# SEAtide V3.3 User Guide

## Qld-Gulf


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## ACKNOWLEDGEMENT OF THIRD-PARTY REAL-TIME DATA

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## TABLE OF REVISIONS

| Version | Description | Date | Prepared By | Approved By |
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| A | First Release V3.3b | 04-Apr-2019 | B. A. Harper BE PhD CPEng NER RPEQ | B. A. Harper |
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## RELEASE STATUS

Client Confidential

*Front Cover Credit:*
*Tully Heads in Far North Queensland after Tropical Cyclone Yasi, Feb 2011; ABC News.*

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# 1 Overview

*SEAtide* is an interactive software system that operates on personal computers using 64-bit Microsoft Windows™ operating systems (e.g. Windows 10). The purpose of *SEAtide* is to provide a rapid prediction and analysis system to enable suitably trained and experienced tropical cyclone (TC) forecasters and emergency managers to evaluate the possible impact of *storm tide* and associated extreme wind threats to coastal communities.

*SEAtide* provides an operating interface that is designed to be intuitive, easy to learn for an experienced professional and economical in its operation. The *SEAtide* concept focuses on the importance of allowing for uncertainty in the forecast TC track and intensity parameters and the inter-relationship with the astronomical tide.

The predictions from the system are targeted towards providing clear and concise information about location, magnitude and timing of storm tide and associated extreme wind events as well as the probability of exceedance associated with a range of possible forecast outcomes. This information can then be assessed to determine what actions might be necessary to advise the community on precautionary or evasive actions, or to initiate evacuation.

Specific features of *SEAtide* include:

- Generalised application to any coastal region;
- Rapid simulation of storm tide scenarios;
- Consideration of storm surge, astronomical tide and breaking wave setup;
- Easy entry of TC parameters, including importing of Agency Forecast Tracks;
- Deterministic (single storm scenario) or probabilistic (simulation) modes;
- Predictions shown in UTC or local time zones;
- Hazard-line (MEOW-style) warning maps in standard EMA mapping colouring;
- Concise browsing and sorting of model predictions;
- Time history graphs for all available locations;
- Spatial profiles of predicted storm tide levels or components at specific times;
- Summary probability distributions at a specific site;
- Ability to "step through" a storm scenario within the hazard map;
- Ability to import externally modelled data for comparison;
- Extensive hardcopy, numeric and graphics export capabilities;
- Surface wind and MSL pressure visualisation and export;
- Multiple sessions may coexist on a single PC;
- Download and display of real-time tide gauge, wave buoy and wind data (where available).

The *SEAtide* storm tide predictions are based on previously developed numerical models of storm tide for specific coastal regions (e.g. SEA 2002, GHD/AMC 2014) that are then combined with a set of user-supplied TC parameters. New regions can be added at any time to extend the coverage of the model or finer scale models can be added later to replace initially larger scale models or expand the parameter set.

***SEAtide* has been extensively calibrated and tested but responsibility in its use and interpretation lies with the operator. Systems Engineering Australia Pty Ltd (SEA) has taken all reasonable steps and due care to ensure that the software is accurate and reliable within the context of the adopted modelling assumptions. SEA expressly excludes all liability for errors or omissions, whether made negligently or otherwise, for loss, damage or other consequences that may result from the application of *SEAtide*.**

# 2 Definitions

It is important to understand the various water level components that *SEAtide* considers when making a prediction. The predicted "storm tide level" is an absolute elevation that includes the combined effects of storm surge, breaking wave setup and the astronomical tide, as shown schematically in the beach crossection of Figure 2.1.

This is separate from the individual "magnitudes" of each component, which are not absolute levels. For example, at any specific site, a TC with given parameters of intensity, speed and direction will generate an "*x*" m surge magnitude and a breaking wave setup magnitude of "*y*" m. These will occur largely independently[1] on a background of a varying tidal level, such that the relative timing of the storm and the tide will dictate the "total absolute" level, which is referred to as the *storm tide* level.

Each of these components is separately available within *SEAtide* and the user can choose which combination of components to consider. By default, the total storm tide (surge+setup+tide) is reported, together with the predicted times when total water levels are expected to exceed the expected Highest Astronomical Tide (HAT)[2], which can vary markedly along specific sections of coast or when moving offshore from the coast.

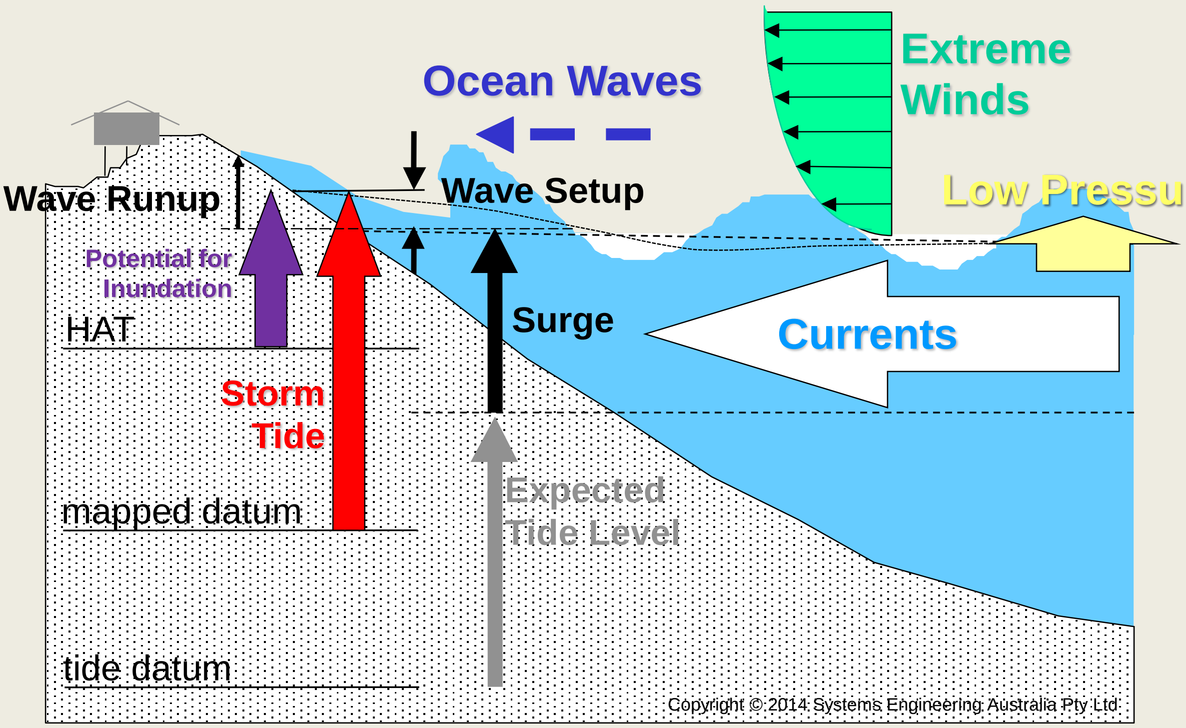



Figure 2.1 Water level components of TC storm tide.

All absolute levels are reported to the applicable national mapping datum (e.g. Australian Height Datum (AHD) in Australia), which must not be confused with any local tide datum (e.g. Lowest Astronomical Tide LAT[3]) as published in Tide Tables. The degree of inundation that might be possible will then be the difference between the local mapped ground level elevation and the

[1] Depending on the regional parametric model characteristics, *SEAtide* may include specific non-linear surge and setup allowances of order 10% that result from changes in the tidal depth, but the effects are often small.
[2] This is the level that represents the highest astronomic-only induced tide at a site over an 18.6 year epoch, although tide levels close to HAT may still occur annually. The official HAT level can be typically exceeded annually in combination with commonly occurring weather-related fluctuations.
[3] Only the BoM *Totem* graphical option and *BoM Summary Report* additionally show storm tide levels to LAT datum.

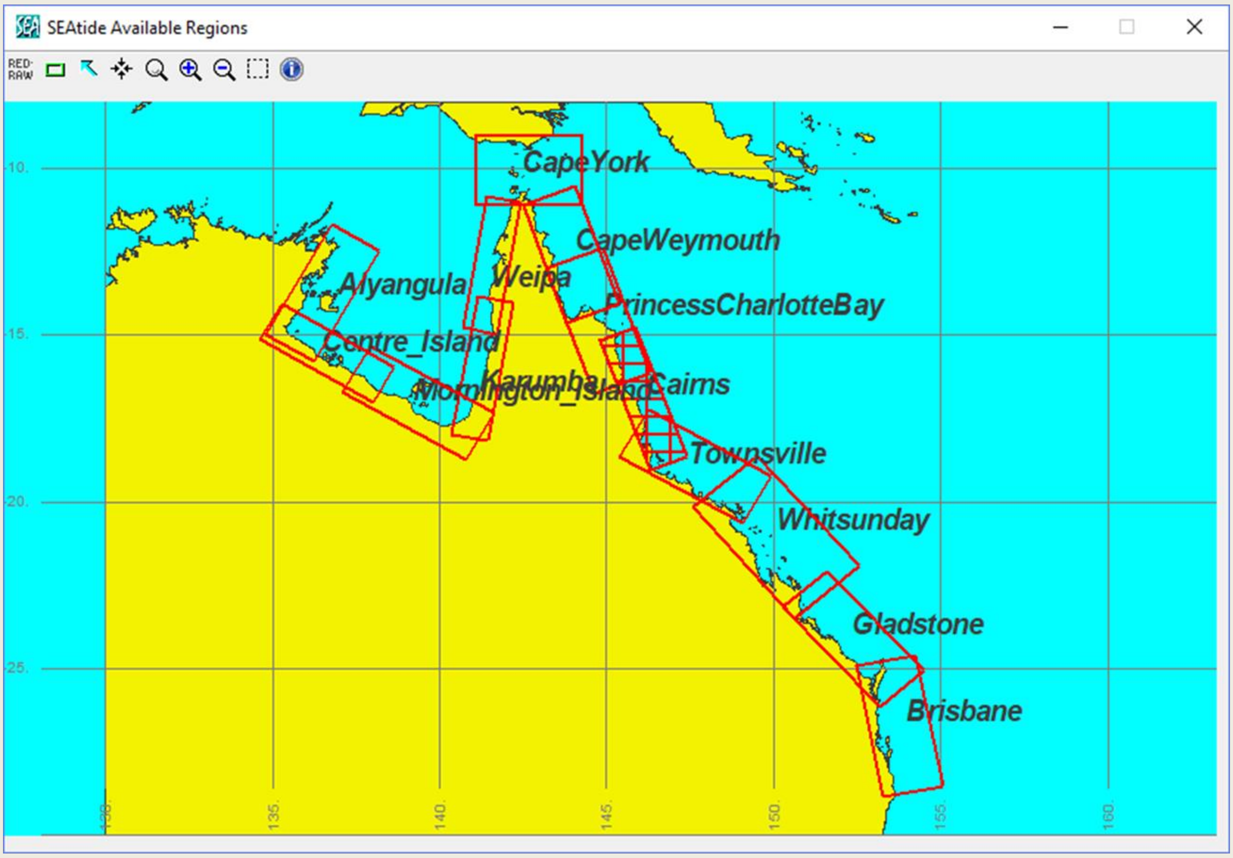
reported level from *SEAtide*. The local ground level will need to be obtained from a suitably detailed external source such as a local map or list of known benchmarks etc.

If available for specific regions, *SEAtide* also has knowledge of the "dune crest elevation", which is an estimate of the highest ground level immediately fronting the coastline. This value is used to adjust the breaking wave setup estimate such that, as the land is inundated, the wave setup component is reduced.

*SEAtide* does not currently include the possible effects of intermittent wave runup, which is a localised phenomenon requiring even more detailed site information. However, wave runup will also occur during a storm tide event where there is significant wave action and its effect will be evident from beach debris surveys and the like.

## 2.1 Model Coverage

The model coverage can be confirmed (refer Section 5.2) by selecting View Maps from the Startup Wizard Dialog, which will display as follows:




Each red rectangle indicates the model coverage for that stretch of coastline, with a total of 14 regions between Byron Bay in NSW to Gove on the NT coast.

The hatched region represents the default, in this case Cairns region, but regions are normally automatically selected according to the specified storm track information entered by the user.

# 3 *SEAtide* Storm Tide Prediction Concepts

## 3.1 Basics

*SEAtide* is principally a model designed to predict storm tide occurrences as a TC crosses or nears a coastline. In deepwater away from land the storm tide is essentially limited to a pressure deficit component approximately equal to a 1 cm rise for each hPa of pressure drop from the surrounding ambient environment. Accordingly, when running *SEAtide*, the context of interest is a TC that is approaching near or about to cross a (model defined) “coastline”. Importantly, *SEAtide* will only produce predictions at locations that have been declared to the model and it does not provide a “gridded” output that could be contoured, for example, to indicate the variability of water levels across an enclosed bay. Only the “coastal” points are reported. This concentration on the coastal margin rather than the full ocean domain provides *SEAtide* with its rapid prediction advantages and its focus on the threat of interest, namely inundation of coastal lands and possible drownings.

## 3.2 Model Regions

*SEAtide* operates always within the context of a “model region”, which is defined by the supplied parametric[4] model for storm surge and waves. The extent of each modelled region is typically of the order of 400 km alongshore, although this is dependent upon specific design factors in specific areas. In order to initiate a prediction, the TC must be located within the model ambit of one of the available regions and “close” to a coastline (refer later). At model start-up, there is an allocated default region, and the region is changed automatically depending on the specified storm fix or at the user’s choice.

## 3.3 Model Storm Parameters

The following TC parameters are available for modification, based on a Harper and Holland (1999) model concept, as proposed by Harper (2001) for Queensland, e.g.:

- Storm MSL central pressure; $p_c$ (hPa)
- Ambient or environmental MSL pressure; $p_n$ (hPa)
- Radius to maximum winds; *RMW* (NM)
- Windfield peakedness; *B*
- Track or forward motion vector; $V_{fm}$ (kn) and $\theta_{fm}$ (deg bearing), or
- Radius to gale-force winds; *Rgales* (NM)

Because not all of these parameters might be readily available in a forecast situation, the model also offers default values on a regional basis and has various options for enabling the user to specify these details. Internally, the storm “intensity” is based on $\Delta p = p_n - p_c$ and the maximum wind speed is a derived parameter.

All parametrically modelled regions are additionally built using a “double Holland” wind model concept (e.g. Thompson and Cardone 1996) that provides for an inner and outer vortex. This improves the ability to simultaneously represent winds at large radii as well as the steepness of the inner vortex. In these cases, the outer vortex parameters are fixed to regionally-defined values and the user manipulates only the inner vortex parameters. Each region (RDF file) records the base parameters that have been used for development. Appendix B provides details of the

[4] A parametric model is a simplified predictive model that has been derived from a set of pre-simulated tropical cyclone scenarios using a full numerical ocean model. Refer SEA (2002) for further details.

relationship between the wind model parameters to assist in matching the typically forecast *Vmax* intensity metric to the modelled winds.

