Treefall Pattern Analysis Software Installation/Basic Use Guide

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1. Prerequisite Requirements

- **ArcGIS Pro Version 3.1** (newer versions may also work but ESRI is very protective about licensing so newer versions may not be backwards compatible...)
  https://www.esri.com/en-us/arcgis/products/arcgis-pro/overview

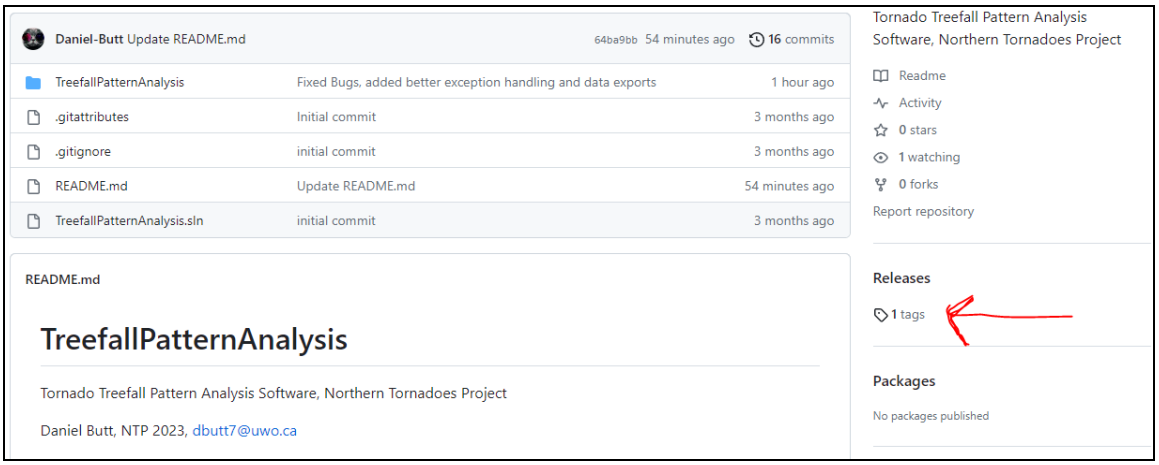
- **Tornado treefall vectors** (must be a polyline shapefile were each vector is a polyline)
  NTP automated tree tagging software GitHub (see install manual for instructions)
  https://github.com/Daniel-Butt/Tree_Tagger_ArcGIS_Add_On
  Requires a powerful GPU.

- **Tornado center line** (treefall convergence line, as a single polyline)

2. Installation

1. Go to the GitHub page:
https://github.com/Daniel-Butt/TreefallPatternAnalysis

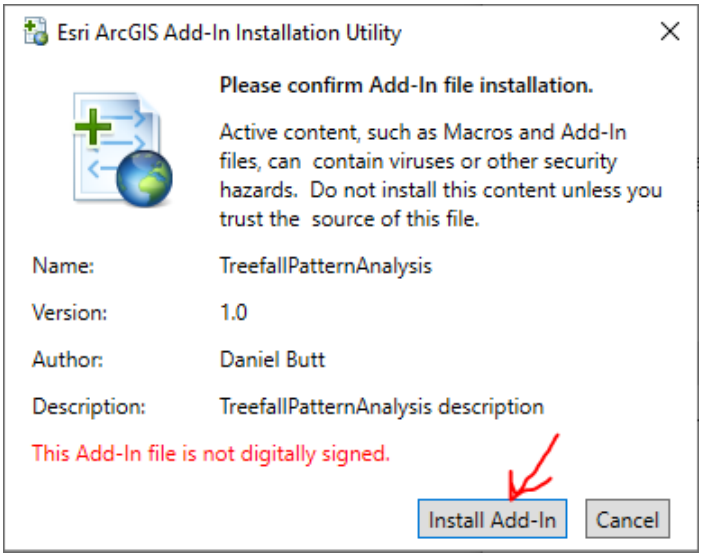
2. Click on "releases" on the right hand side



3. Select the latest release and download the zip file labelled "TreefallAnalysis.zip"

4. Extract the zip file and remove the innermost folder labelled "TreefallAnalysis"

5. Inside this folder you should find a file called TreefallPatternAnalysis.esriAddinX, this is the installer. run it to install the add-in.



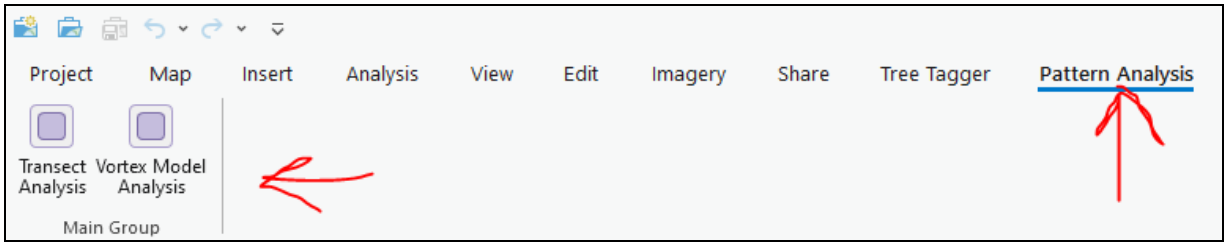
6. Find and open the binary (bin) install folder for ArcGIS Pro (normally it is under C:\Program Files\ArcGIS\Pro\bin)

7. Paste the TreefallAnalysis folder in the ArcGIS Pro bin folder (make sure the TreefallAnalysis folder is not double foldered, i.e. not TreefallAnalysis\TreefallAnalysis)

Note: In the same TreefallAnalysis folder there should be a folder called "test_data" which contains an example treefall vector field and center line.

