LANDIS-II Base Hurricane v2.0 Extension User Guide

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1 Introduction

This document describes the **Base Hurricane** extension for the LANDIS-II model. For information about the model and its core concepts, see the *LANDIS-II Conceptual Model Description.*

Base Hurricane models tropical cyclones of varying strength making landfall on the US east coast in Virginia, North Carolina, South Carolina, or Georgia. The model is concerned only with sustained wind. Rainfall, storm surge, tornadoes, or inland flooding are not modelled.

Mortalities are computed based on the maximum wind speed of the entire event. Though wind speeds in reality vary over the duration the event, only the maximum wind speed is considered for mortality computation. Other factors such as the effect of soil saturation may be considered to be included in the statistical representation of the Wind Speed Vulnerabilities table.

The terms "hurricane", "tropical cyclone", and "storm" are used interchangeably in this documentation.

1.1 Hurricane Disturbances

During a hurricane time step, multiple tropical cyclone events may occur on the landscape. A storm which is generated by the model may hit the study area, but it may miss it. If a storm passes far enough away from the study area such that the maximum wind speed is too low, no damage is computed.

For any year, the number of tropical cyclones which are to strike on the east coast is randomly generated.

For each storm, initiation parameters are created: Landfall Latitude, Maximum Wind Speed at Landfall, and Storm Track Heading.

Based on these initiation parameters, a Maximum Wind Speed Field is generated on a continental grid, which is then used to compute maximum wind speed for each site of the study area.

Cohort mortality probabilities are computed based on cohort species and age compared to the maximum wind speed based on the Wind Speed Vulnerabilities table.

1.1.1 Climate Change

Version 0.1 does not provide a way to allow storm occurrence probabilities to change over time or to allow maximum wind speed over time.

1.2 Modelling of Landfall Wind Speed

An important controlling parameter for the model is the maximum wind speed of the storm when it makes landfall. After landfall the wind speeds are assumed to decrease.

Each storm is assigned a random landfall wind speed on a log-normal distribution. The scale of these values is determined by three parameters set in the input file: LowBoundLandfallWindSpeed, ModeLandfallWindSpeed, and HighBoundLandfallWindSpeed.

The distribution is depicted in Figure 1 with labels for the three controlling values.

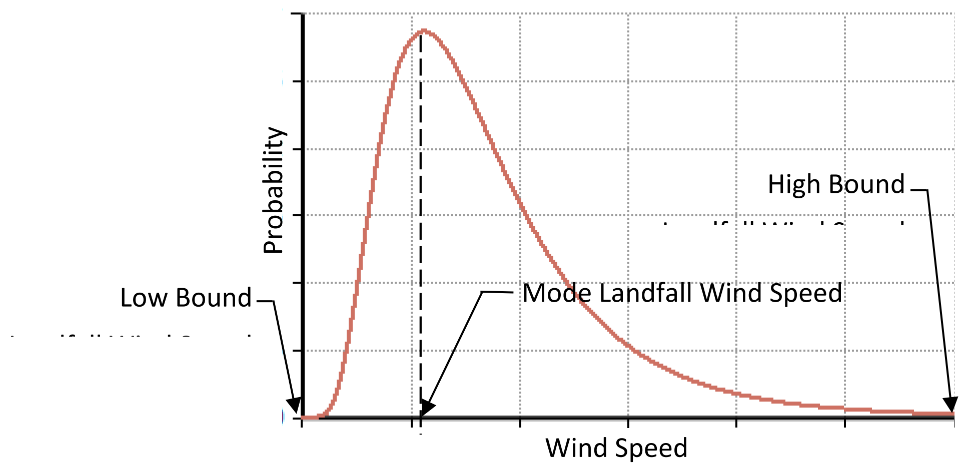

Figure 1: Log-Normal Distribution of Randomly Generated Landfall Wind Speed Values

Note that the image[1] for Figure 1 has been modified by revising the axes and adding labels.

[1] From http://wiki.analytica.com/index.php?title=File%3ALogNormal(median%3D3,stddev%3D2).png, accessed July 31, 2019.

1.3 Locating Study Area on the Continental Grid

Some hurricanes strike the east coast of the United States but follow a course that is harmless to a given study area. To simulate this, storms are created to make landfall at a random latitude between 30.7° and 38.45°. The storm center then progresses inland along a straight line at a randomized heading between 280° and 360° (Azimuth).