## 3.4 Model Tracks and the Reference Fix

A *SEAtide* TC track is straightline-only with constant intensity parameters and hence implies an "equilibrium" condition. This is justified by the context of "near landfall", where only the final 12 h or less will normally significantly influence the resulting storm tide. Accordingly, the parameter set provided to the model must be considered as an "average" description over this nominal period but applicable at a specific site. While this might at first seem restrictive, it is more than compensated by the model's ability to undertake a simulation of as many variants as the user decides (refer later under simulation). Only a single **reference fix** is initially required to define the so-called **reference track** (lat, lon, UTC).

## 3.5 Model Landfall and Timing Windows

The underlying models are built assuming that a prediction is required at or near the likely time of "landfall". In the case of a true land-crossing event, this means a prediction window commencing (typically[5]) 18 h prior to landfall and extending up to (typically) 12 h after landfall (i.e. 30 h in total). In the case of a storm that is moving essentially parallel to a coastline, the same window exists but it is relative to an orthogonal drawn from a region-specific coastal reference point and normally extends further in time. These concepts are presented in detail in Appendix C.

The model graphed storm tide predictions are then further restricted to a "viewport" of ± 12 h of the reference fix.

## 3.6 Model Parameter Limits

Because of the nature of the simplifications in the underlying parametric models, *SEAtide* will typically have limitations on the parameter space available to the user. If the user chooses parameters outside of that space the interface will indicate which of the entered parameters is in error. This is done using a system of "warning lights" that vary in colour. The user can view the associated warning messages and the *View | Parameter Limits* menu item can be used to examine the full set of parameters that were used to formulate the model.

One of the principal limitations in any region will be the allowable track bearing range. To limit the effort in constructing the parametric models, typically the range of model track bearings is restricted by concentrating on the climatology records. This may result in some tracks not being able to be modelled in *SEAtide* because they are either very unlikely or if they do occur, are deemed not to present a high level of threat. The valid regional track bearings can be displayed for reference at any time.

## 3.7 The Deterministic or Most Likely Prediction

By default, *SEAtide* will initially provide a *Deterministic* storm tide prediction. This simply means that the provided fix parameters will be used to construct a single storm tide simulation. The context of this prediction is then that these parameters represent the "best estimate" of the storm characteristics and the timing of its approach, such that the resulting storm tide prediction is deemed the "most likely" scenario (refer later the available display *modes* in Section 4.4). In deterministic mode, the model allows the user to produce hazard maps of the highest modelled levels (or magnitudes, depending on which water level component is selected). The deterministic

[5] The exact timing window can vary between model regions.

peak total water level is often referred to as the MEOW or *Maximum Envelope of Waters* view of the scenario.

Alternatively, the user can "step through" a time development of the event (termed a *snapshot*) and trace the dynamic instantaneous behaviour of the scenario, whereby the movement of the surge wave across the region can be monitored. Similarly, time history graphs of the water level components can be produced at any of the model sites and spatial profiles of the components at specific times can be viewed, saved or printed for distribution. A summary site-specific "totem pole" water level and tide range graphic can also be produced.

### 3.7.1 The Deterministic Dependent Prediction

This is a special additional data viewing mode that tabulates the components of the total water dependent at the time of the peak total water level rather than the individual component peak values. In this mode the displayed water level components are additive to give the indicated peak total water level value at each site.

## *3.8 The Probabilistic Prediction*

The full power of *SEAtide* is realised in the *Probabilistic* prediction mode, whereby the user acknowledges the level of uncertainty present in the deterministic fix parameters by providing a set of complementary statistical parameters. For example, rather than relying on a single estimate for the central pressure, a positive and negative standard deviation or highest and lowest limits can be specified that makes allowance for the forecast uncertainty and allows a skewness or bias to be applied to that estimate. Likewise, uncertainty in the speed or bearing or radius can also be specified. With this information, the model can then be instructed to undertake a simulation that uses the supplied statistical information to automatically and randomly choose a series of alternative scenarios.

The number of simulations required to fully and reliably explore the parameter space then depends on just how variable the user has made the parameter set. By default, the minimum number of scenarios generated is 100 but more[6] might be desirable in some highly variable situations. The user can gauge the effectiveness of the sampling by examining the model output for smoothness and visually observe the track distribution as the storms are generated[7]. Alternatively, the user may select the *Auto* option, which will generate as many scenarios as necessary to ensure that the peak storm tide levels across all sites are not exceeded for up to the specified number of consecutive events. This acts as a persistence of non-exceedence test and has the recommended minimum count of 50 consecutive events. The number of events that will be simulated in *Auto* mode will depend on the spread of the specified uncertainty values.

When a Forecast Track fix is imported, *SEAtide* will use any "uncertainty radius" information to automatically assign uncertainty ranges to the track bearing and forward speed parameters, such that when the simulation is run, all synthetic fixes will lie within the radius of uncertainty of the reference fix.

The type of model output available in *Probabilistic* mode is analogous to the deterministic case, except that time history information is replaced by probability of exceedance information. For example, the 50% probability of exceedance is the median or "expected" value arising from the

[6] The permitted range is from 10 to a maximum of 1000 scenarios.
[7] As the model needs to retain all information for all scenarios to produce the probabilistic result, there is an overhead in terms of the temporary storage space that the model will need to be granted to complete the analysis. This will depend on the number of prediction sites in a specific region, but with current computer storage capacity should not normally be a problem. Temporary work files are deleted on exit.

simulation, while the 0% exceedance reports the MEOW exceedance level[8]. Typically, the model allows ready access to the 50%, 90% and 0% exceedance values as being of most interest to the user, but specific intervals can also be interrogated, printed or plotted. In terms of spatial profiles, these are available as either water level components at a common exceedance level or a single component at a range of exceedance levels. It can be noted that in the probabilistic mode the presentation of the individual water level components is not additive (i.e. each exceedance probability curve applies independently to an individual water level component). This focuses attention on the range of water level contributions rather than a single outcome. The total water level exceedance probability however remains the principal parameter of interest and is always forced “to the front” when viewing the results.

### 3.8.1 The Peak Probabilistic Prediction

This is a special additional data viewing mode that tabulates the components of the highest total water from all the probabilistic cases for a single site that are generated by a single storm. This is selectable only from the 0% exceedance case, but the presentation options are equivalent to the “deterministic” case. In this mode the displayed water level components are additive because they all apply at the time of the peak predicted total water level. It can be noted that not every site might have the same storm event producing its peak condition, the result is a function of the number of storms that have been generated and does not contain information about the variability around that water level or around that site. The totem graphical output indicates the parameters of the peak probabilistic event for that specific site.

## *3.9 Model Temporal and Spatial Resolution*

This depends on the underlying regional model definitions but is normally 10 min in time and typically[9] between 550m (“C” grid resolution) and 2.8 km (“B” grid resolution) in space. The spatial resolution is always evident from the hazard map interface, whereby individual model along-coast locations can be identified. These are derived from the original full numerical model resolution.

To calculate probability of exceedance it is necessary for a “histogramming interval” to be applied so that counts of exceeding any given level can be recorded during an event. The adopted vertical resolution is 0.1 m for total storm tide, storm surge, wave setup and tide magnitude, while for significant wave heights the vertical resolution is 0.2 m. The probability of exceedance of any level or magnitude is then interpolated for values between 100% and 0%. The vertical resolution should be borne in mind when, for example, comparing values of the 0% exceedance with the discrete peak probabilistic value, even though they are analogous[10].

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[8] Technically the 0% level would be the next discrete water level that was not exceeded but that prevents display of useful timing information, so the MEOW level is adopted as the nominal 0% exceedance.

[9] The spatial resolution is adapted to suit the environments. The Cape York region has increased resolution of 1.85 km for B and 370 m for C, while all Gulf of Carpentaria regions have a 1.48 km B grid resolution without any C grids.

[10] The data browser output resolution is also set at 1 decimal point to avoid clutter and to not overstate the precision of the estimates. Minor round-off may therefore be evident when comparing some specific values that are additive or are expressed as differences.

# 4 Operational Overview

A schematic overview of the model operation is given in **Figure 4.1**, showing a few files are required initially to establish the model environment. After that, the basic user actions are "create", "edit" and, following the analysis, "viewing" of the predictions. At all times, *SEAtide* displays the regional hazard map window, which forms the principal user interface and has extensive map manipulation capabilities.

## *4.1 Input Files*

From the user perspective, *SEAtide* relies on one input file for its operation, as follows:

- A storm Scenario file (*.cyc) created through user selections

An additional (optional) input file is:

- An Agency Forecast Track[11] file (normally a *.csv)

These files are text-based but should not be directly edited by the user outside of the *SEAtide* interface unless specifically advised by SEA. The Scenario file includes all the storm-specific parameters, both deterministic and probabilistic, that enable *SEAtide* to perform the prediction. Forecast Track files provide multiple fixes from which a Scenario can be selected or modified. After input, the *SEAtide*-relevant track information is stored in the CYC file (up to 3 tracks can be stored).

The Scenario and Track files can be located anywhere the user chooses. The default for both is <SEAtide_install>\SEAtide_User, unless otherwise specified in the installation INI file as the *CYC_Filepath* or *TCT_Filepath* (refer Appendix A). Both will be automatically reset to be any folder that the user chooses from a subsequent folder selection dialog.

Scenario files are continually updated in response to any user *Updates* and can optionally be saved as new versions if required. Only one scenario can be active at any one time but multiple SEAtide sessions can co-exist for a single user. The symbol ■ will appear next to the *Update* button if it needs manual updating for a change to have effect.

**Figure 4.1** indicates that a Forecast Track file is an input-only option, whereby the required track parameters are transferred into the CYC file format. If a new Scenario is being created *SEAtide* will assign the relevant model *region*(s) and select an initial "best guess" track fix automatically. The user can later override this by selecting a specific track fix in preference to the initial *SEAtide*-selected fix, load alternate Forecast Tracks and/or edit the track data.

## *4.2 User Actions*

The principal user actions are simply to *create* or *edit* Scenario files prior to *analysing* and then *viewing* the model results. To facilitate the most common sequence of events a *wizard* is automatically provided at start-up that will offer the user these basic options. When choosing to explicitly change a model *region*, the user will be provided with a map interface to select the region of interest.

The *view* option is particularly powerful, allowing the user to browse predictions of any water level component for any site in the region on a tabular basis and for the results to be sorted by

[11] Non-Government organisations will not necessarily have access to an agency forecast track file. However there is the option to download real-time public domain forecast information provided by the agency that SEAtide will convert into an equivalent agency track file.

magnitude (default), alphabetically by site name, either all sites or only named sites, and to view predictions in terms of pre-defined geographic (spatial) site groupings called *zones*.

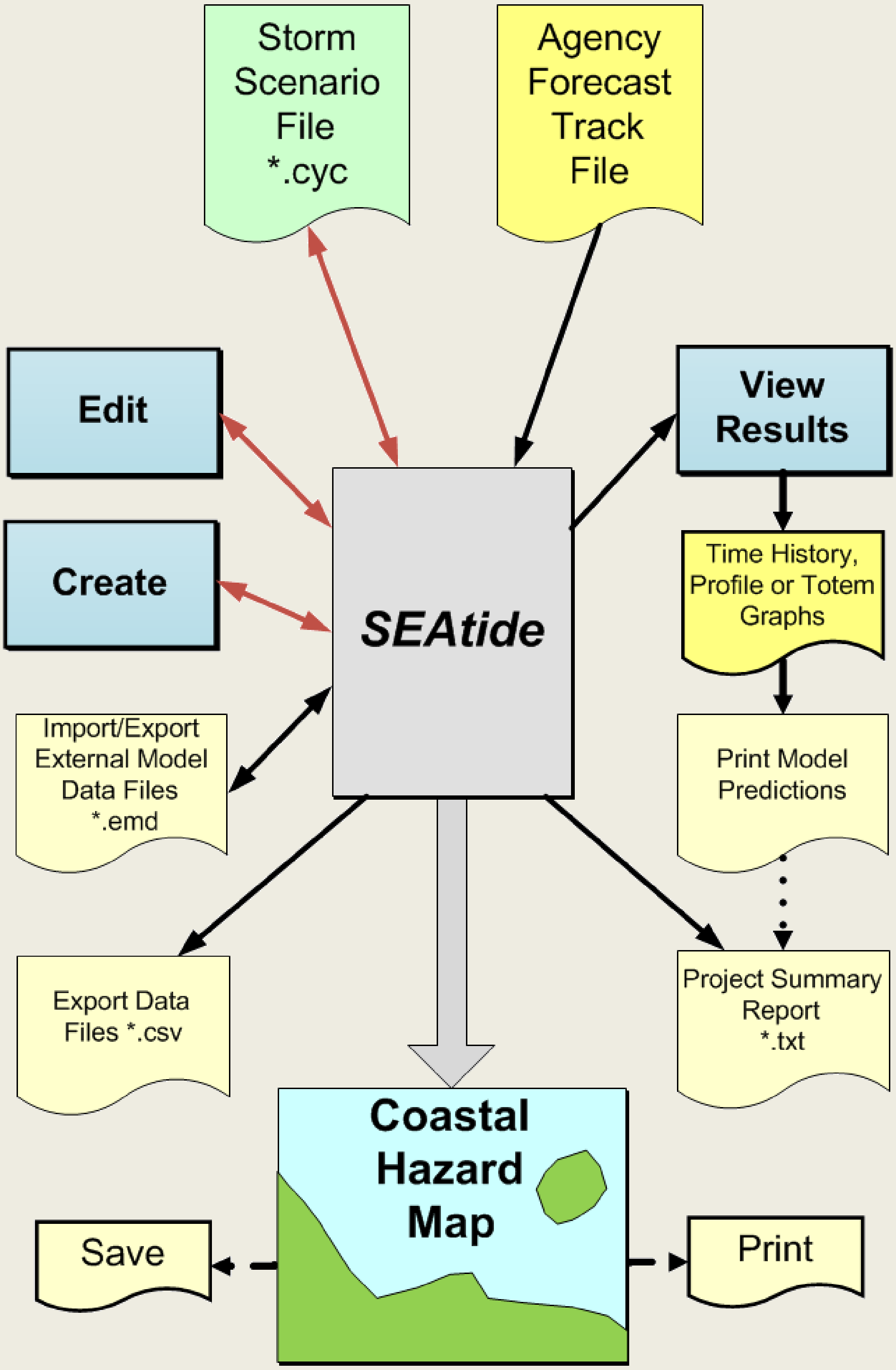



Figure 4.1 Schematic Overview of *SEAtide* Operation.

The *view* feature automatically displays the peak predicted level, the time of exceeding and/or falling below HAT, the elapsed time above that level and, for probabilistic cases, the probability that HAT will be exceeded at any location. Any predicted level in excess of HAT is flagged in **red**, indicating increased potential for damage to life or property at that location. Non-threatening water levels are indicated in **green**.

The *view* feature also provides a portal for the user to produce summary hardcopy reports and to generate graphical output either in time history format for a particular site or in spatial format for a particular *zone*. Australian BoM-compatible site-specific “totem pole” graphical outputs are also available.