3. Basic Use Guide

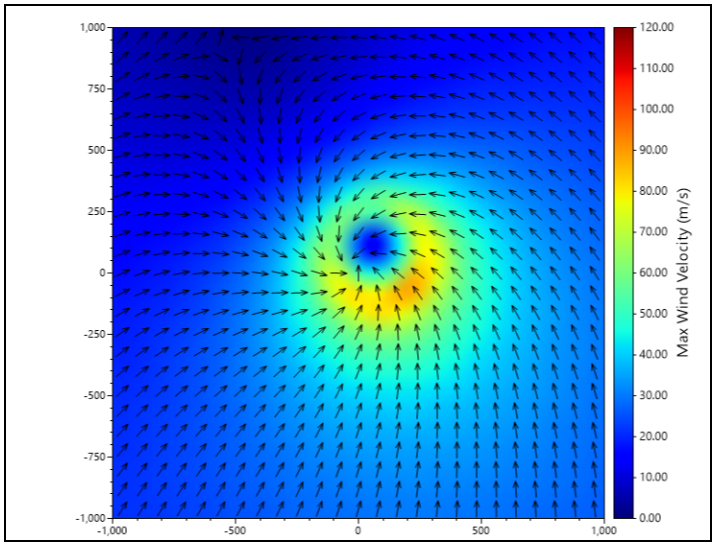
If installed correctly you should see the following in the top toolbar once you enter an ArcGIS Pro project:



Clicking on either the "Transect Analysis" or "Vortex Model Analysis" buttons will open the associated application.

3.1. Graphs

Any graph you see in this software was built using the ScottPlot library https://scottplot.net/, and as such has many useful features, but also some downsides.



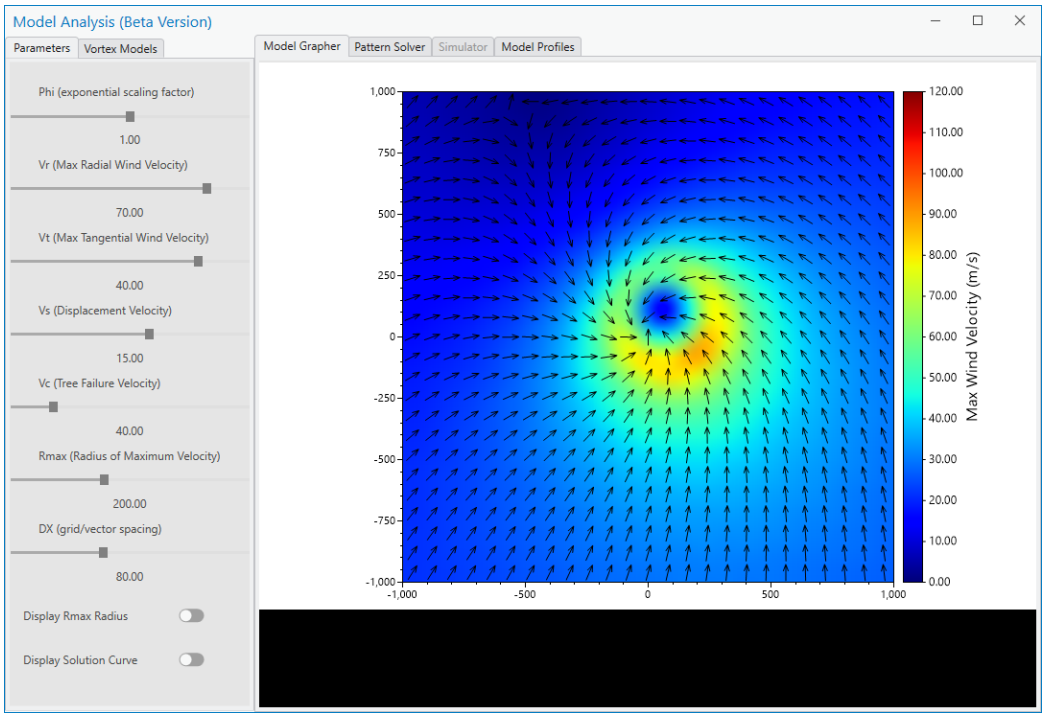
Any graph can be:

- Saved as an image (right click)
- Opened in full screen (right click)
- Panned (left click)
- Rescaled (drag right click)
- Zoomed/**Reset zoom** (middle mouse/middle click)

Note: Often Graphs start out zoomed incorrectly, this is a bug I'm working on, to reset the zoom, simply press the middle mouse button while over the graph.