Given this approximation of a continent-sized grid, the study area must be located in reference to this. To accomplish this, the input file contains two parameters for establishing the location of the study area by fixing its center point on the grid. This is done by setting a value for Center Point Latitude and Center Point Distance Inland.

All values are shown graphically in Figure 2.

1.3.1 Center Point Latitude

This is the Latitude of the center point of the study area. Together with Center Point Distance Inland, the location of the study area with respect to the coast is set.

1.3.2 Center Point Distance Inland

Distance from the study area center point to the nearest point on the Atlantic seaboard coast. Units are kilometers (or Miles if InputUnitsEnglish is set.)

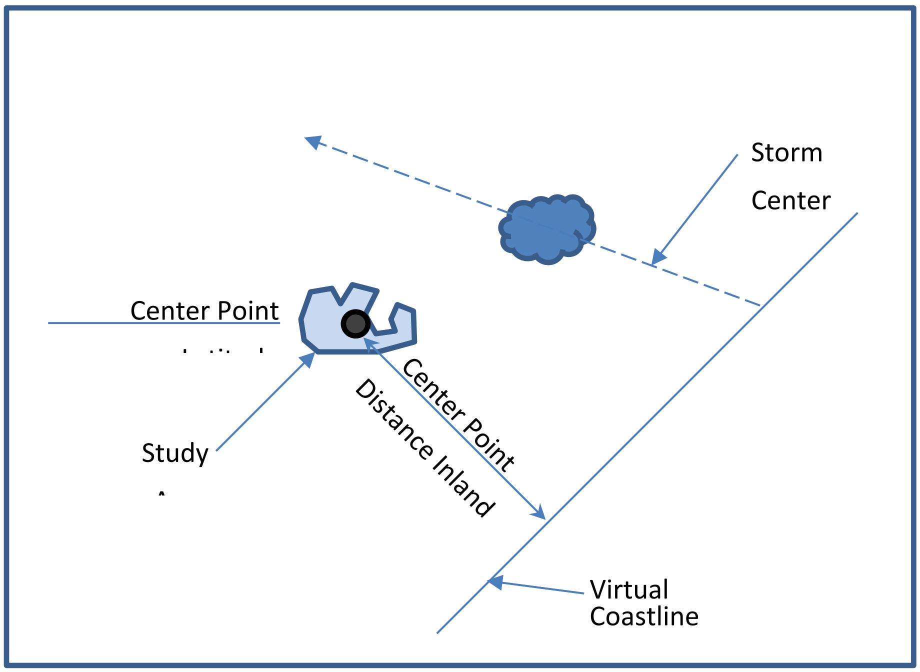

Figure 2: Schematic showing how study area relates to random storm events

The virtual coastline is set to strike a 45° angle at all points. The wind speeds encountered at the study area depend on the distance of each site from the center line of the storm. If the storm is far enough from the study site, no impacts are modelled.

Though the model uses a "virtual coastline" at 45°, the Center Point Distance Inland value should be determined by measurement on a map.

1.4

1.5 Major Releases

1.5.1 Version 2.0

The first official release of Base Hurricane.

1.6 Minor Releases

1.7 Acknowledgements

Funding for the development of LANDIS-II has been provided by the United States Department of Defense.

2 Input File

The input parameters for this extension are specified in one input file. This text file must comply with the general format requirements described in section 3.1 Text Input Files in the LANDIS-II Model User Guide.

2.1 LandisData

This value of this parameter must be "Base Hurricane".

2.2 Timestep

This parameter is the timestep of the hurricane extension. Value: integer > 0. Units: years.

2.3 Storm Occurrence Probabilities

The number of storms which make landfall on the east coast of the United States has varied over the past three decades with the number ranging from zero to two. The user controls the likelihood of storm occurrences with the Storm Occurrence Probabilities table, formatted as follows:

```
>> Likelihood a given year will have this number of storms
>> On the US southeastern seaboard, based on 1979 -- 2018.
>> For climate change, adjust this table
StormOccurrenceProbabilities
 >> Storms
 >>  Per
 >>  Year       Probability  << Sum must = 1.0
        0           0.60
        1           0.33
        2           0.06
        3           0.01
```

2.4 Input Units English

The instruction, `InputUnitsEnglish`, is optional. When present, it directs the model to interpret all wind speeds in the input file as statute miles per hour. It is a single word with no other parameters.

