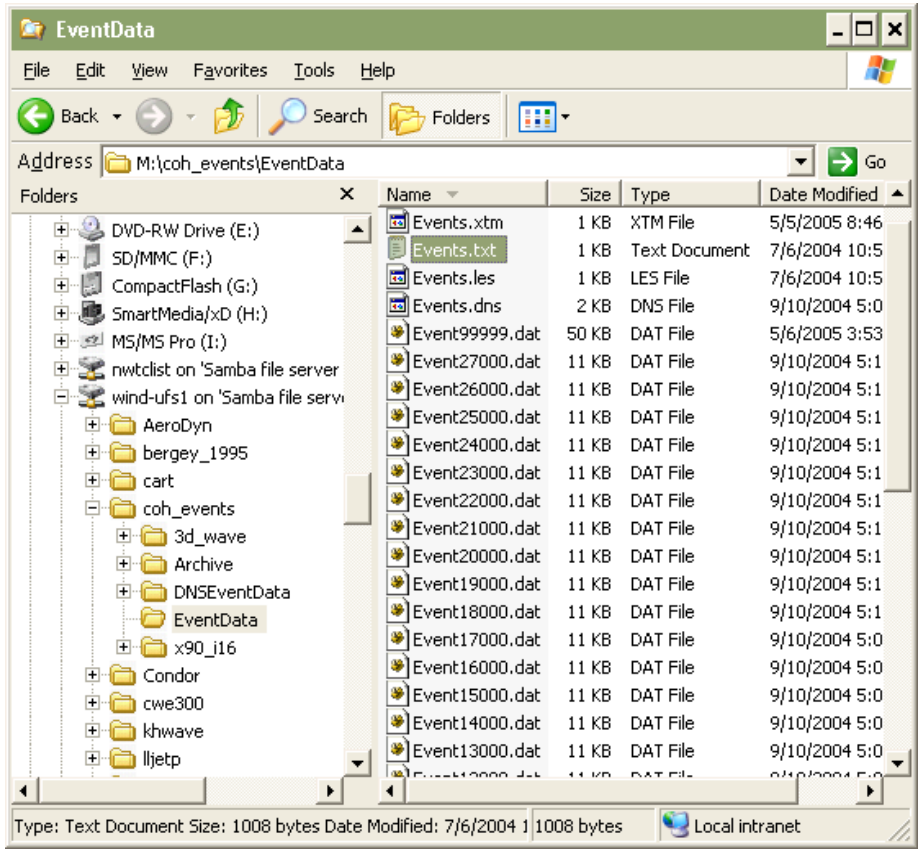
TurbSim's
Coherent Turbulence Scaling Parameters

```
--------Coherent Turbulence Scaling Parameters---------------
"M:\coh_events\evt" CTEventPath - Name of the path where even
"Random"            CTEventFile - Type of event files ("LES",
true                Randomize   - Randomize the disturbance s
 1.0                DistScl     - Disturbance scale (ratio of
 0.5                CTLy        - Fractional location of towe
 0.5                CTLz        - Fractional location of hub
30.0                CTStartTime - Minimum start time for cohe
```

Used only when coherent structure files are generated, i.e. **`WrACT=true`**

# Coherent Turbulence Scaling: Path

- Parameter 1, **`CTEventPath`**: Coherent turbulence events path name
  - Definition: The name of the path where the coherent event definition files are located (EventData folder from coherent structure archive)
  - Folder should contain files named Events.dns, Events.les, Events.xtm, and several Event*xxxxx*.dat files



# Coherent Turbulence Scaling: Event Types

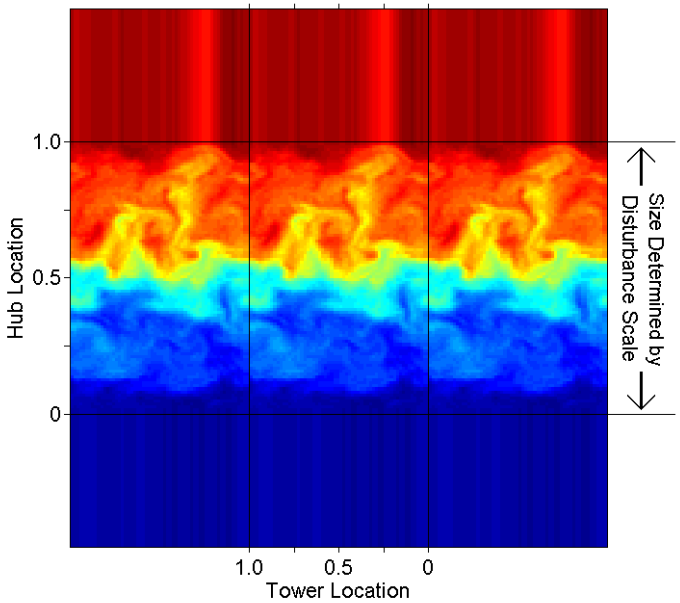
- Parameter 2, **`CTEventFile`**: Type of coherent turbulence events files
  - Definition: A string indicating which type of KH-billow simulations to use as the superimposed coherent structures
    - Valid values: “Random”, “les”, or “dns”
      - LES uses pieces of the LES simulation of the KH-billow
      - DNS uses pieces of the DNS simulation of the KH-billow
      - RANDOM picks uniformly between the LES and DNS pieces
    - All events in one simulation are of the same type (even when RANDOM is used)