3.2. Vortex Model Analysis

Clicking on the "Vortex Model Analysis" button will open this window.



This is primarily a tool for analyzing different vortex models, their associated wind fields, and the treefall pattern they create. Switching to the "Pattern Solver" tab will show you the treefall pattern. Adjusting the various sliders will change the field and/or the treefall pattern.

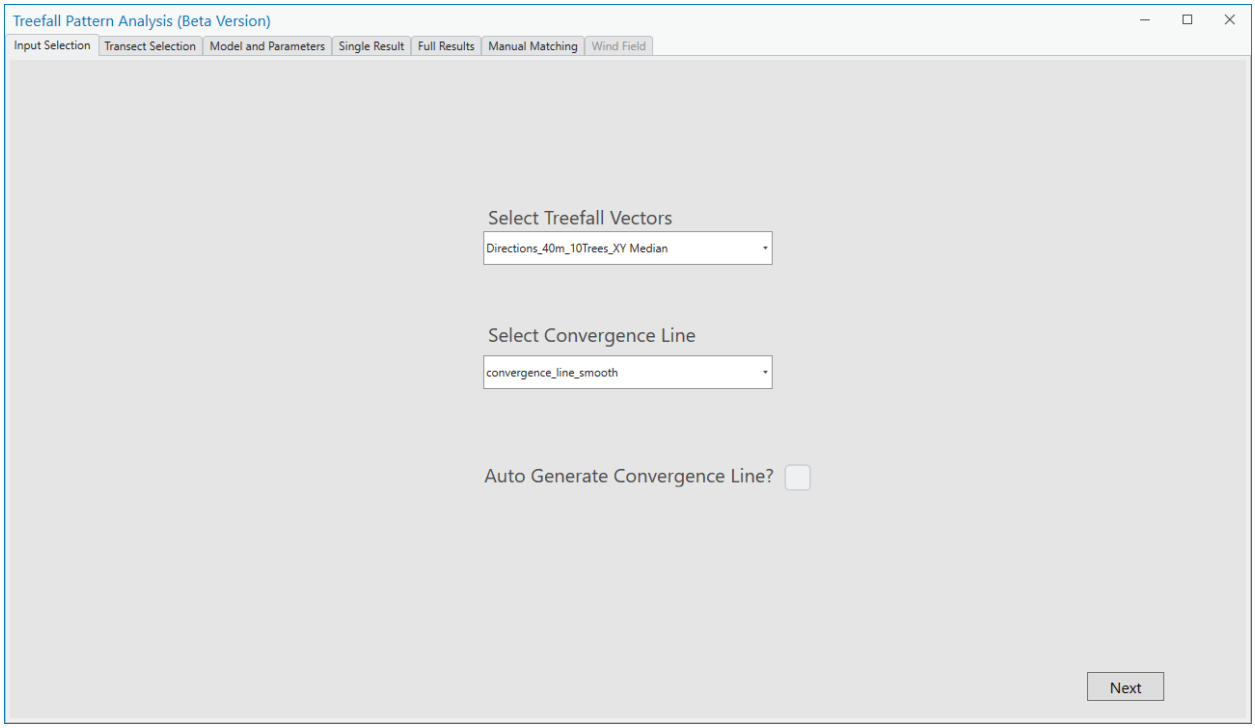
This tool is very helpful for getting a sense of the types of treefall pattern which the various vortex models can simulate.

3.3. Transect Analysis

Clicking on the "Transect Analysis" button will open this window.
This is the main software, used for fitting and matching treefall patterns.

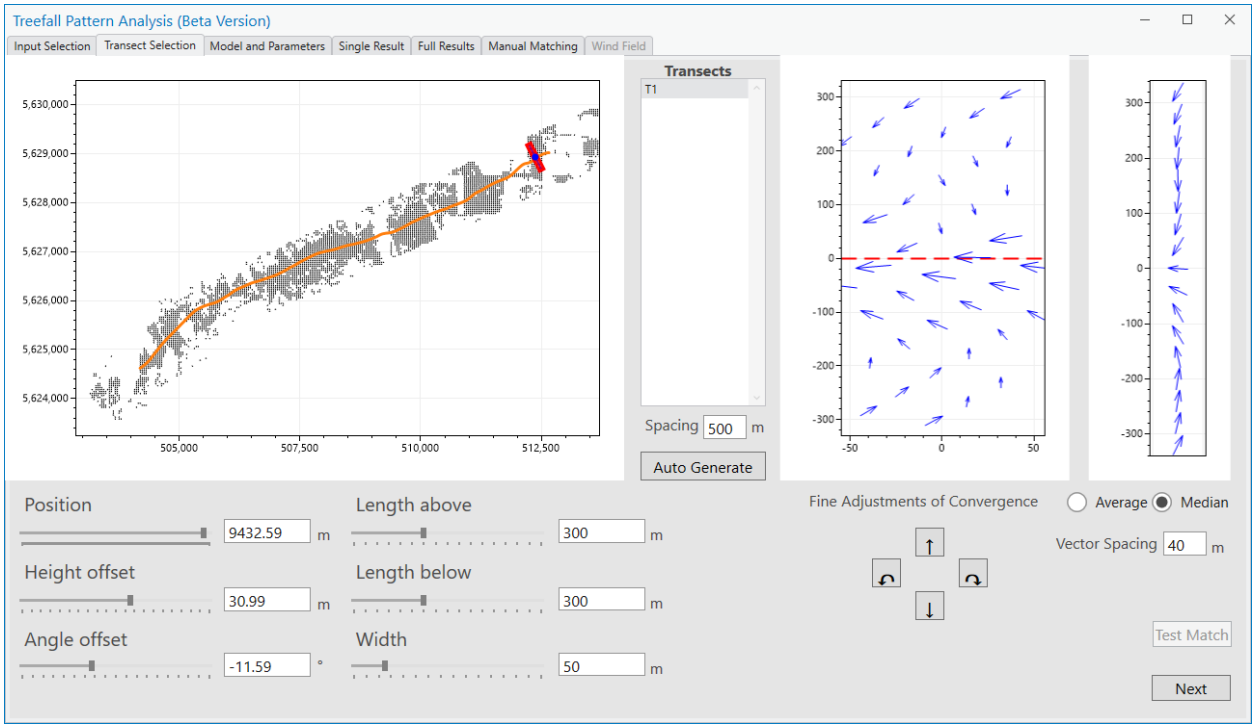
When the application first opens you should see the input selection window,