If the instruction is omitted, wind speeds in the input file are interpreted as kilometers per hour.

This instruction only impacts interpretation of speed in the Base Hurricane input file. Wind speeds reported in the .gis output file are in kilometers per hours in every case.

Internally all wind speeds are converted to kilometers per hour.

2.5 Modelling of Landfall Wind Speed

Landfall Wind Speed is randomly determined with parameters controlled by three input file variables. See Section 1.2 for a description of these variables.

2.5.1 Low Bound Landfall Wind Speed

This is the lowest wind speed that a tropical cyclone may have.

2.5.2 Mode Landfall Wind Speed

This is the most frequent wind speed that a tropical storm may have.

2.5.3 High Bound Landfall Wind Speed

This is the highest wind speed that a tropical storm may have.

2.6 Locating Study Area on the Continental Grid

The location of the study area must be set with respect to the coastline. See Section 1.3 for a description of these variables.

2.6.1 Center Point Latitude

Latitude of the center point of the study area.

2.6.2 Center Point Distance Inland

Distance from the study area center point to the nearest point on the Atlantic seaboard coast. Units are kilometers (or Miles if InputUnitsEnglish is set.)

2.7 Wind Speed Vulnerabilities

High winds kill cohorts at different rates according to species and age. To represent this, the mortality probabilities are entered into the Wind Speed Vulnerabilities table, a segment of which is depicted here.

```
WindSpeedVulnerabilities

>> Species    MaxAge Mortality Probabilities

LobPine          30         60:0.05   75:0.18   110:0.75   140:1.0

LobPine          60         60:0.1    75:0.23   110:0.75   140:1.0

LobPine          999        60:0.1    75:0.29   110:0.75   140:1.0
```

Column 1 contains the name of the species. This should be consistent with species names in the species txt file.

Column 2 contains the maximum cohort age in years for the given table row. The final row for any species should have a very high age (such as 999) to represent the oldest cohorts.

Column 3 and following contain colon-delimited pairs of values where the first number is the wind speed and second number is the probability of mortality. For example, a value of "60:0.05" means that site wind speeds of less than 60 kph (or mph if set to English) result in 5% cohort mortality.

2.8 MapNames

This file parameter is the template for the names of the wind severity output maps. The parameter value must include the variable “timestep” to ensure that the maps have unique names (see section 3.1.8.1 Variables in the LANDIS-II Model User Guide). The user must indicate the file extension. The user must also include sub-directory name(s) as needed.

2.9 LogFile

The file parameter is the name of the extension's event log file.

3 Output Files

The wind extension generates two types of output files: a) a map of maximum wind speed for each impacting storm, and b) a log of hurricane events for the entire scenario.

3.1 Max Wind Speeds Maps

The max wind speeds map shows the maximum wind speed for each cell of the study area for a given storm, but only if that storm has impact on the study area.

3.2 Hurricane Events Log

The event log is a comma-separated-value text file that contains information about every storm over the course of the scenario. Every storm is logged whether it impacts the study area or not. The following shows a few example lines from a Hurricane Events log:

```
Time,Year,Hnumber,LandfallLatitude,LandfallMaxWindSpeed,PathHeading,StudyAreaMaxWS,StudyAreaMinWS,ImpactsStudyArea,

2, 0, 1, 37.496244969, 184.59228, 287.20567103, 50.741793923, 50.118503489, No,

4, 3, 1, 33.328035624, 117.59228, 310.33885173, 95.055793432, 89.084047488, No,

6, 4, 1, 36.707886883, 99.59228, 321.156182736, 50.352382226, 49.772806788, No,

6, 4, 2, 33.718704734, 117.5922, 337.996077723, 102.67339822, 95.937507593, Yes,
```

In this example, the first three storms do not impact the study area because they are so far from it that the highest maximum wind speed is lower than the minimum impactful wind speed from the Wind Speed Vulnerabilities table. In year four, two storms make landfall on the east coast, but only the second one impacts the study area.