# Coherent Turbulence Scaling: Randomize

- Parameter 3, **`Randomize`**: Randomize the disturbance scale and location?
  - Definition: Determines if the size and location of the KH-billow pieces will be picked randomly by TurbSim or specified by the user
    - Valid values: True or False
  - If true, the billow will cover
    - The entire rotor disk 75% of the time
    - The lower half of the rotor disk 12.5% of the time
    - The upper half of the rotor disk 12.5% of the time

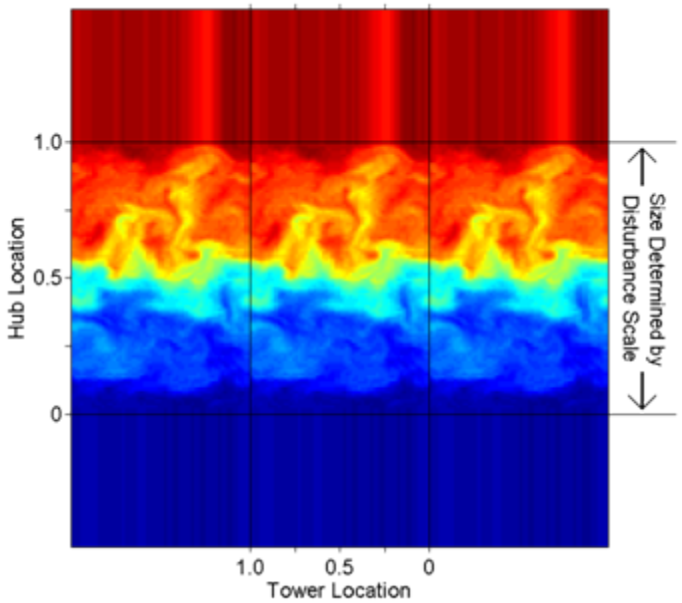
# Coherent Turbulence Scaling: Size

- Parameter 4, **`DistScl`**: Disturbance scale
  - Definition: The size of the KH disturbance relative to the rotor disk (ratio of KH height to rotor diameter)
    - Valid values: any number
      - 1.0 covers the rotor disk
      - 0.5 covers half the rotor disk
    - If KHTEST option is used, the disturbance scale is always 1.0
  - Ignored when **`Randomize=true`**



# Coherent Turbulence Scaling: Location

- Parameter 5, **`CTLy`**:
  - The fractional location of the tower centerline from the right to left side (looking downwind) of the coherent event dataset
    - Valid values: any number
    - Structures are periodic in the y (horizontal) direction
- Parameter 6, **`CTLz`**:
  - The fractional location of hub height from the bottom of the dataset
    - Valid values: any number
      - A number between 0 and 1 will put the billow on the rotor disk
    - Structures are constant above and below the dataset
- Ignored when **`Randomize=true`**
- Both parameters are 0.5 when KHTEST is used



# Coherent Turbulence Scaling: Start Time

- Parameter 7, **`CTStartTime`**: Minimum start time for coherent turbulence
  - Definition: The time, in seconds, to wait before a coherent event can be superimposed on the background wind
    - Valid values: any positive number
  - Determines where the first coherent event is placed in the coherent turbulence file
    - First event cannot occur before **`CTStartTime`**
  - Used to ensure that a coherent event doesn't occur during the startup transition

# Running the Code

- Create an input file
  - modify one from the TurbSim archive
- Type `TurbSim` *`InputFileName`* at a command window
  - *`InputFileName`* is the name of the input file you created
  - Your computer must be able to locate the TurbSim.exe executable file