## 4.3 Model Output

Other than the interactive *view* mode, the principal output from the model is the *hazard map* and *project summary* report, both of which can be printed directly from within the model or saved externally as required. All graphical output can either be saved to a graphics file, copied to the clipboard or the underlying data exported.

The default report folder is <SEAtide_install>\SEAtide_user but can be specified in an INI file as the *REP_Filepath* (refer Appendix A) and is automatically reset to be any folder that the user subsequently chooses from a folder selection dialog.

The *hazard map* is manipulated via a graphical layer control field that displays a wide array of prediction information depending upon the user selection. Storm tide levels are indicated on the map numerically and as coloured “hazard strips” joining the sites. The colouring for the storm tide component follows the EMA-approved standard colour scheme, which can be compared with formal hazard and evacuation maps.

The *project summary* report is a comprehensive report that details all the model parameters used to make the prediction, followed by a tabular listing in magnitude order by site name, location etc. The peak predicted levels, excess of water level over HAT[12] and the times of exceeding are jointly presented in UTC and local time. Both the *deterministic* prediction for all sites and the 50% and 0% *probabilistic* prediction are provided. This file, in a plain text format, is saved to disk and may also be directed to a printer from within *SEAtide*.

Several additional *export* outputs are also available, including site-specific exceedance and persistence or detailed spatial information in various formats to allow downstream data processing or importing into a GIS context. All graphical output can be saved to file or the clipboard and the data for any graphical output may also be exported to a file. Export files are in comma delimited format and may be imported directly into a spreadsheet program.

The hazard map window and any *SEAtide* graph may be saved in a graphic file format (e.g. JPG or PNG) or sent directly to a printer or PDF generator.

## 4.4 Display and Mapping Modes

As outlined earlier, the user has a choice of display and mapping modes depending on the specific interface.

These can be either:

- Deterministic (Independent) – the peak value of each component is shown
- Deterministic (Dependent) – the value of each component at the time of the peak total water level is shown
- Probabilistic – the probability of exceedance of each component is shown
- Peak Probabilistic – the value of each component at the time of the peak total water level of the highest single stochastic event at each site is shown

[12] Only sites that are estimated to have water levels exceeding HAT are listed.

The following table summarises which model contexts offer the various display modes:

| | Hazard Maps | Browser Views | Exported Files | Graphs | Reports |
|---|---|---|---|---|---|
| Deterministic | ✓ | ✓ | ✓ | ✓ | ✓ |
| Deterministic/Dependent | | ✓ | ✓ | n/a | |
| Probabilistic | ✓ | ✓ | ✓ | ✓ | ✓ |
| Peak Probabilistic | ✓ | ✓ | ✓ | ✓ | |

## 4.5 Additional Features

*SEAtide* has the ability to overplot the *deterministic* prediction on any applicable *probabilistic* prediction to enable comparison between the two estimates. This automatically becomes available when both types of predictions are available. This will indicate where the deterministic prediction sits relative to the uncertainty limits that have been provided to the probabilistic simulation.

Additionally, predictions can be imported from an external model data file (e.g. from MMUSURGE or similar numerical hydrodynamic model) and similarly overplotted for comparison. The *external model data* (emd) file format must be followed to achieve this feature. *SEAtide's* specific details about the region sites can also be exported to assist in this exercise. An existing *SEAtide* prediction can also be exported into an *emd* format and later re-imported if required for comparison purposes.

An array of mapping tools is available that allow the user to pan or zoom within the available map limits. A seamless transition is available between fine scale and coarse scale mapped coastlines and a distance and bearing measurement tool is provided, together with a latitude-longitude positional readout. The level of detail is automatically adjusted depending upon the selected level of zoom.

In addition to the standard background coastal map, raster road map, satellite images and the like can be displayed if there is internet access available.

Real-time data download and display of various tide gauge, storm tide gauge and waverider sites is available for comparison with model simulations. If the wind feature is available this extends to BoM and AIMS wind stations. Note that to “see” real-time data, a storm scenario must be created that is within the real-time UTC display window. The exception to this is the special “hindcast mode” whereby previously saved historical data can be displayed instead of real-time data.

All display windows can be dynamically resized.

If licenced, *Import | Climate Selection* is available to enable selection of either synthetically-simulated TC tracks relevant to the region of choice, or historical TC tracks. Filters are available to set the parameter ranges that will apply to the import. In conjunction with the wind feature, probabilistic wind fields can be calculated. Appendix E has preliminary Help notes.

# 5 Sequential Screen Shots

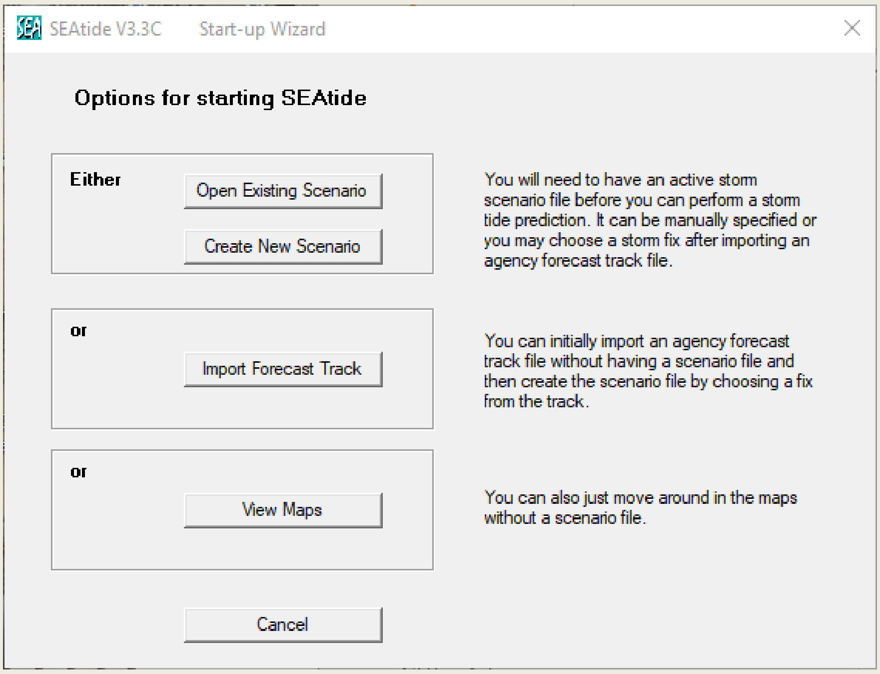
## 5.1 Start-up

The program will initially look to recover details of the last model session to facilitate user interaction. This includes the directory paths and filenames of the last used scenario files by the user, which are stored in the Windows registry. If unsuccessful, a dialog will appear to prompt the user to change to a preferred directory path for the commencement of the session.

The licence details are then displayed while progress of model data loading is displayed.


## 5.2 Wizard

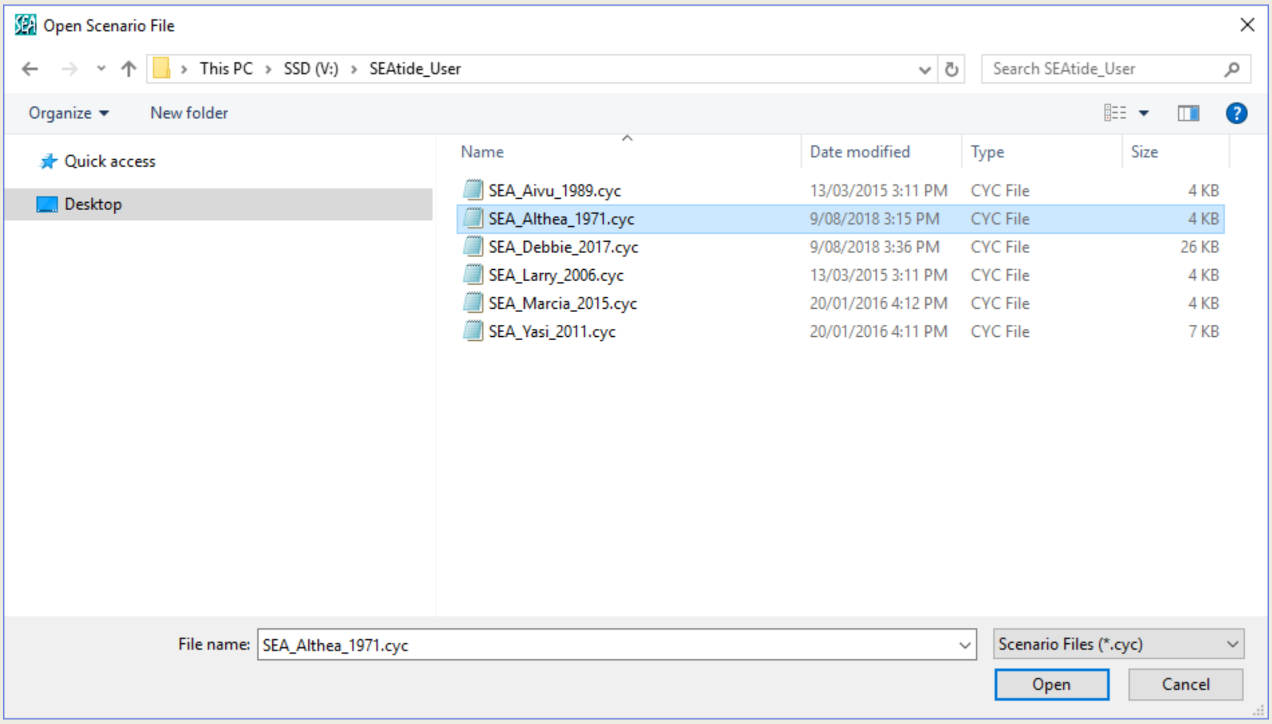
A start-up wizard dialog is automatically launched to assist the inexperienced user in setting up or choosing scenario files. This also displays the current *SEAtide* model version details.



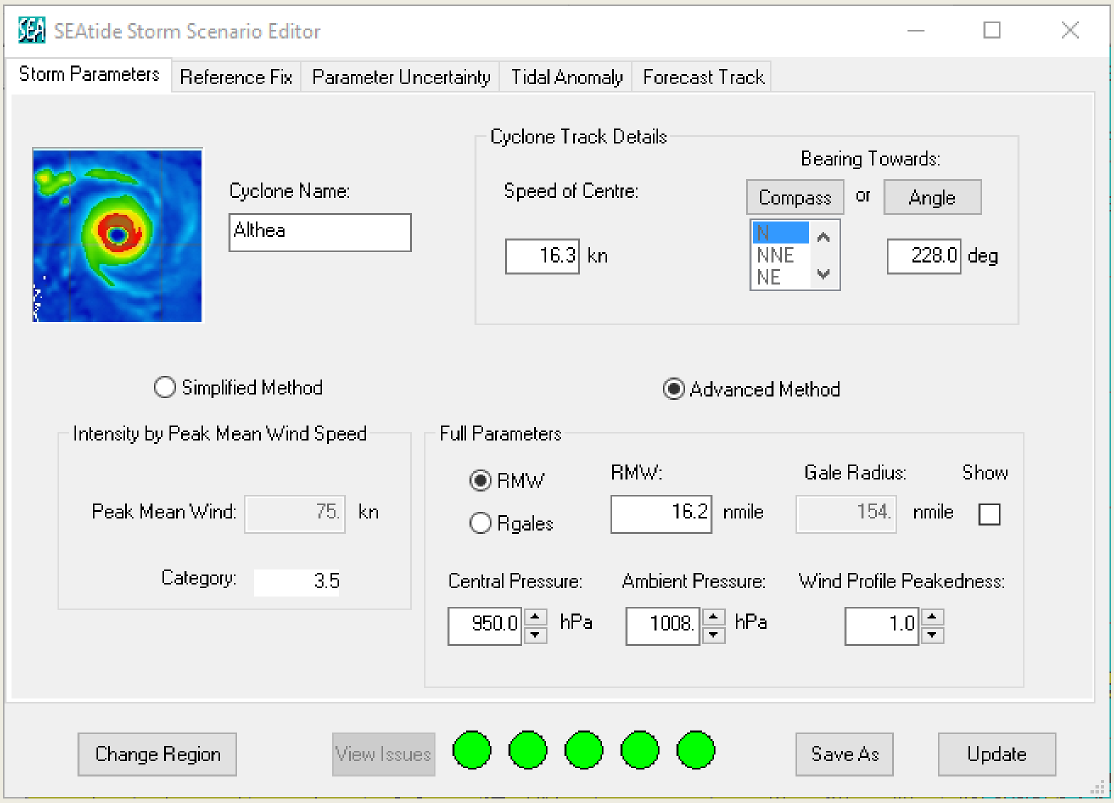

These options are largely self-explanatory but also have a brief summary. If Cancel is selected the same features can be accessed via the menu and toolbar options.

## 5.3 Opening an Existing Scenario

This would be a commonly used option from the Wizard interface. The user is presented with a file selection dialog that will show all candidate CYC files within the current default CYC path. If necessary, the user may navigate to any other directory to locate the CYC file of interest, e.g.




In this case the SEA_Althea_1971.cyc is chosen and the Open button selected (or the file may be double-clicked). Cancel can be used to abort this action. A floating window is then opened that displays the details of the chosen storm scenario and to enable editing if required.