Year 1 and year 2 have no rows because zero storms were generated for those years.

3.2.1 Time

The time step of the given storm.

3.2.2 Year

The year number of the given storm.

3.2.3 HNumber

The hurricane number of the given storm in the current year.

3.2.4 LandfallLatitude

The latitude where the given storm makes landfall (crosses the coast line).

3.2.5 LandfallMaxWindSpeed

The wind speed of the given storm at the point of landfall.

3.2.6 PathHeading

The direction (in Azimuth form) that the given storm takes as it progresses inland.

3.2.7 StudyAreaMaxWindspeed

The highest maximum wind speed of any active site in the study area.

3.2.8 StudyAreaMinWindspeed

The lowest maximum wind speed of any active site in the study area.

3.2.9 ImpactsStudyArea

"Yes" if the given storm has a chance of causing any mortalities in the study area. "No" if it does not.

4 Example Input File

```
LandisData  "Base Hurricane"


Timestep  2


>> Likelihood a given year will have this number of storms
>> On the US southeastern seaboard, based on 1979 -- 2018.
>> For climate change, adjust this table
StormOccurrenceProbabilities
 >> Storms
 >>  Per
 >>  Year       Probability  << Sum must = 1.0
        0           0.60
        1           0.33
        2           0.06
        3           0.01


InputUnitsEnglish


>> Max Wind Speed at Landfall is on a log normal distribution
LowBoundLandfallWindSpeed   42 >> mph


>> For climate change, adjust these two upwards
ModeLandfallWindSpeed      74 >> mph
HighBoundLandfallWindSpeed  150 >> mph  Values greater than this are recomputed, so it truncates here.


>> Study area location (Center point of the raster)
>> These are for Fort Bragg
CenterPointLatitude               35.11  << decimal degrees
```

```
CenterPointDistanceInland   100   << miles


WindSpeedVulnerabilities
>> Species           MaxAge              Mortality Probabilities
LobPine              30            60:0.05    75:0.18    110:0.75    140:1.0
LobPine              60            60:0.1     75:0.23    110:0.75    140:1.0
LobPine              999           60:0.1     75:0.29    110:0.75    140:1.0
LongleafPine         30            60:0.05    75:0.18    110:0.75    140:1.0
LongleafPine         60            60:0.1     75:0.23    110:0.75    140:1.0
LongleafPine         999           60:0.1     75:0.29    110:0.75    140:1.0
ShortPine            30            60:0.05    75:0.18    110:0.75    140:1.0
ShortPine            60            60:0.1     75:0.23    110:0.75    140:1.0
ShortPine            999           60:0.1     75:0.29    110:0.75    140:1.0
SlashPine            30            60:0.05    75:0.18    110:0.75    140:1.0
SlashPine            60            60:0.1     75:0.23    110:0.75    140:1.0
SlashPine            999           60:0.1     75:0.29    110:0.75    140:1.0
WhiteOak             20            60:0.01    75:0.05    95:0.45     110:1.0
WhiteOak             60            60:0.01    75:0.10    95:0.55     110:1.0
WhiteOak             999           60:0.1     75:0.30    95:0.65     110:1.0
TurkeyOak            20            60:0.01    75:0.05    95:0.45     110:1.0
TurkeyOak            60            60:0.01    75:0.10    95:0.55     110:1.0
TurkeyOak            999           60:0.05    75:0.30    95:0.65     110:1.0
SweetGum             20            60:0.01    86:0.06    110:0.45    140:1.0
SweetGum             90            60:0.01    86:0.06    110:0.45    140:1.0
SweetGum             999           60:0.01    86:0.06    110:0.45    140:1.0
RedMaple             30            60:0.1     75:0.50    110:0.86    140:1.0
RedMaple             50            60:0.1     75:0.80    110:0.86    140:1.0
RedMaple             999           60:0.1     75:0.80    110:0.86    140:1.0
TulipTree            30            60:0.1     75:0.50    110:0.833   140:1.0
TulipTree            50            60:0.1     75:0.80    110:0.833   140:1.0
```

```
TulipTree           999          60:0.1    75:0.80   110:0.833  140:1.0


>> >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>


MapNames  hurricane/maxWindspeeds-{timestep}.gis

LogFile   hurricane/hurlog.csv
```