3.3.1. Input Selection



Using the drop down selection boxes, select the treefall vector polyline shapefile and convergence (center) polyline shapefile. Then press the "next" button to continue.

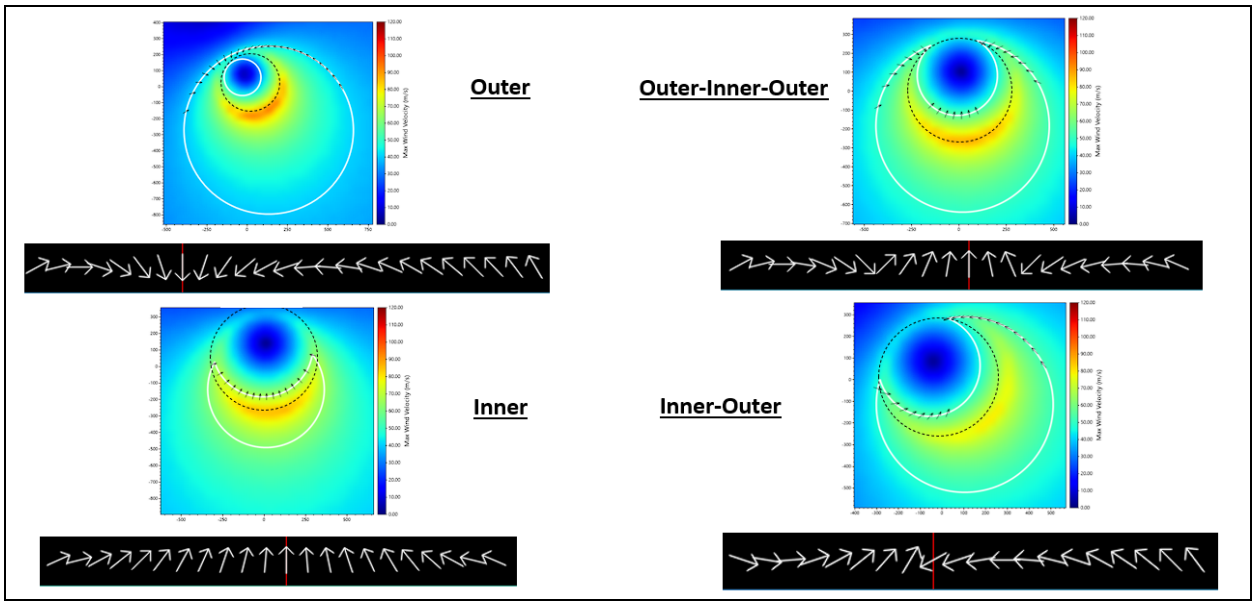
3.3.2. Transect Selection



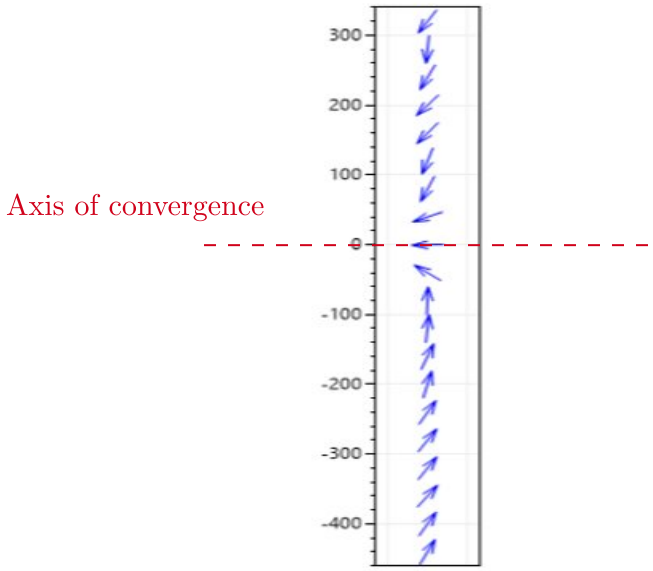
Using the transect list box labelled in bold as "Transects", right click and select "new" to create a default transect. Use the various sliders to move, scale, and rotate the transect. In real-time you should see the transect change in the graph on the left as well as, the vectors inside the transect box and the associated averaged treefall pattern change in the graphs on the right. The averaged treefall pattern vector spacing can be changed using the text box below the pattern graph. This spacing should be adjusted proportional to the overall damage width of the tornado.