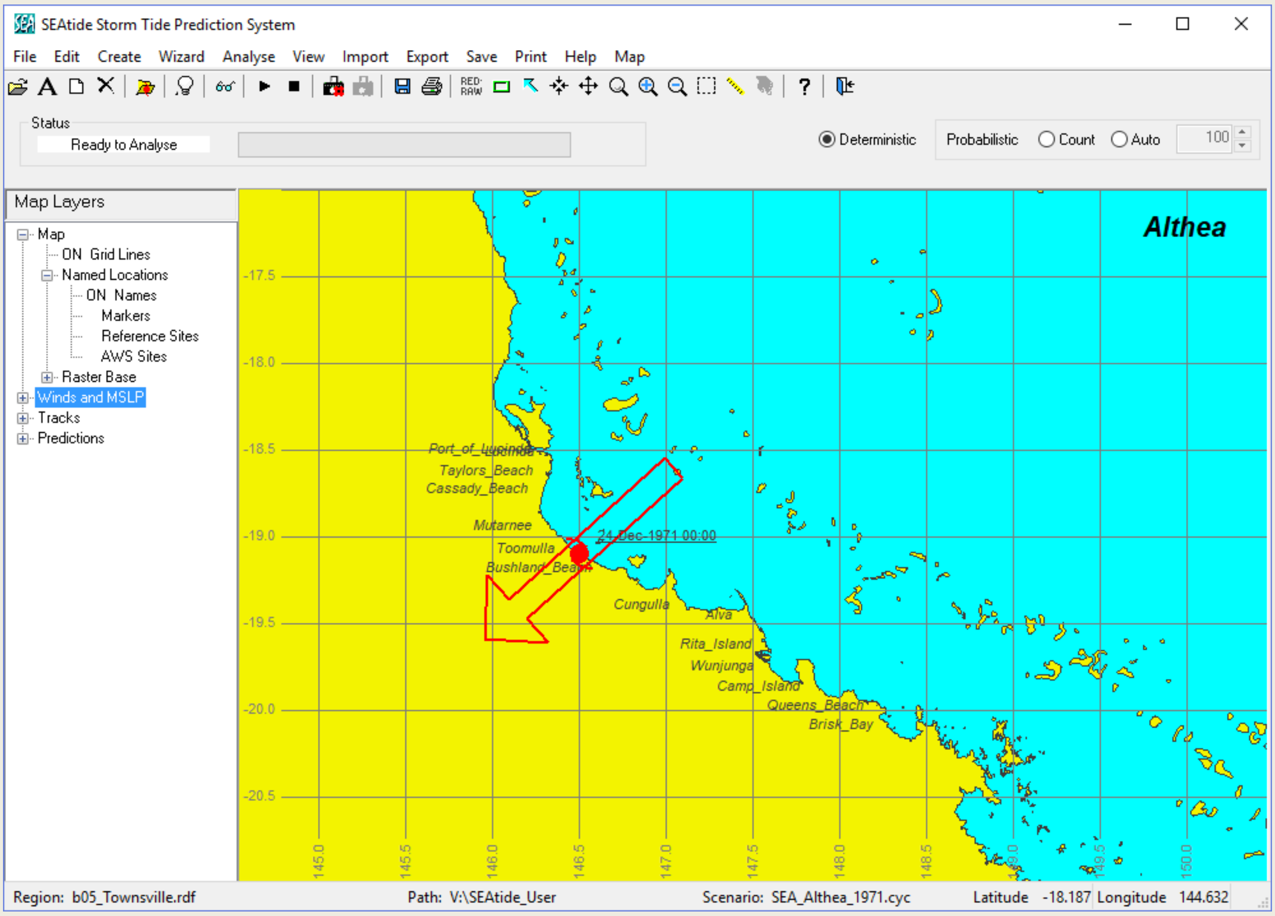
If no critical errors are detected in the specified parameters (indicated by the five **green** icons that relate to each of the tabs in the scenario editor window above), there is now sufficient information to proceed with a storm tide prediction. Details of the scenario editor and these coloured icons will be discussed later.

Meanwhile, the base hazard map user interface is now also displayed with the selected *scenario* name in the top RHS of the map window, i.e. "Althea" in this example.

The storm scenario that is now able to be modelled is shown on the map window, based on the CYC file *reference fix* displayed as the red storm symbol within the large red directional arrow, together with the UTC timestamp of that fix.

Several labelled coastal prediction sites have also been displayed. This initial starting map viewport is automatically chosen to show the full extent of the model region (Townsville) that is associated with this scenario.

The chosen *region*, *filepath* and *scenario* file are now indicated on a status bar along the bottom of the map window, with the latitude and longitude readouts of the last map cursor position. Along the top of the window is a selection of menu items, with some of the more frequently used options repeated in the toolbar immediately below. To the left of the hazard map is the map layer control pane, which has four[13] root layers controlling the display of *Map*, *Tracks* and *Predictions*. These expand to reveal lower options in response to either user selections (via left button double-click or select/enter) or in response to the model status.




Above the map layer pane and below the button toolbar on the LHS is a *status* pane where the model reports progress and status at various times. Opposite this on the RHS is the selection

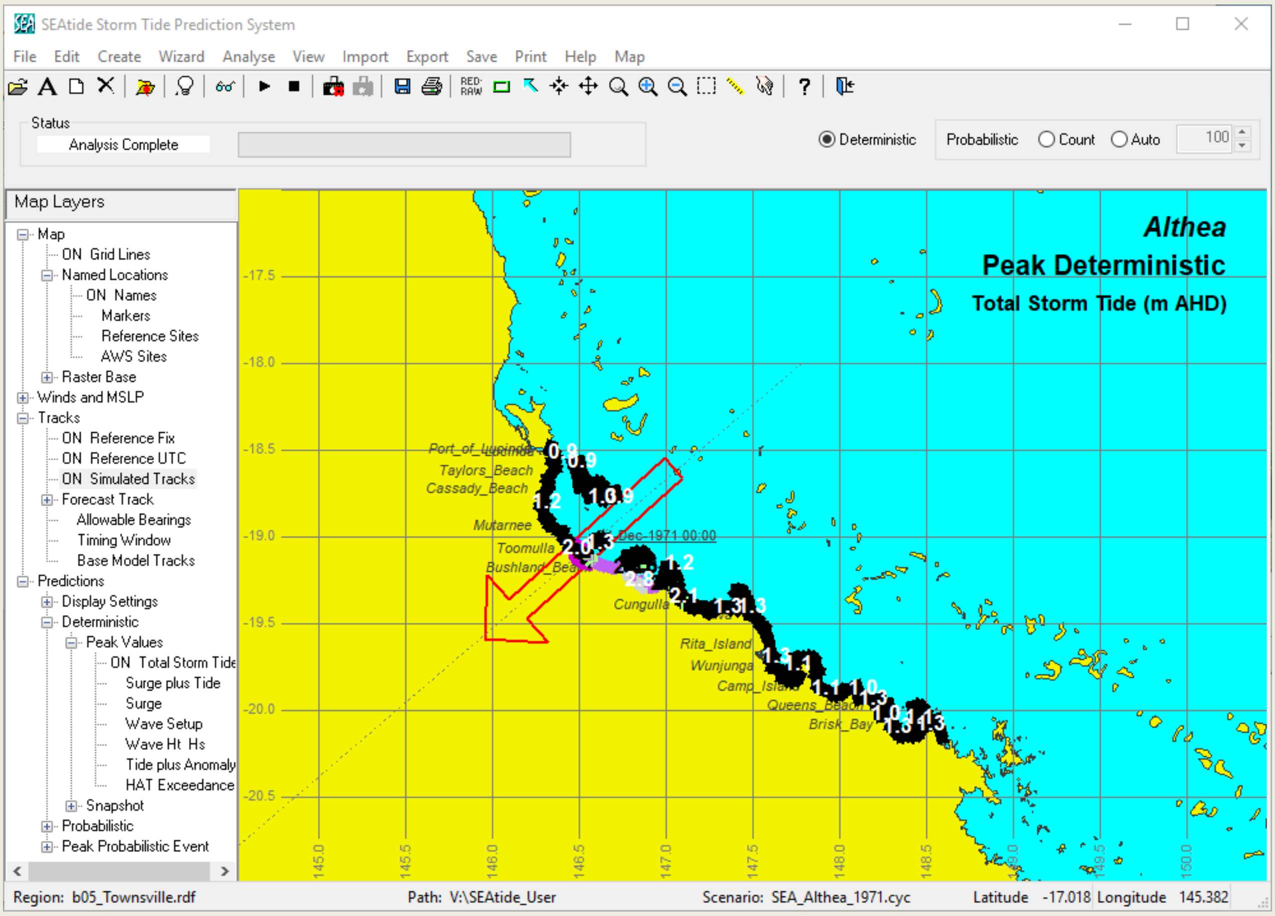
[13] The optional "Winds and MSLP" layer will only be visible if the licence allows.

zone for either *deterministic* or *probabilistic* predictions. By default, single *deterministic* predictions are active, but upon selection of *probabilistic* (either *Count* or *Auto*), the associated storm count spinner can be adjusted as required (refer later).

The user can now proceed directly into an analysis or readjust the viewport, edit the existing storm scenario and/or import a Forecast Track etc. For illustration we proceed by pressing the *Analysis Start* button in the toolbar. After a few seconds, the model completes its prediction and displays the results in the map window.

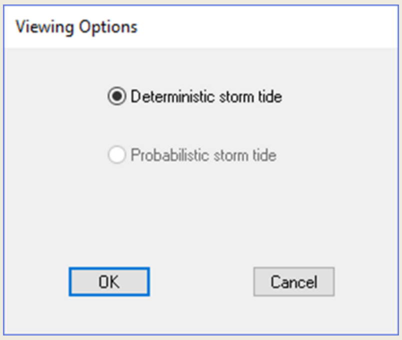
## 5.4 Results of the Analysis

In this next screen view, the status pane now indicates that the analysis is complete, and the hazard map has been updated to show the peak deterministic total storm tide levels along the coast, both numerically and according to EMA standard colours, although the zoom level at this stage does not provide the level of detail that might be desirable near the landfall point.




There are no times displayed on this map view as this is a MEOW condition over the period of the simulation (times are available in *view* and graphical outputs).

The map layer pane on the LHS has now been expanded to reveal the current map settings. For example, under the *Tracks* root level an *ON* status shows against the layers for *Reference Fix, Reference UTC* and *Simulated Tracks* while under the *Prediction* root the *Total Storm Tide* status is ON under the *Deterministic* and *Peak Values* layers. Automatically the user is offered the choice to view the tabulated results from this analysis, as follows:




In this case, only the *deterministic* option is available. If an external model data file (emd) is subsequently imported, this will appear as an additional option at this point. If *cancel* is chosen the user can perform map actions and return later via the menu *view* option.

## 5.5 The View Browser

The main view browser is then presented, showing a tabular listing of the peak values of the parameter predictions at various coastal sites that are organised on a series of tabs according to the combinations of water level components. Various display *Modes* are available, with the default being *Deterministic*. *Site* selection can be *Named Only* or *All*, *Sort* selection can be *Magnitude*, *Site Name* or *Zone* and *Time Zone* can be *UTC* or *Local*.

### 5.5.1 The Deterministic View

The data shown below is for the top (leftmost) tab of *Total Storm Tide (m AHD)*. It is clearly labelled at the top of the first column as *Deterministic* and the indicated levels are therefore considered the most likely (unlike a probabilistic prediction, which will have a probability of exceedance). The default view, as indicated by the setting of radio buttons along the top, is that *Named Only* sites have been displayed, that they are sorted[14] by descending *magnitude* and the times shown are in *UTC*. Also, all the parameters in any of the tabs will show their highest values at any time throughout the simulation (the so-called *independent* values, as per Section4.4).

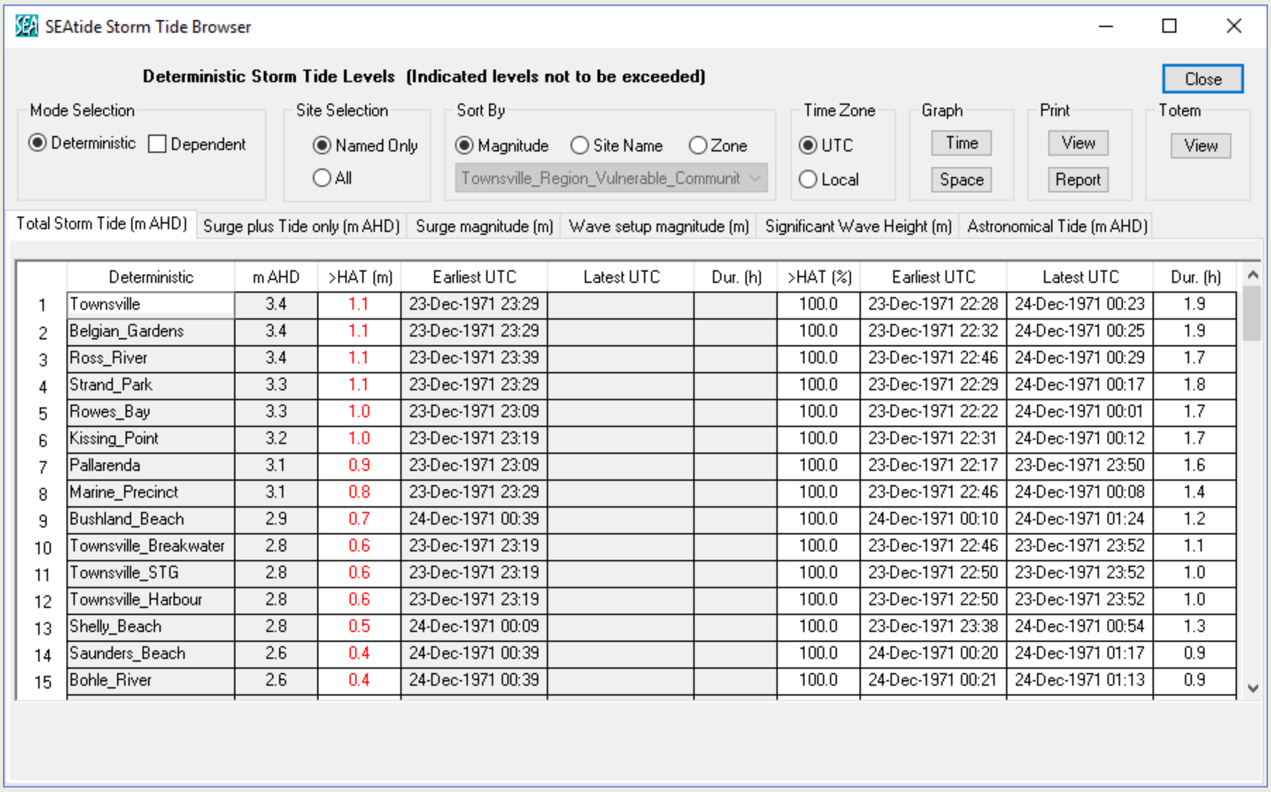
Out of all the named locations within the model region for this scenario the model has very quickly identified the site of *Townsville* as having the highest predicted total storm tide level of 3.4 m, as shown in the “m AHD” column. Other unnamed sites may actually be higher though and the user should explore that option by adjusting the view selection controls[15] to show *all* sites.

The third column “>HAT (m)” shows that *Townsville* total water levels are estimated to reach 1.1 m above the local HAT level (highlighted in **red** to indicate being > HAT), and the earliest UTC time of reaching that level is indicated. The next two columns “Latest UTC” and “Dur (h)” are not applicable in this case as the indicated value is the peak. The next column “> HAT (%)” shows the probability of exceeding HAT, which is 100% in this case because it is expected to exceed HAT (this column is more informative in the probabilistic case). Finally, the times when HAT would be exceeded and the duration above HAT are displayed. At *Townsville* the total storm tide is

[14] In order to "lock" the location of sites when moving between viewing tabs it is necessary to first select *Sort by Site Name*, then scroll to and select the site that you wish to be visible, then toggle between *All* and *Named Only*. Repeat for another site. Alternatively, the user might prefer the use of zones for such a task, where the sites are fewer and are always geographically ordered.