# Running the Code

C:\WINDOWS\system32\cmd.exe

```
C:\DATA\Fortran\IVF Projects\TurbSim\Release\Test>turbsim GPLLJ_large.inp

C:\DATA\Fortran\IVF Projects\TurbSim\Release\Test>"C:\Data\Fortran\IVF Projects\TurbSim\Release\T
Sim.exe" GPLLJ_large.inp

 Running TurbSim (v1.40, 12-Sep-2008).
 Linked with the NWTC Subroutine Library (v1.01.09, 18-Jan-2008).

 Reading the input file "GPLLJ_large.inp".
 RanLux luxury level set by RLuxGo :    3 p =          223
 RanLux initialized by RLuxGo from Seeds     2318573           0           0
    A default value will be used for the roughness length.
    A default value will be used for the site latitude.
    A default shear or friction velocity will be used.
    A default value will be used for the mixing layer depth.
    A default value will be used for the mean hub u'w' Reynolds stress.
    A default value will be used for the mean hub u'v' Reynolds stress.
    A default value will be used for the mean hub v'w' Reynolds stress.
    A default value will be used for the u-component coherence parameters.
    A default value will be used for the v-component coherence parameters.
    A default value will be used for the w-component coherence parameters.
    A default value will be used for the coherence exponent.

 You have requested that the following file(s) be generated:
    GPLLJ_large.wnd (an AeroDyn/BLADED full-field wnd file)
    GPLLJ_large.cts (a coherent turbulence time step file)
    GPLLJ_large.u (a formatted full-field U-component file)
    GPLLJ_large.v (a formatted full-field V-component file)
    GPLLJ_large.w (a formatted full-field W-component file)
 RanLux luxury level set by RLuxGo :    3 p =          223
 RanLux initialized by RLuxGo from Seeds     2318573           0           0
 Calculating the spectral and transfer function matrices:
    u-component matrices
    v-component matrices
    w-component matrices
 Generating time series for all points:
    u-component
    v-component
    w-component
 Computing hub-height statistics
 Writing statistics to summary file
 Generating coherent turbulent time step file "GPLLJ_large.cts"
 Generating BLADED binary time-series file "GPLLJ_large.wnd"
 Generating full-field formatted file "GPLLJ_large.u".
 Generating full-field formatted file "GPLLJ_large.v".
 Generating full-field formatted file "GPLLJ_large.w".

 Processing complete.  116.72 CPU seconds used.
```

# Generating Coherent Structures

- Steps for generating and using coherent structure files:
  - Download (and run) the “Coherent Structures Archive” from the Design Codes website (only once)
    - TSM_structures.exe is large
    - Running the archive will create two folders:
      - EventData: location used in the TurbSim input file
      - x90_i16: location used in the coherent turbulence parameter (*.ctp) input file for AeroDyn
  - Create the TurbSim input file
    - Set **`WrACT=true`**
    - Spectral model cannot be IECKAI or IECVKM
    - Set Richardson number >= -0.05
    - Set values in the “Coherent Turbulence Scaling Parameters” section

# Generating Coherent Structures

- Steps for generating and using coherent structure files (continued):
  - Run TurbSim
    - Files generated: *RootName*.sum, *RootName.*wnd, and *RootName.*cts
  - Create the Coherent Turbulence Parameter (*FileName*.ctp) input file for AeroDyn,
    - Specify locations for
      - *RootName*.cts
      - *RootName*.wnd
      - The path to the x90_i16 folder from the coherent structure archive
  - Run an AeroDyn-based design code (FAST, YawDyn, or MSC.Adams®)
    - Specify the location of *FileName*.ctp for the **`WindFile`** parameter in the AeroDyn input file

# Coherent Turbulence Parameter File

- Example file, TurbSim_AD.cpt is in the TurbSim archive
- The name of this wind file must be specified in the AeroDyn input file

```
Example Turbulence parameter input file. AeroDyn 12.57
# Parameters that can vary from one turbine simulation to the n
"H:\values_x90\x90_i16" | CTSpath  - Path to coherent turbulenc
".\turbsim\TurbSim.cts" | CTTSfile - File containing the time s
".\turbsim\TurbSim.wnd" | CTbackgr - Name of file containing ba
 1                      | CT_DF_Y  - Decimation factor in y dir
 1                      | CT_DF_Z  - Decimation factor in z dir
```

# Coherent Turbulence Parameter File

- Parameter 1, **`CTSpath`**:
  - Definition: The path name of the binary data files from the coherent structures archive
    - The “x90_i16” folder from the archive
- Parameter 2, **`CTTSfile`**:
  - Definition: The file containing the coherent turbulent time-step data generated by TurbSim
    - The *RootName*.cts file
- Parameter 3, **`CTbackgr`**:
  - Definition: The file containing the background full-field data generated by TurbSim
    - The *RootName*.wnd file

# Coherent Turbulence Parameter File

- Parameter 4, **`CT_DF_Y`**:
  - Definition: The decimation factor for the y direction of the KH billow data
    - 1 uses every point (2 uses every other grid point)
- Parameter 5, **`CT_DF_Z`**:
  - Definition: The decimation factor for the z direction of the KH billow data
    - 1 uses every point (2 uses every other grid point)
- The decimation factors haven’t been tested well
- We recommend using a value of 1