Ultimately, the goal is to fit transects that produce averaged treefall patterns which are as similar as possible to the types of patterns which can be simulated (see Vortex Model Analysis).

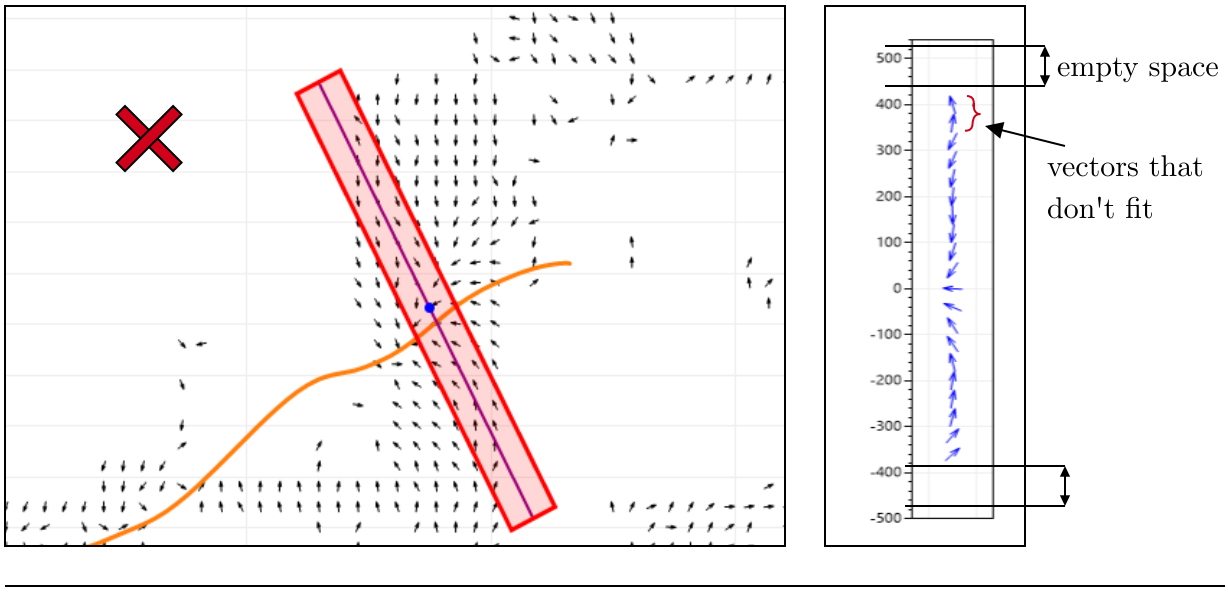
The main types of patterns are as follows,

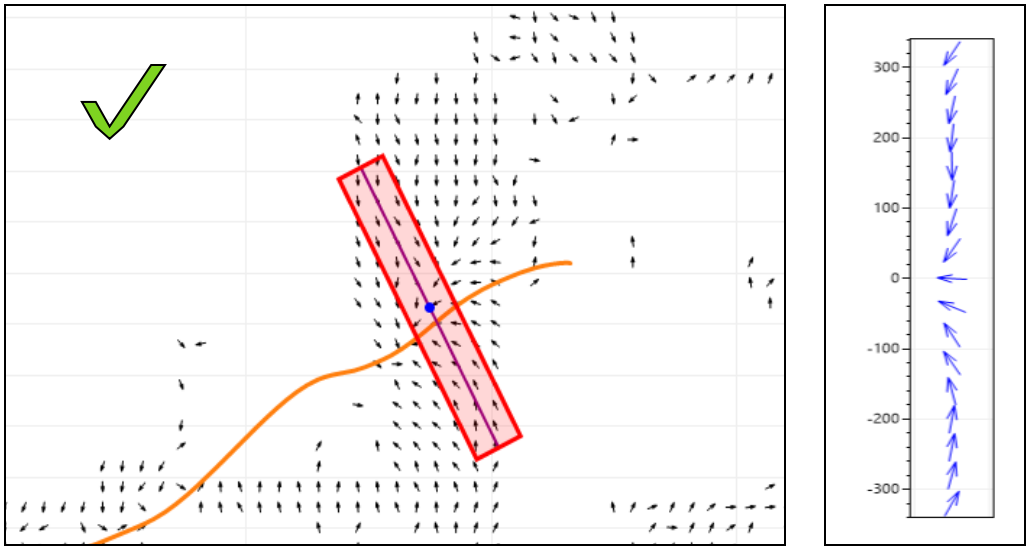


When fitting a transect, the average treefall pattern should converge at 0 and be as close to horizontal as possible (except in the case of the Inner-Outer pattern which converges "asymptotically" around an axis of discontinuity)