[15] The map interface also facilitates locating the non-named region of peak surge in a graphical way.

therefore predicted to exceed HAT[16] for about 1.9 h. A similar period is indicated for *Belgian_Gardens*.




| | Deterministic | m AHD | >HAT (m) | Earliest UTC | Latest UTC | Dur. (h) | >HAT (%) | Earliest UTC | Latest UTC | Dur. (h) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Townsville | 3.4 | 1.1 | 23-Dec-1971 23:29 | | | 100.0 | 23-Dec-1971 22:28 | 24-Dec-1971 00:23 | 1.9 |
| 2 | Belgian_Gardens | 3.4 | 1.1 | 23-Dec-1971 23:29 | | | 100.0 | 23-Dec-1971 22:32 | 24-Dec-1971 00:25 | 1.9 |
| 3 | Ross_River | 3.4 | 1.1 | 23-Dec-1971 23:39 | | | 100.0 | 23-Dec-1971 22:46 | 24-Dec-1971 00:29 | 1.7 |
| 4 | Strand_Park | 3.3 | 1.1 | 23-Dec-1971 23:29 | | | 100.0 | 23-Dec-1971 22:29 | 24-Dec-1971 00:17 | 1.8 |
| 5 | Rowes_Bay | 3.3 | 1.0 | 23-Dec-1971 23:09 | | | 100.0 | 23-Dec-1971 22:22 | 24-Dec-1971 00:01 | 1.7 |
| 6 | Kissing_Point | 3.2 | 1.0 | 23-Dec-1971 23:19 | | | 100.0 | 23-Dec-1971 22:31 | 24-Dec-1971 00:12 | 1.7 |
| 7 | Pallarenda | 3.1 | 0.9 | 23-Dec-1971 23:09 | | | 100.0 | 23-Dec-1971 22:17 | 23-Dec-1971 23:50 | 1.6 |
| 8 | Marine_Precinct | 3.1 | 0.8 | 23-Dec-1971 23:29 | | | 100.0 | 23-Dec-1971 22:46 | 24-Dec-1971 00:08 | 1.4 |
| 9 | Bushland_Beach | 2.9 | 0.7 | 24-Dec-1971 00:39 | | | 100.0 | 24-Dec-1971 00:10 | 24-Dec-1971 01:24 | 1.2 |
| 10 | Townsville_Breakwater | 2.8 | 0.6 | 23-Dec-1971 23:19 | | | 100.0 | 23-Dec-1971 22:46 | 23-Dec-1971 23:52 | 1.1 |
| 11 | Townsville_STG | 2.8 | 0.6 | 23-Dec-1971 23:19 | | | 100.0 | 23-Dec-1971 22:50 | 23-Dec-1971 23:52 | 1.0 |
| 12 | Townsville_Harbour | 2.8 | 0.6 | 23-Dec-1971 23:19 | | | 100.0 | 23-Dec-1971 22:50 | 23-Dec-1971 23:52 | 1.0 |
| 13 | Shelly_Beach | 2.8 | 0.5 | 24-Dec-1971 00:09 | | | 100.0 | 23-Dec-1971 23:38 | 24-Dec-1971 00:54 | 1.3 |
| 14 | Saunders_Beach | 2.6 | 0.4 | 24-Dec-1971 00:39 | | | 100.0 | 24-Dec-1971 00:20 | 24-Dec-1971 01:17 | 0.9 |
| 15 | Bohle_River | 2.6 | 0.4 | 24-Dec-1971 00:39 | | | 100.0 | 24-Dec-1971 00:21 | 24-Dec-1971 01:13 | 0.9 |

By scrolling down the table, the first site indicated with a **green** >HAT value will be where the predicted peak level is just less than the local HAT value. The columns on the RHS indicating persistence above HAT are then omitted, indicating no inundation above HAT is predicted[17].

Selecting other available tabs will reveal the equivalent information about the absolute elevation of:

- *Surge plus Tide (m AHD)*

or the magnitude-only water level components:

- *Surge (m)*
- *Wave Setup (m)*

plus:

- *Significant Wave Height (Hs m)* and associated Peak Spectral Wave Period (*Tp s*).

The water level component magnitudes and the peak wave details are provided[18] to assist in interpretation of the dynamics of the event and are clearly labelled to avoid confusion with *absolute* AHD levels.

[16] HAT is used because it is the absolute level that the sea would not normally be expected to exceed and hence, above that level, residents would likely become aware of a potential inundation event and possibly become alarmed. The actual value of the HAT level is not emphasised here because it is the level of the storm tide itself relative to any local ground level that is the critical flooding metric. However, the potential "depth" relative to HAT is reported to provide an indication of the worst possible inundation at that locality on otherwise normally dry land. The actual HAT values are available in the *Astronomical Tide* tab or when choosing a time history graph.

[17] Note that wave runup may still reach higher levels but only in an intermittent manner. The height of wave runup is very dependent on the beach face slope and other parameters, but may exceed a further one or two metres in some exposed situations.

The final tab:

- *Astronomical Tide (m AHD)*

shows the highest High Water prediction and its associated time within the model prediction time window at each site. All the site-specific HAT estimates are also available in that tab.

The *Time* reference can also be changed to reflect local time at all sites, rather than UTC, which is useful for comparing with published tide table times[19] or for emergency communication.

Across the top of the browser window are further options for viewing the modelled results, either as *Graphs* (time or space) or as *Print* versions of the graphical view or as a summary report. A BoM-Qld *Totem* graphical output is also available for any site, which can then be exported for dissemination.

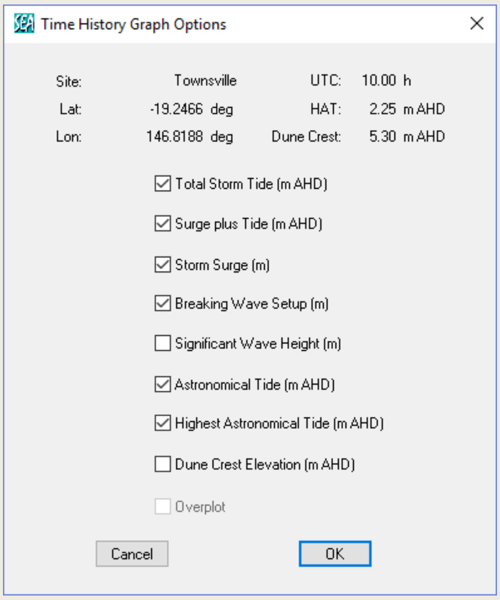
### 5.5.2 The Dependent Deterministic View

Before leaving the browser view, it can be noted that the *Dependent* checkbox is not set by default. If the user chooses this option, then the heading will change to *Deterministic Storm Tide Levels (At time of the peak Total Storm Tide)* and the values in the tabs will show the values of each water level component *dependent* on the time of the total water level.

The leftmost column heading also changes to "@ Peak deterministic" for clarity. In this case the total water level tab remains unchanged, but the other tabs will reflect the values at the time of the peak total water level and there will be "Latest UTC" and "Dur" values in cases where those values at the time of the peak total water level might be less than the overall peak value. In this mode, the displayed water level components are additive because they all apply at the time of the peak predicted total water level.

## *5.6 Time Series Graph*

To illustrate the graphical options at this point, the mouse is used to select the tabular row containing *Townsville* and the *Graph/Time* button is selected, leading to the following option selection window:

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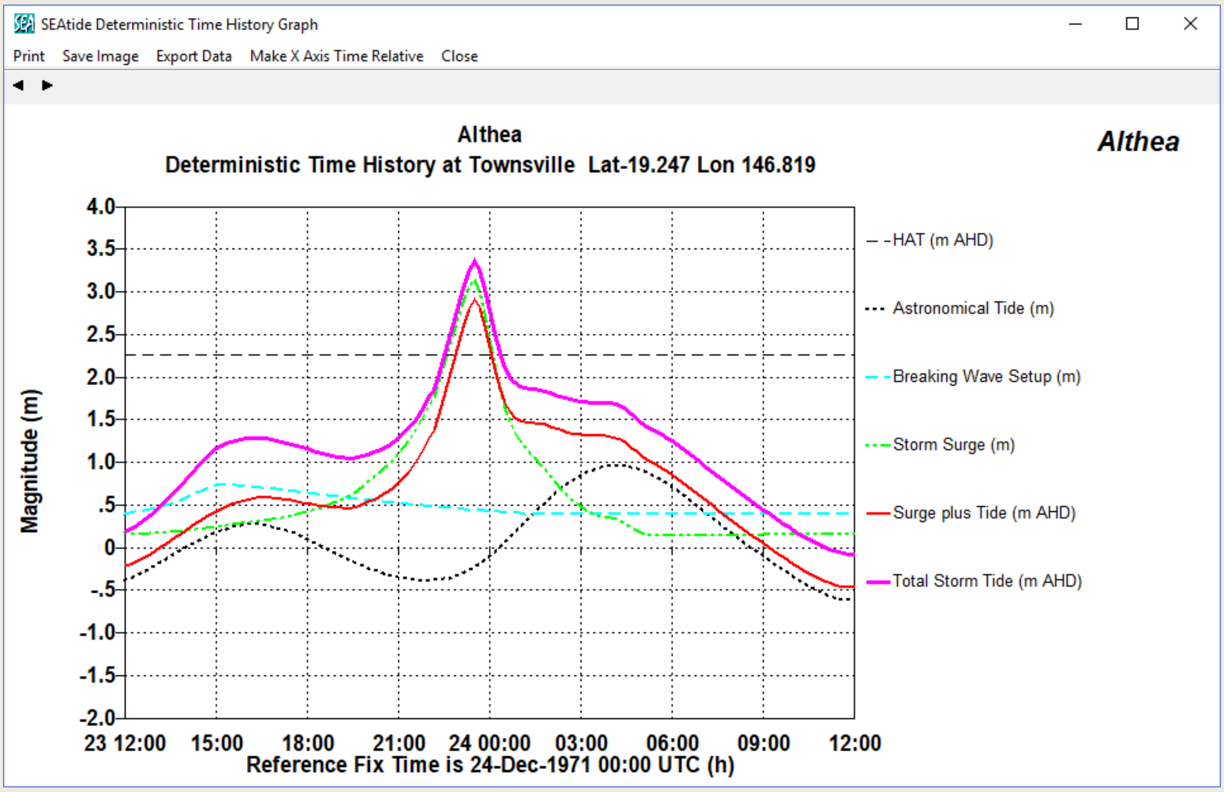
[18] In some protected sites modelled wave data may not be specifically available so a default value of Hs=0.5 m and Tp = 5 s may be substituted to indicate a nominal level of wave activity.

[19] SEAtide may not exactly agree with published heights or times of high or low tide for specific standard ports, however the differences will normally be unimportant in terms of the timing of the actual impact of the storm tide.

This window confirms that the site selected is *Townsville* and provides some specific details of this site, such as its *lat/lon* position, *time zone* relative to UTC, the HAT level and the local *dune crest level*. This latter level is the height at which the model will limit the action of *breaking wave setup* as an additional steady water level component on top of the *surge plus tide* level. This is on the basis that the wave setup attenuate as the sea begins to flood over the land and any local superelevation will tend to dissipate in the form of currents. This dune crest is only approximate and should not be relied upon for estimating the depth of flooding, which can only be obtained by comparing the total storm level (m AHD) to an accurate ground level map.

This window then allows the user to select those water level components that are desired on the time history graph. An *overplot* option becomes additionally available if there is an active external model data prediction available or if there is real-time data available.

On completion of this window the time series graph is displayed as shown below. The time axis view is always fixed at ± 12 h relative to the *reference fix*. By default, the time axis is labelled in absolute time, but a menu button is available to toggle between absolute and relative-to-landfall time labelling.




The vertical axis is generically labelled as *magnitude* and the legend must be consulted to identify the datum label of the various components, their line colour and line style. In this case, the variation in the predicted astronomical tide (black dashed) is clearly indicated, contrasted by the fixed elevation of HAT.

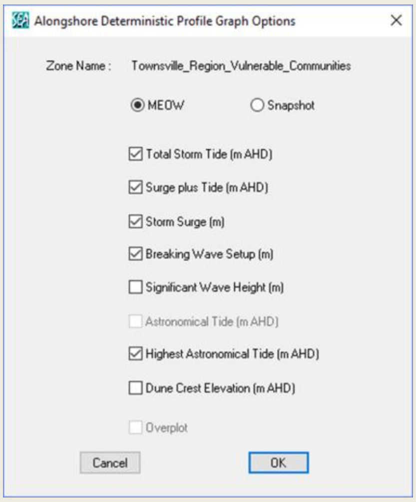
The water level components can then be seen to variously combine with the predicted tide level to produce the *total storm tide* (heavy purple line) in m AHD. The green *surge plus tide* line is also provided to show the effect without wave setup (blue) because of the aforementioned interaction with *dune crest* (although not evident in this case).

The graph window menu options allow the user to *print*, *save image* or even *export data* that has been used to create the graph. Additionally, the toolbar arrows in the top LHS can be used to select immediately adjacent coastal sites within its *zone* and thus explore a specific area prior to returning to the browser *view* window.

Multiple time series graph windows can also be created from the browser view for other sites and arranged for viewing comparisons.

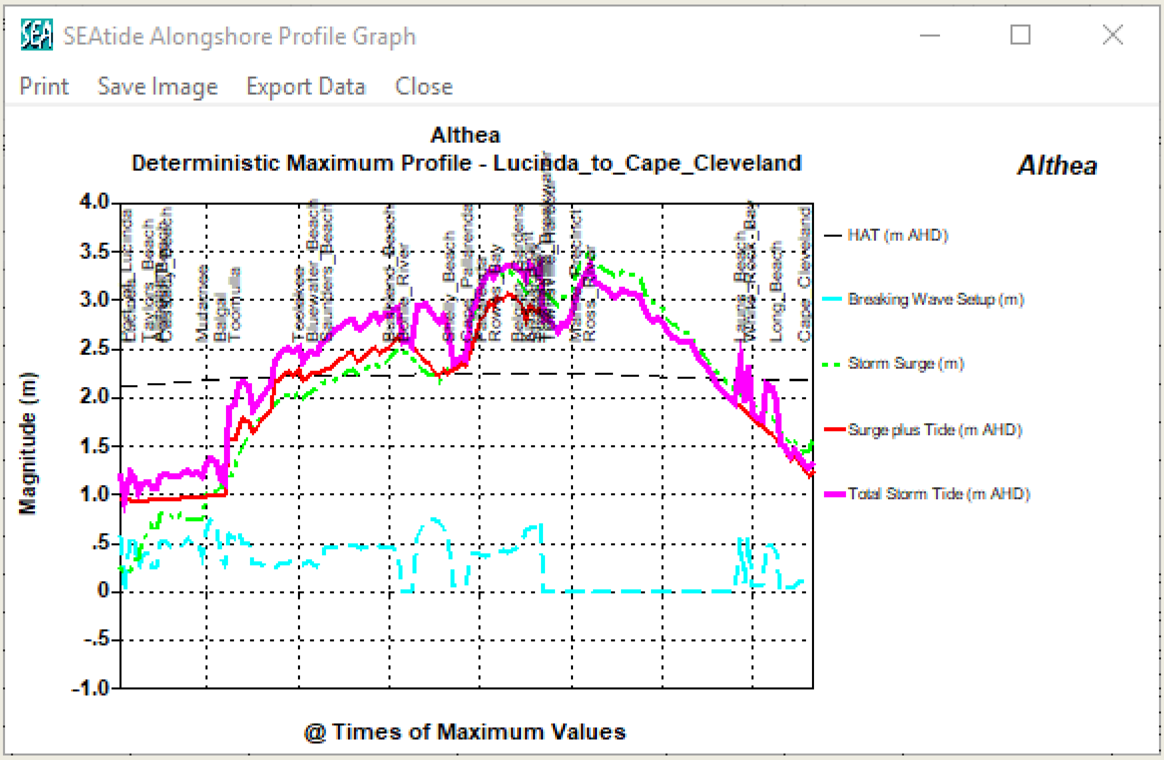
## 5.7 Spatial Profile Graph

After returning to the browser view, we then can activate the *Sort by Zone* option, choose the *Lucinda_to_Cape_Cleveland* zone for interest, which will arrange the sites in a geographic order from north to south, and then select the *Graph/Space* button. This invokes a window similar to the time series graph option:




In this case there is the option of showing either a *MEOW* profile, which is irrespective of time, or a *snapshot profile* that will show the along-coast storm tide profile at particular times and allow moving between times. Again, an *overplot* option can be active.