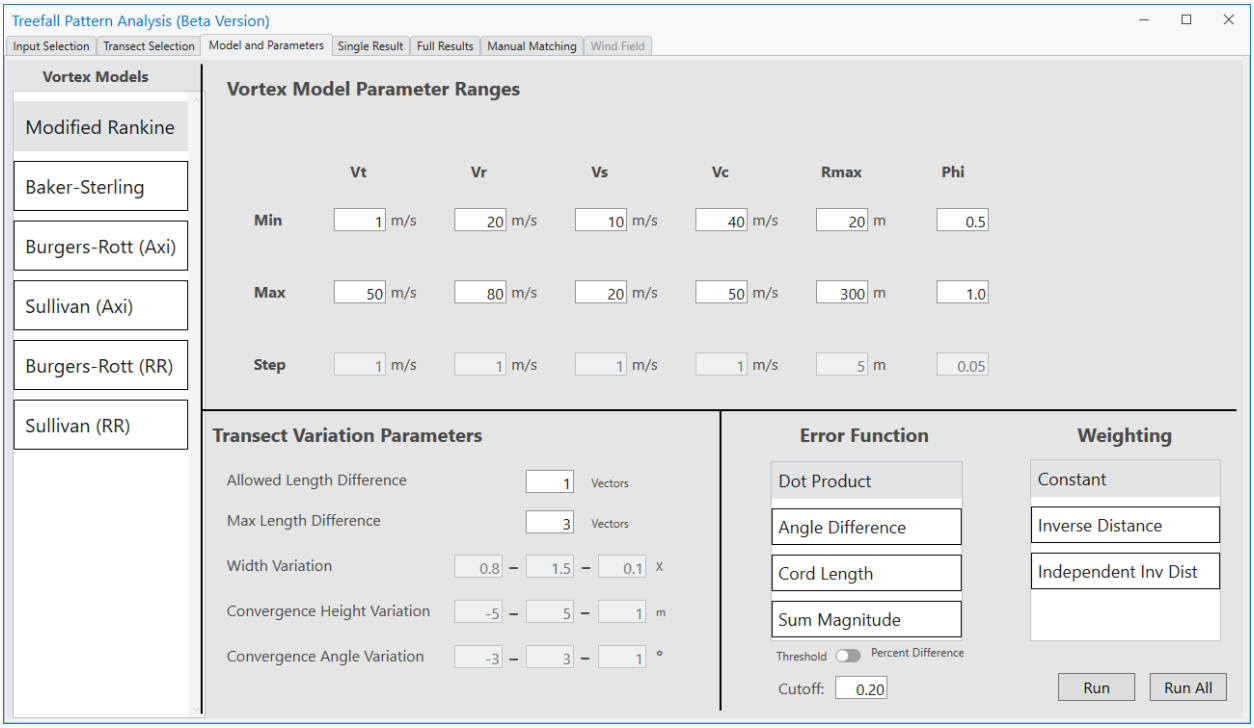
Additionally, the transect should extend the majority if not all the damage width.





Once you have fit and are satisfied with your transect(s) press the "next" button to continue.

3.3.3. Model and Parameter Selection



In this menu you can enter the range of matching parameters, select which vortex model to run (or run them all), select the allowed variation parameters, and select the comparison (error) function.

Pressing the "Run" button will match using only the selected vortex model (left panel). Results are then displayed in the "Single Results window"

Pressing the "Run All" button will run all models. Results are then displayed in the "Full Results window"

<u>Vortex model parameters</u>

V_t = Maximum tangential velocity, generally 1 - 50 m/s
V_r = Maximum radial velocity, generally 20 - 80 m/s
V_s = Vortex translation velocity, generally 5 - 25 m/s
V_c = Average tree critical failure velocity, generally 35 - 65 m/s
R_{max} = Radius of maximum velocity, generally less than half damage width
φ = Exponential decay / growth factor used for Rankine Model, generally, $0.5 \leqslant \varphi \leqslant 1.5$