The default *MEOW* option produces:

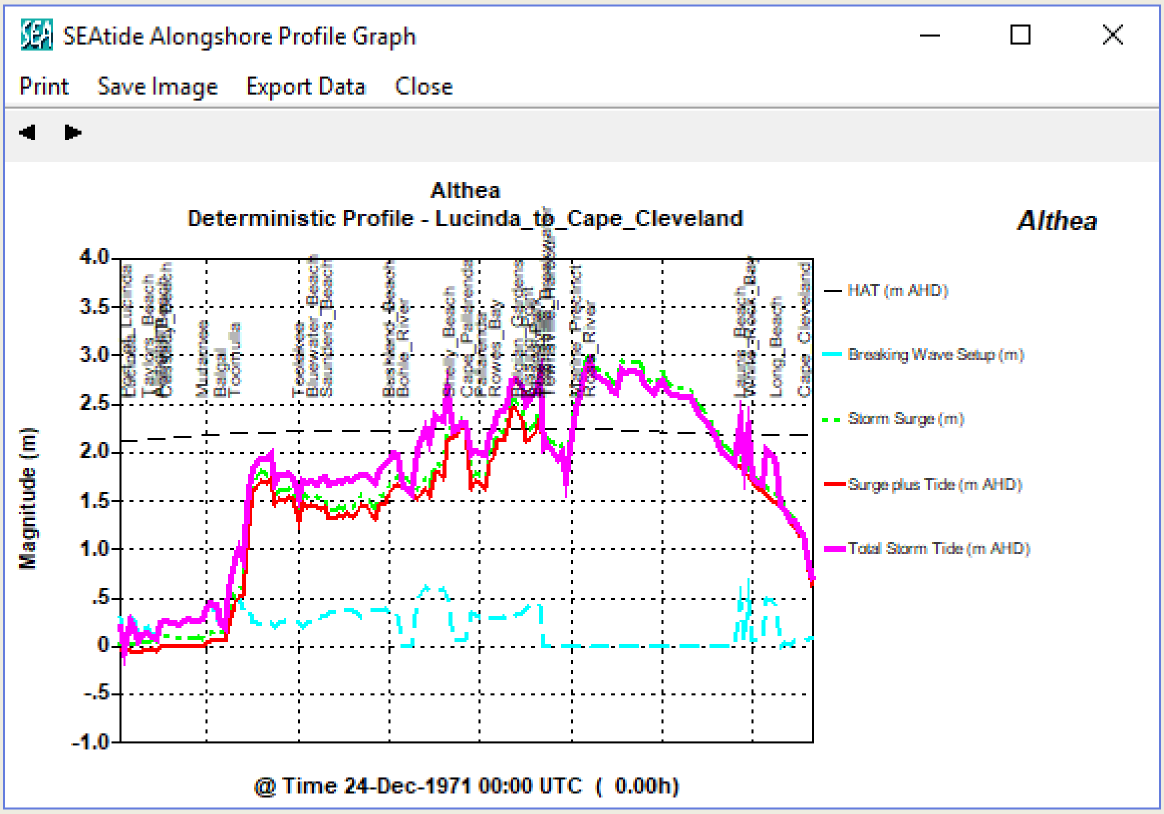


In this case the horizontal axis is simply a site count along the declared along-coast profile from north to south and the sites possessing names are labelled accordingly in the body of the graph. Details of the sites in this profile *zone* can be examined in detail from the browser window if necessary.

This output shows the variability predicted in the *wave setup* component (blue), which is reflected in the variability of the *total storm tide level* (purple). This is a function of both local nearshore *significant wave height* and *dune crest* and *beach slope* variability. HAT can also be seen to vary slightly along the coast (black).

The region of peak *storm surge* impact (green) can be seen to be between *Cape_Pallarenda* and *Townsville_Breakwater*, where Magnetic Island forms a constriction near the coast.

After returning to the browser *view* window and choosing the *snapshot profile* option, the following graph is produced:




This is similar to the previous, but the horizontal axis now contains the timestamp, which by default is the *reference fix* time, but in this case the profile development can be explored over time by using the arrow toolbar buttons to adjust the timestamp either backward or forward in time. This view shows the alongshore profile 1 hr before the *reference fix* time.

## 5.8 Browser View Print Options

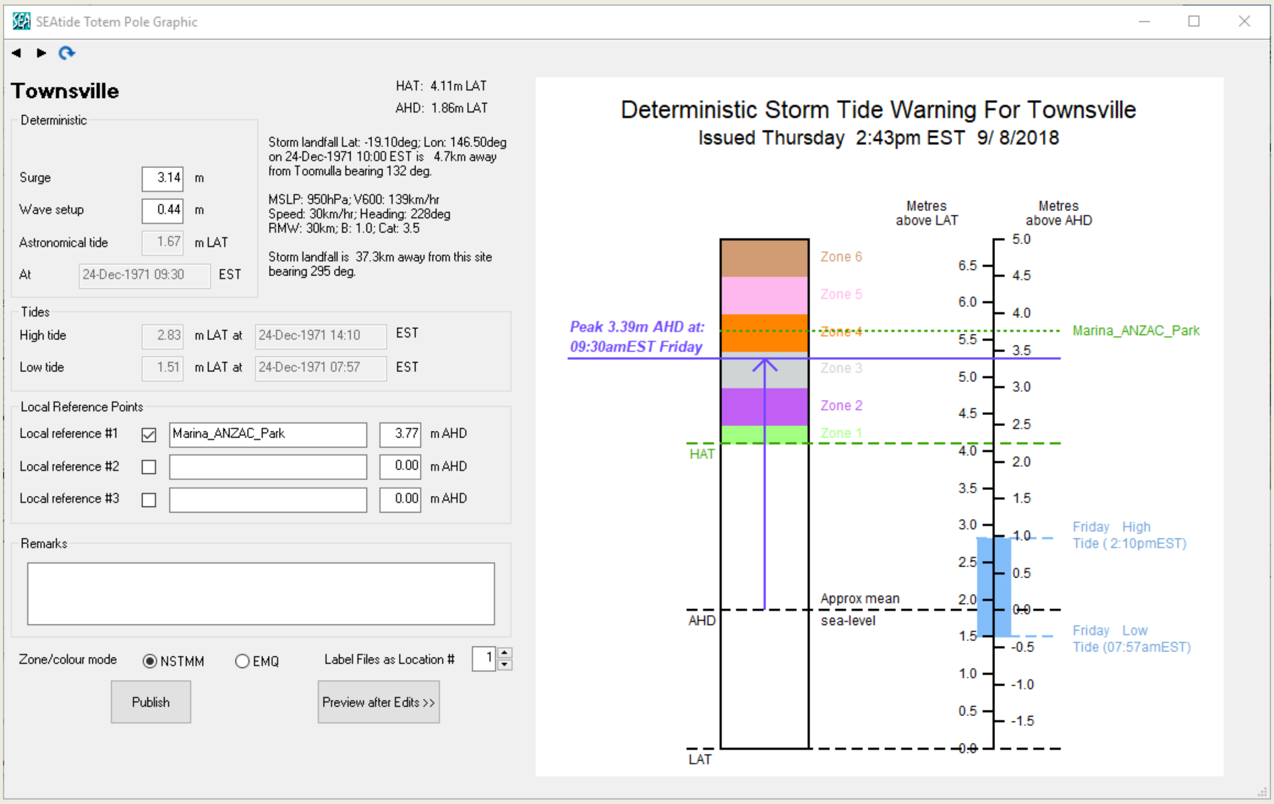
Returning to the *browser view*, the print options available are to either produce a hardcopy *view* of the displayed tabbed window predictions or to produce a *summary report* file. The former option is useful for quickly obtaining a raw hardcopy of the visible tabbed field data only, although it is devoid of headings and other details.

In contrast, the summary report produces a detailed and documented text file. The user will first be prompted to supply a filename and destination directory for the summary report and then offered the option of printing the file on one of the available networked printers or PDF etc.

It is intended that the summary report provide a documented record of a final forecast scenario. For this reason it is in the form of a plain text file. However, to avoid any confusion, the *summary report* includes only the *total storm tide* level for the deterministic case and, if available, the 50%, 90% and 0% probability of exceedance cases. If output for the other parameters (e.g. *Surge magnitude*) is required, then they must be output using the view *option* or else via the various Export options.

## 5.9 The BoM Totem Graphical Output

This graphic is based on the Qld-BoM operational specification as at 2012 and is selected from the *Totem View* button. The resulting deterministic result for *Townsville* is shown below.




This graphic provides a summary of the total storm tide prediction in the form of a "totem" or "tide pole" for a specific location. All displayed storm tide times are in the site local time zone and rounded to the nearest 5 minutes. It indicates graphically the peak of the prediction in terms of both the elevation in AHD and also relative to the LAT (tidal datum) as used in published tide tables. HAT and AHD levels at this site relative to the LAT datum are also indicated.

The times of the predicted high and low tides nearest to the time of the estimated peak total storm tide level are also indicated both graphically and in the table.

The site-specific HAT and AHD levels are also shown graphically and the NSTMM (DES 2002) standard inundation colours are used to colour the totem as a default. Alternatively, location-specific EMQ evacuation zone colours[20] may be specified instead. This requires use of the *Preview after Edits >>* button if changing colour schemes.

Details of the storm landfall location, time and other storm parameters are displayed for reference. This relates the landfall point to the closest named model site and also the distance and bearing from the present site to the landfall site.

The data regarding the predicted *Surge* and *Wave Setup* values may also be edited[21] to suit operational needs and the *Preview after Edits >>* button will update the graphic accordingly.

The graphic also includes specific “local reference” site names and elevations that may be of critical interest but that are not actual modelled sites. An example might be the name of a bridge or causeway that has a specific elevation, and which is important for evacuation planning, or the location and elevation of a safety refuge and the like. These “local reference” details can be specified in the model SAS file for each region (refer Appendix A). These can be added or excluded to the final published graphic product. A *Remarks* field that can contain any relevant text is also available for publishing.

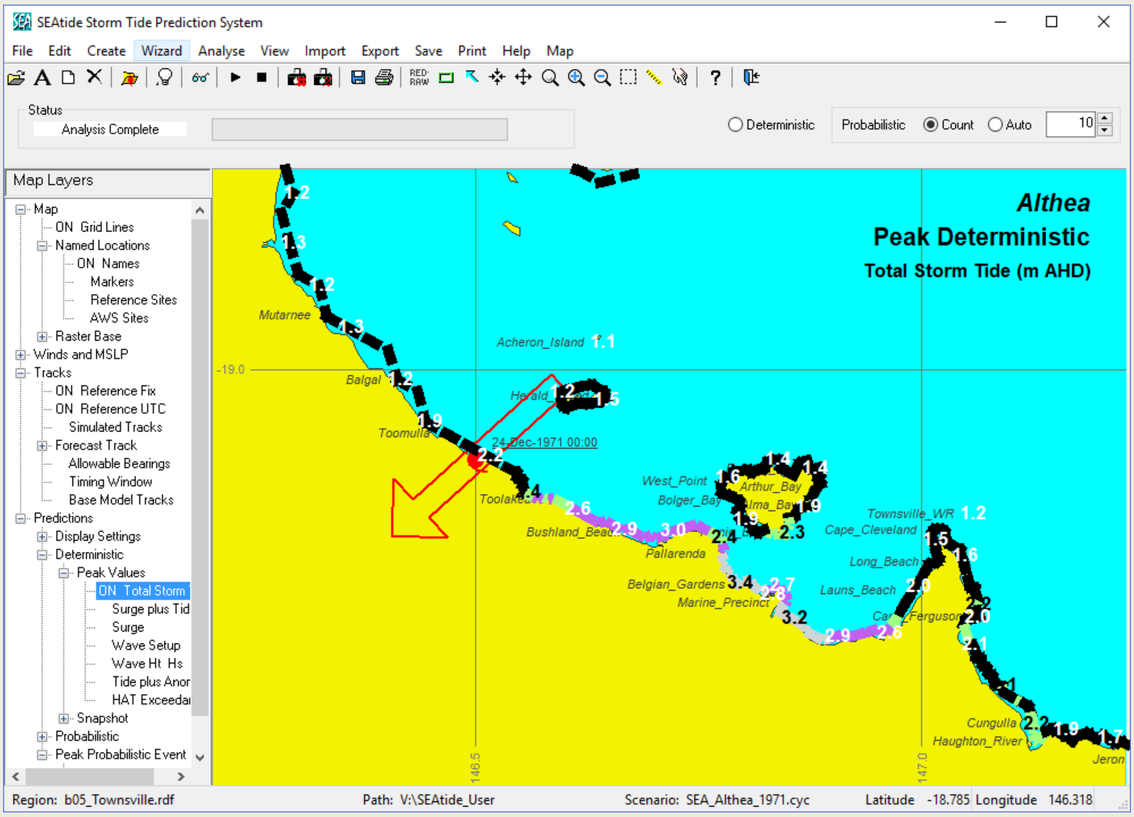
When satisfied with the final graphic and all its information the user can *Publish* it, whereby the graphic is exported together with an HTML text wrapper that can be loaded directly onto a web page for warning dissemination. The *Label Files as Location #* feature is used to brand the published output file. A CSV file log of any manual edits to the original predictions is maintained as an audit trail. These exports are all written to the specified *REP_Filepath* in the INI file.

The more complex and detailed probabilistic version of this graphic is illustrated in Section 5.11.

[20] This system is not yet universal so the user must beware of possible regional differences if relying on this display.
[21] An audit log is maintained of any changes to these values.

## 5.10 The Hazard Map and Mapping Tools

The user can explore the *hazard map* in detail by utilising the various mapping tools, such as being able to quickly zoom in to an area of interest, e.g. using the rectangle zoom tool:




The available mapping tools via the toolbar buttons are:


Clears the current view, redraws and restores the default tool pointer.


Restores the full map view, depending on whether in fine or coarse map context.


Select an object (functionality varies) using left click.


Centre the map view at the selected cursor position using left click.


Drag/pan the map from the cursor starting to the ending position using left click / drag / release.


Push-pull zoom (in-out) and re-centre map at the starting position using left click / drag / release.


Left click to zoom in by a fixed percentage of the current viewport.


Left click to zoom out by a fixed percentage of the current viewport.


Rectangle zoom, left click on corner and hold / drag-select to enlarge any region.


Measure distance and bearing left click at start point/drag to end point/release.


Left click to select AWS sites (if hazard map layer is active and licence permits)

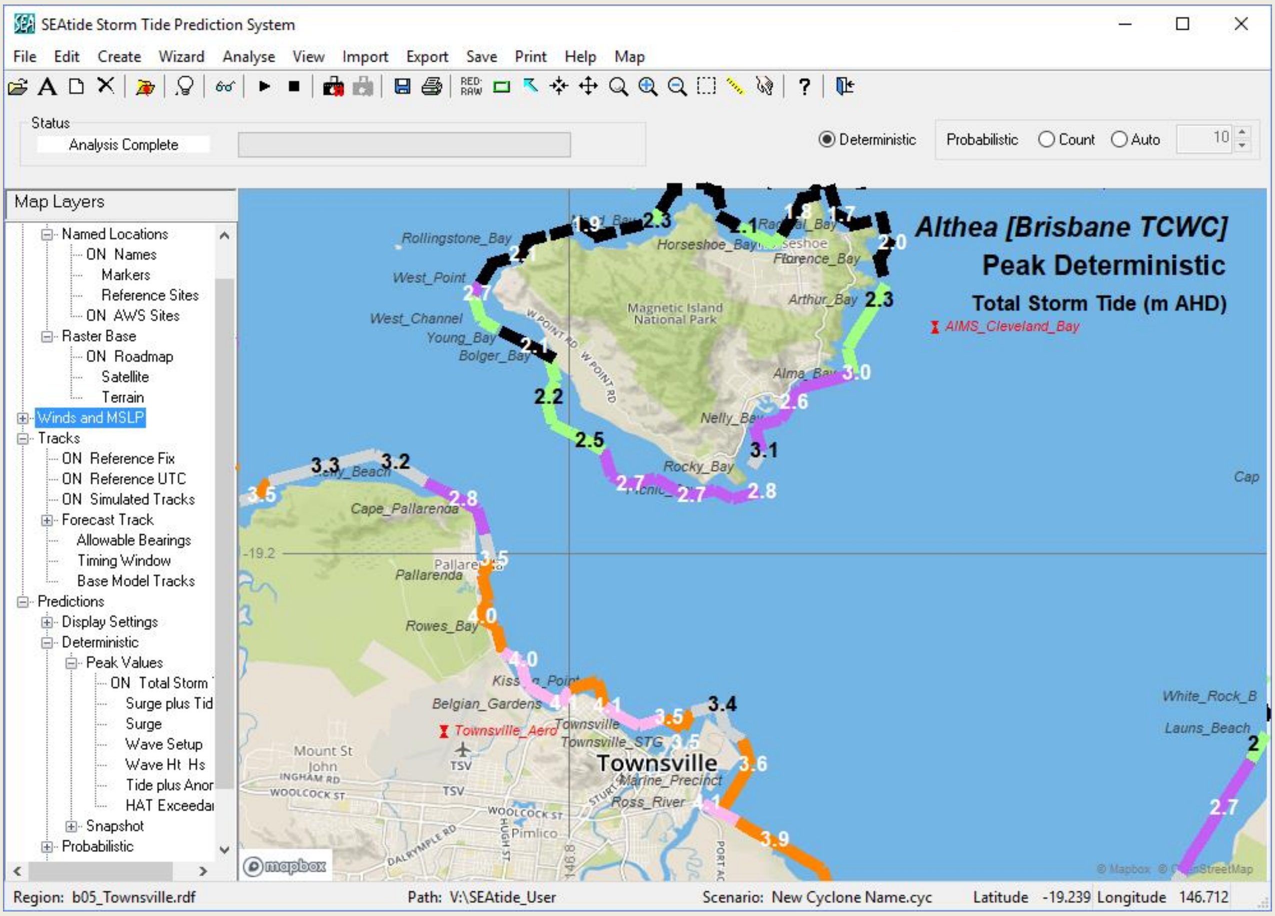
The correspondence between toolbar buttons and menu items on the hazard map window is:

| | **Button** | **Menu** | **Sub-Menu** |
|---|---|---|---|
| | Open Scenario | File | Open Storm Scenario File |
| | | File | Save Summary Report |
| | | File | Print Summary Report |
| | Edit Scenario | Edit | Edit Storm Scenario |
| | Close Scenario | Edit | Close Storm Scenario |
| | Create a New Storm Scenario | Create | New Storm Scenario |
| | Import a Forecast Storm Track File | Import | Forecast Track File |
| | | Import | Modelled Data |
| | Wizard | Wizard | Open \| Create \| Import \| Maps |
| | Start Analysis | Analyse | Start |
| | Stop Analysis | Analyse | End |
| | Browse Deterministic Results | View | Deterministic Storm Tide |
| | Browse Probabilistic Results | View | Probabilistic Storm Tide |
| | | View | Imported Storm Tide |
| | | View | Parameter Limits |
| | View Maps | View | Maps Only |
| | Save | Save | Summary Prediction Report |
| | | | Hazard Map file \| Clipboard |
| | Print | Print | Summary Prediction Report |
| | | Print | Hazard Map |
| | | Export | Summary % CDF Statistics |
| | | Export | Site Specific Persistence %CDFs |
| | | Export | External Model File |
| | | Export | Model Details |
| | | Export | Wind and MSLP Fields |
| | | Export | GIS Profile File |
| | | Export | BoM Summary File |
| | | Map | View Only |
| | | Map | Origin and Scale |
| | Help | Help | Contents |
| | | Help | User Guide |
| | | Help | Send Email |
| | | Help | Error Log |
| | | Help | Third Party Data |
| | | Help | About |
| | Exit | File | Exit |

### 5.10.1 Raster Map Backgrounds

These are selectable under the *Raster Base* layer control, which offers *Roadmap*, *Satellite* or *Terrain* style views as provided through Mapbox[22].

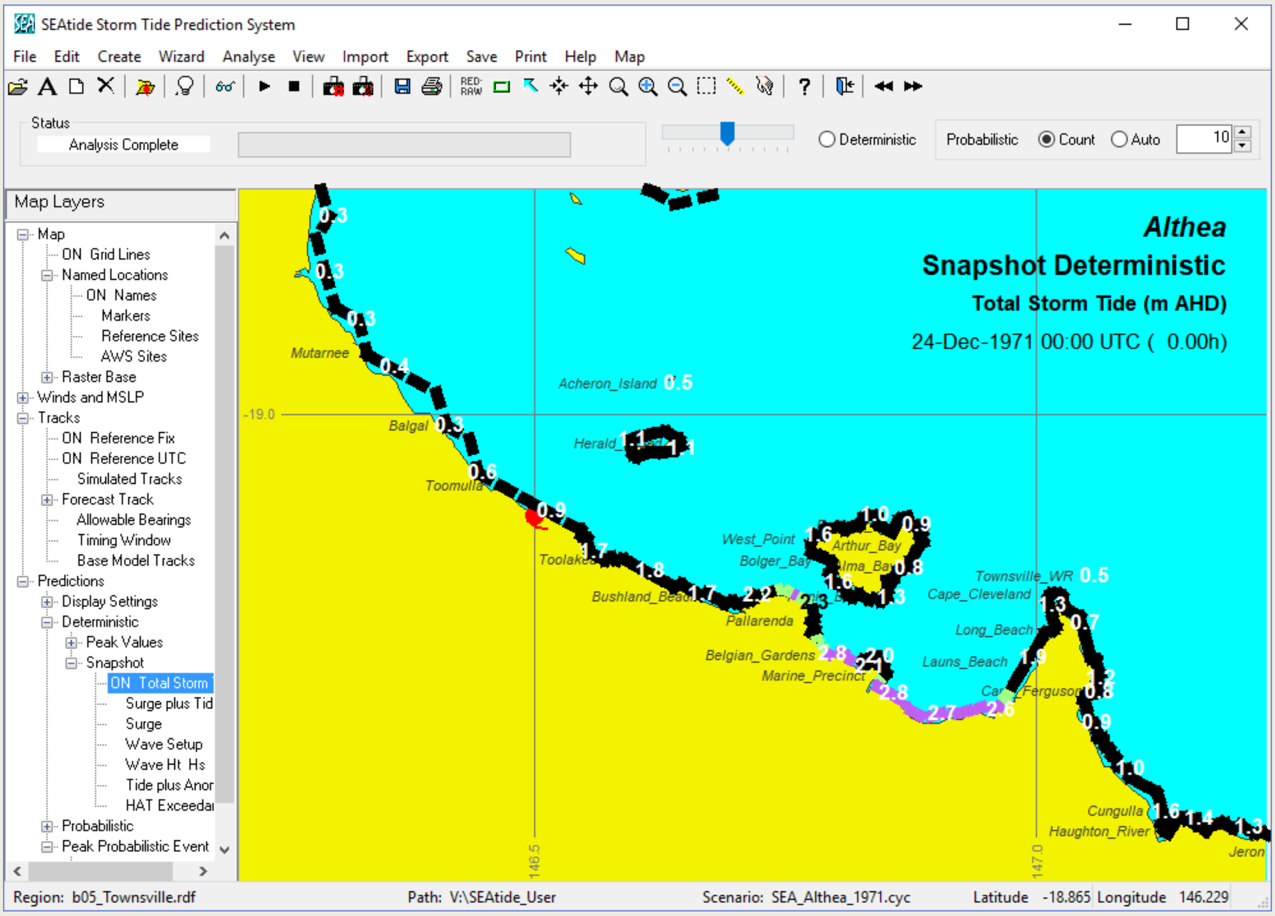
In the following *Roadmap* example, the zoom has been increased sufficiently to identify the major road network in and around Townsville and on Magnetic Island. In this view the *AWS Sites* layer has also been activated to show the location of wind measuring sites.




### 5.10.2 Snapshot Mapping Mode

In addition to the MEOW hazard map mode, the *deterministic* case can also provide a *snapshot* mode that allows the user to step through the simulation in time. This mode is selected by expanding the *Snapshot* layer and double-clicking, for example, on the *Total Storm Tide* option. When that is done, the previous *Peak Values* layer collapses and the new map shows:

[22] https:\\mapbox.com\maps *Help* | *Third Party Data* provides further data attribution links.




In this view the user can adjust the snapshot timestamp by either using the slider that has appeared below the toolbar near the status pane, or by using the added toolbar arrow buttons[23]. At all times the location of the storm centre is shown (red) and the timestamp is updated, together with the time in hours relative to the *reference fix* time.

## 5.11 Probabilistic Scenarios

This is initiated by firstly selecting the *probabilistic* option located above the hazard map pane on the RHS. This makes the *storm count* spinner active, so the user can decide how many scenarios are required to adequately sample the uncertainty. This can be either a trial and error approach using a fixed *Count*, with the smoothness of the final probability graphs (refer later) being an indicator of how many storms are needed. A default count of 100 is offered by the model. Alternatively, the *Auto* option will keep simulating until at least the indicated number of consecutive counts does not increase the total storm level at any of the sites.

After deciding on the *storm count* (we choose the minimum possible *Count* of 10 here only for illustration), the *Analyse* button or menu item is selected and the model commences the specified number of scenario simulations. The first scenario modelled is always the *deterministic* scenario and as the extra storms are generated by random number sampling (Monte Carlo) techniques they are progressively shown on the hazard map, thus providing a visual feedback on how the specified uncertainty is affecting the tracks. This also shows how each track emanates from a common base position that has been extended back in time and space from the *reference fix*, as detailed in Appendix C.

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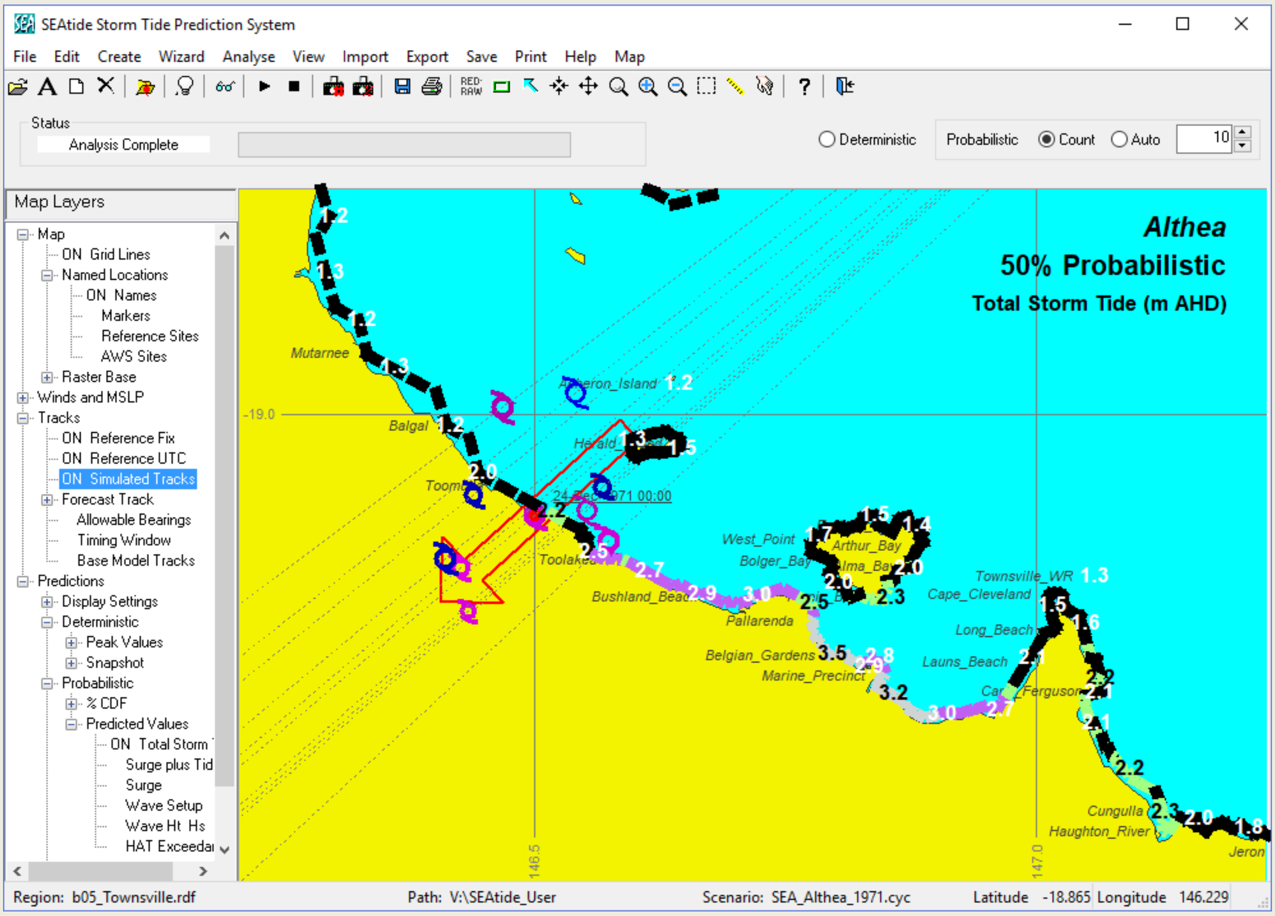
[23] In addition, after selecting the slide control with the mouse, the UpArrow and DownArrow keyboard controls can be used to step forwards or backwards in time and the PageUp and PageDown keyboard controls move in larger steps.