Transect variation parameters

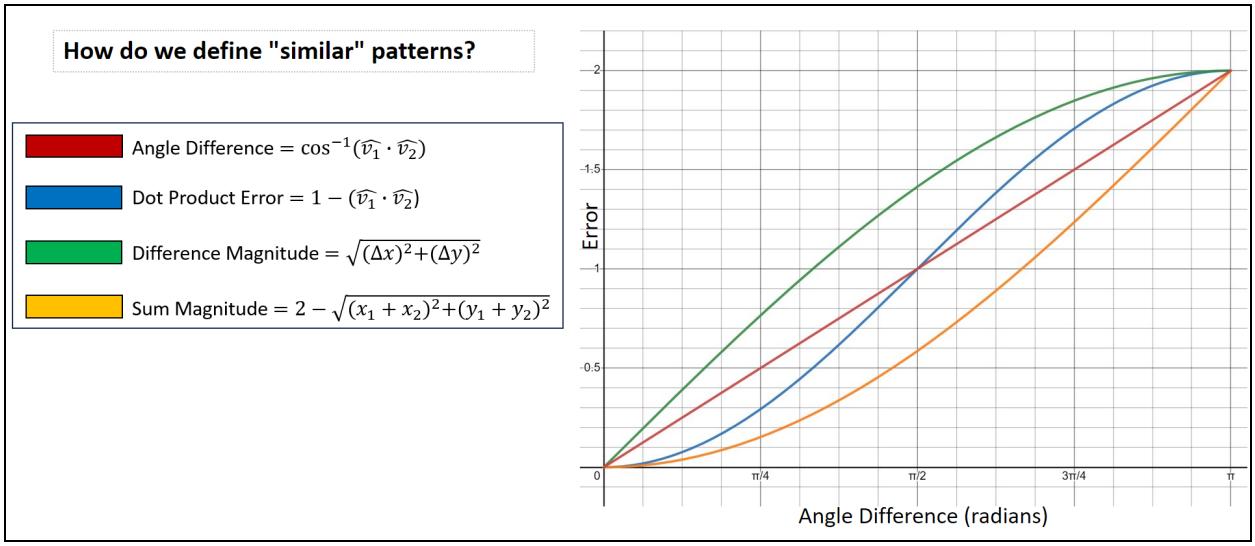
Used to ensure the length of the patterns match appropriately.

Allowed Length Difference: The allowed length difference between the observed (fit) average treefall pattern and the simulated pattern, above and below the axis of convergence respectively, in vectors. Any simulated pattern which is longer or shorter, above or below this is limit will not be considered.

Max Length Difference: Sum of the length differences above and below must be less than this value for a simulated pattern to be considered(default is 3 which effectively turns this parameter off for an allowed length difference of 1)

For example if the allowed length difference and max length difference were 1 then the simulated pattern could be 1 vector longer or shorter than the observed pattern, above or below the axis of convergence, but not both above and below.

Error functions



Generally stick with either Angle Difference or Dot Product.

Vector Weighting

Should all the vectors be considered equally when comparing patterns?

Constant: All vectors are weighted equal.

$$w_i = 1$$

Inverse Distance: Vectors are weighted less linearly based on the distance from the axis of convergence relative to the max distance.

$$w_i = 1 - \frac{d_i}{d_s + \max(L_a, L_b)}$$

Where d_i is the vector's distance from the axis of convergence, d_s is the vector spacing, and L_a, L_b are the lengths of the transect above and below the axis of convergence.

Independent Inverse Distance: Vectors are weighted less linearly based on the distance from the axis of convergence relative to the independent length above or below.

$$w_i = 1 - \frac{d_i}{d_s + L}, L = \begin{cases} L_a & \text{if vector is above convergence} \\ L_b & \text{if vector is below convergence} \end{cases}$$

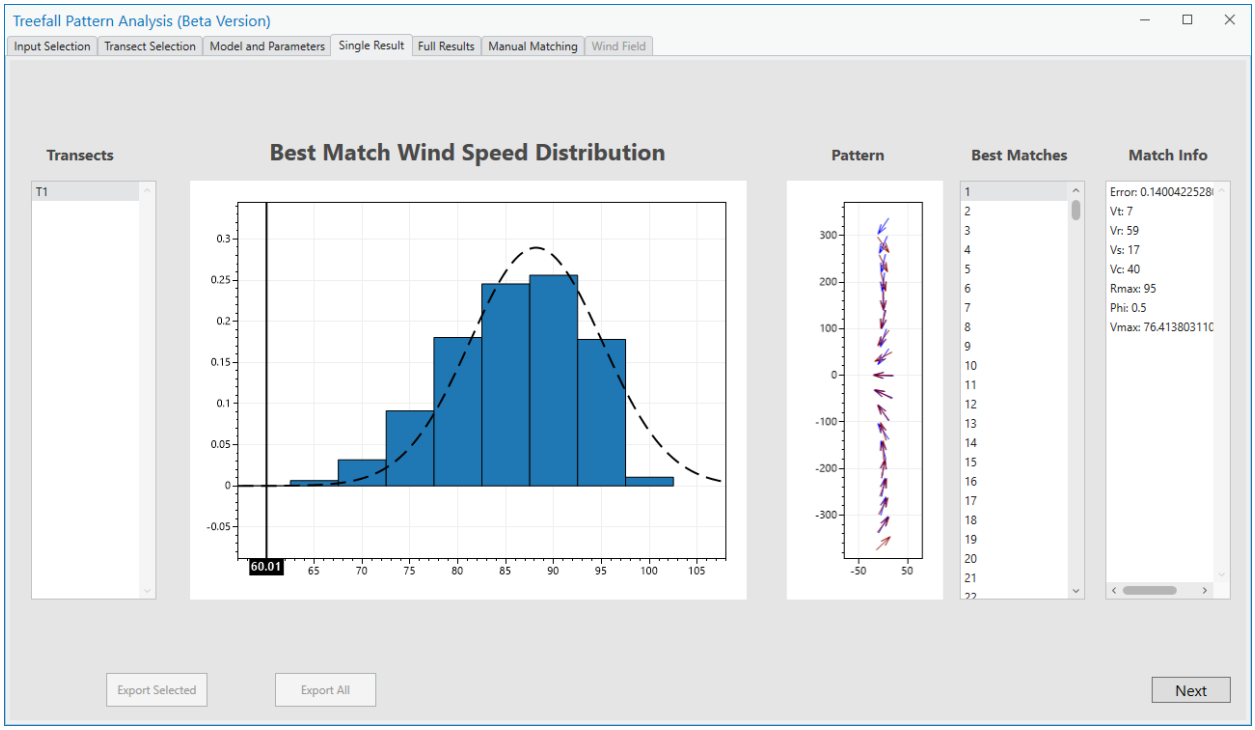
Cutoff

The cutoff value selects which simulated patterns are considered to be possible matches.

Threshold: Only simulated patterns with an error less than the cutoff are considered.

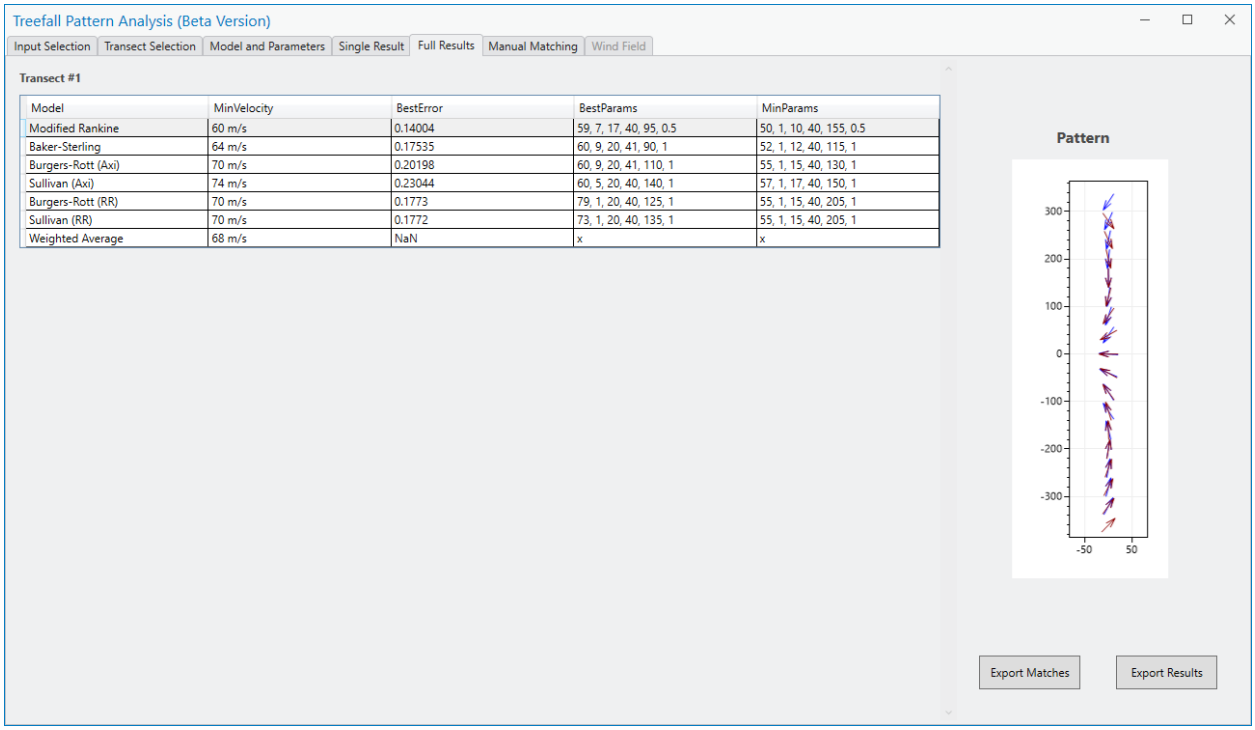
Percent Difference: Only simulated patterns which have an error percent difference less than the cutoff value from the best overall pattern's error are considered.

3.3.4. Single Results



This window shows the max wind speed distribution for the vortices that produced matching patterns. The vertical black line in the graph shows the minimum wind speed which produced a matching pattern. The "Best Matches" list can be used to see the various matched patterns sorted in ascending order of error. Selecting a best match will display its pattern in the pattern graph (red is simulated, blue is observed).

3.3.5. Full Results



This window shows the full results of running all the vortex models on each transect pattern. This includes the best match error and vortex parameters, along with the minimum velocity and parameters required to produce a matching pattern.

Clicking on the table rows will select a model and display its best match pattern in the pattern graph window.

Selecting "Export Results" will export the table to a csv or excel (excel is formatted as a report and includes the best match pattern image).

Selecting "Export Matches" will export all the valid matches as a csv. (this can be a huge file depending on the number of matches found and parameter ranges).