The colours of the simulated storm symbols vary as a function of their intensity relative to the reference fix, which is always light-magenta. Weaker storms will tend towards blues while stronger storms will tend towards darker magenta, greys and blacks.




The increasing size of each symbol reflects *RMW* changes and the increasing line width reflects *B* value changes. Looking at the simulated fix centres, which all have the same *reference time*, it can be seen that there are storms both faster (already crossed the coast) and slower (still offshore) than the deterministic scenario (refer later for more details on the uncertainty parameters used in this instance).

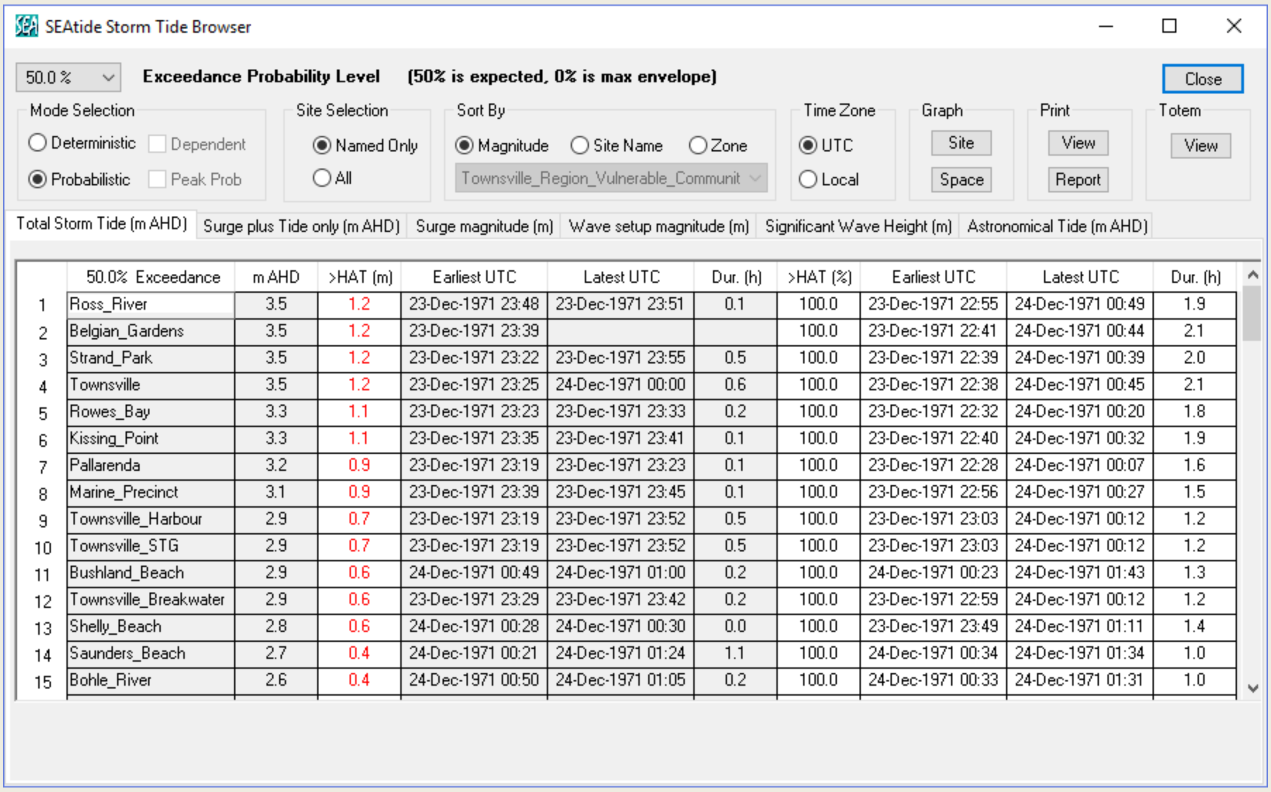
By default, the *deterministic* hazard map is always shown after any analysis is completed but the map layer control is now expanded to reveal separate options for selecting either the 50% 10% or 0% exceedance level and for selecting the water level component to be mapped. In the image above, the user has changed the hazard map view to be the 50% exceedance *total storm tide* prediction by selecting the indicated layer settings.

The *probabilistic* hazard map may then be explored in the same detail as the deterministic, but no *snapshot* mode is available in this context. The map layers can be used to control whether the simulated tracks are displayed or not.

Again, the user is automatically offered the choice of viewing the tabulated output or the  (% camera) button may now be used or *View/Probabilistic* chosen via the menu items. This launches the browser view in a similar mode to that seen earlier for the deterministic case, but now with some additional features.

For example, in the top LHS of the window a drop-down list is available to enable selection of either of the 50%, 60%, 70%, 80%, 90% or 0% exceedance level predictions. For variety, we now also choose to display the Zone *Townsville_Region_Vulnerable_Communities* to limit the number of sites being displayed, and which also lists the sites in geographic sequence.

The model now shows that there is a 50% chance of exceeding 3.5 m AHD at *Belgian_Gardens* for 2.1 h. Also, the *>HAT(%)* column now shows the variability between sites, with the value in that column remaining constant regardless of the chosen level of exceedance being chosen in the % drop down list because it reflects the actual probability of exceeding HAT for the whole 10 scenarios, as shown later on a site graph. Scrolling down to rank 37, for example, it can be seen that *Toomulla* only has an overall 10.6% probability of exceeding HAT.

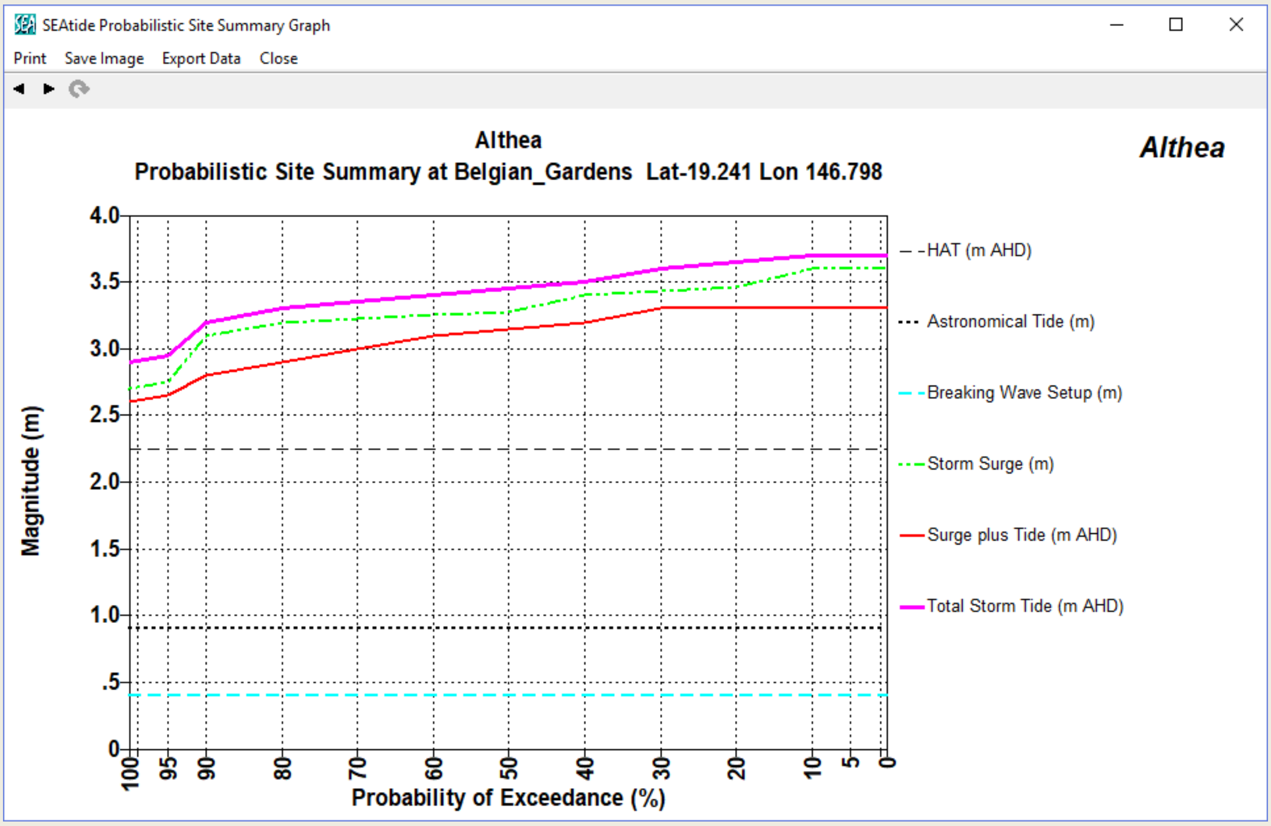



| | 50.0% Exceedance | m AHD | >HAT (m) | Earliest UTC | Latest UTC | Dur. (h) | >HAT (%) | Earliest UTC | Latest UTC | Dur. (h) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Ross_River | 3.5 | 1.2 | 23-Dec-1971 23:48 | 23-Dec-1971 23:51 | 0.1 | 100.0 | 23-Dec-1971 22:55 | 24-Dec-1971 00:49 | 1.9 |
| 2 | Belgian_Gardens | 3.5 | 1.2 | 23-Dec-1971 23:39 | | | 100.0 | 23-Dec-1971 22:41 | 24-Dec-1971 00:44 | 2.1 |
| 3 | Strand_Park | 3.5 | 1.2 | 23-Dec-1971 23:22 | 23-Dec-1971 23:55 | 0.5 | 100.0 | 23-Dec-1971 22:39 | 24-Dec-1971 00:39 | 2.0 |
| 4 | Townsville | 3.5 | 1.2 | 23-Dec-1971 23:25 | 24-Dec-1971 00:00 | 0.6 | 100.0 | 23-Dec-1971 22:38 | 24-Dec-1971 00:45 | 2.1 |
| 5 | Rowes_Bay | 3.3 | 1.1 | 23-Dec-1971 23:23 | 23-Dec-1971 23:33 | 0.2 | 100.0 | 23-Dec-1971 22:32 | 24-Dec-1971 00:20 | 1.8 |
| 6 | Kissing_Point | 3.3 | 1.1 | 23-Dec-1971 23:35 | 23-Dec-1971 23:41 | 0.1 | 100.0 | 23-Dec-1971 22:40 | 24-Dec-1971 00:32 | 1.9 |
| 7 | Pallarenda | 3.2 | 0.9 | 23-Dec-1971 23:19 | 23-Dec-1971 23:23 | 0.1 | 100.0 | 23-Dec-1971 22:28 | 24-Dec-1971 00:07 | 1.6 |
| 8 | Marine_Precinct | 3.1 | 0.9 | 23-Dec-1971 23:39 | 23-Dec-1971 23:45 | 0.1 | 100.0 | 23-Dec-1971 22:56 | 24-Dec-1971 00:27 | 1.5 |
| 9 | Townsville_Harbour | 2.9 | 0.7 | 23-Dec-1971 23:19 | 23-Dec-1971 23:52 | 0.5 | 100.0 | 23-Dec-1971 23:03 | 24-Dec-1971 00:12 | 1.2 |
| 10 | Townsville_STG | 2.9 | 0.7 | 23-Dec-1971 23:19 | 23-Dec-1971 23:52 | 0.5 | 100.0 | 23-Dec-1971 23:03 | 24-Dec-1971 00:12 | 1.2 |
| 11 | Bushland_Beach | 2.9 | 0.6 | 24-Dec-1971 00:49 | 24-Dec-1971 01:00 | 0.2 | 100.0 | 24-Dec-1971 00:23 | 24-Dec-1971 01:43 | 1.3 |
| 12 | Townsville_Breakwater | 2.9 | 0.6 | 23-Dec-1971 23:29 | 23-Dec-1971 23:42 | 0.2 | 100.0 | 23-Dec-1971 22:59 | 24-Dec-1971 00:12 | 1.2 |
| 13 | Shelly_Beach | 2.8 | 0.6 | 24-Dec-1971 00:28 | 24-Dec-1971 00:30 | 0.0 | 100.0 | 23-Dec-1971 23:49 | 24-Dec-1971 01:11 | 1.4 |
| 14 | Saunders_Beach | 2.7 | 0.4 | 24-Dec-1971 00:21 | 24-Dec-1971 01:24 | 1.1 | 100.0 | 24-Dec-1971 00:34 | 24-Dec-1971 01:34 | 1.0 |
| 15 | Bohle_River | 2.6 | 0.4 | 24-Dec-1971 00:50 | 24-Dec-1971 01:05 | 0.2 | 100.0 | 24-Dec-1971 00:33 | 24-Dec-1971 01:31 | 1.0 |

While the *print* options are the same as the *deterministic* case, the *graph* options produce slightly different effects. Firstly *Graph/Site* does not produce a time history but rather a site-specific probability graph (overleaf for *Belgian_Gardens*).

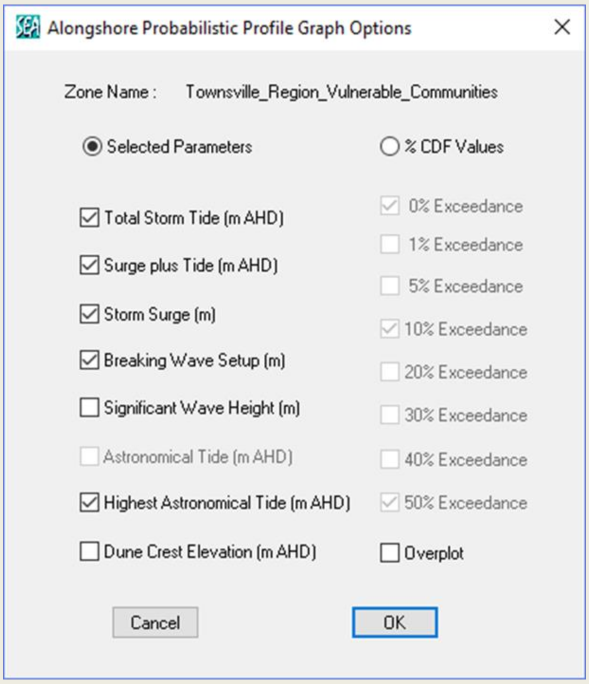
In this case the horizontal axis is probability in %, allowing the user to read off any intermediate probability of exceedance level. In this example there is a 70% chance of the *surge plus tide* components (red) exceeding 3.0 m AHD. HAT is again shown for reference purposes.

In this case it can also be seen that there is no increase in the *total storm tide* level beyond the 10% exceedance level. The arrow buttons can again be used to move between adjacent sites to determine the level of along-coast variability in this *zone*.

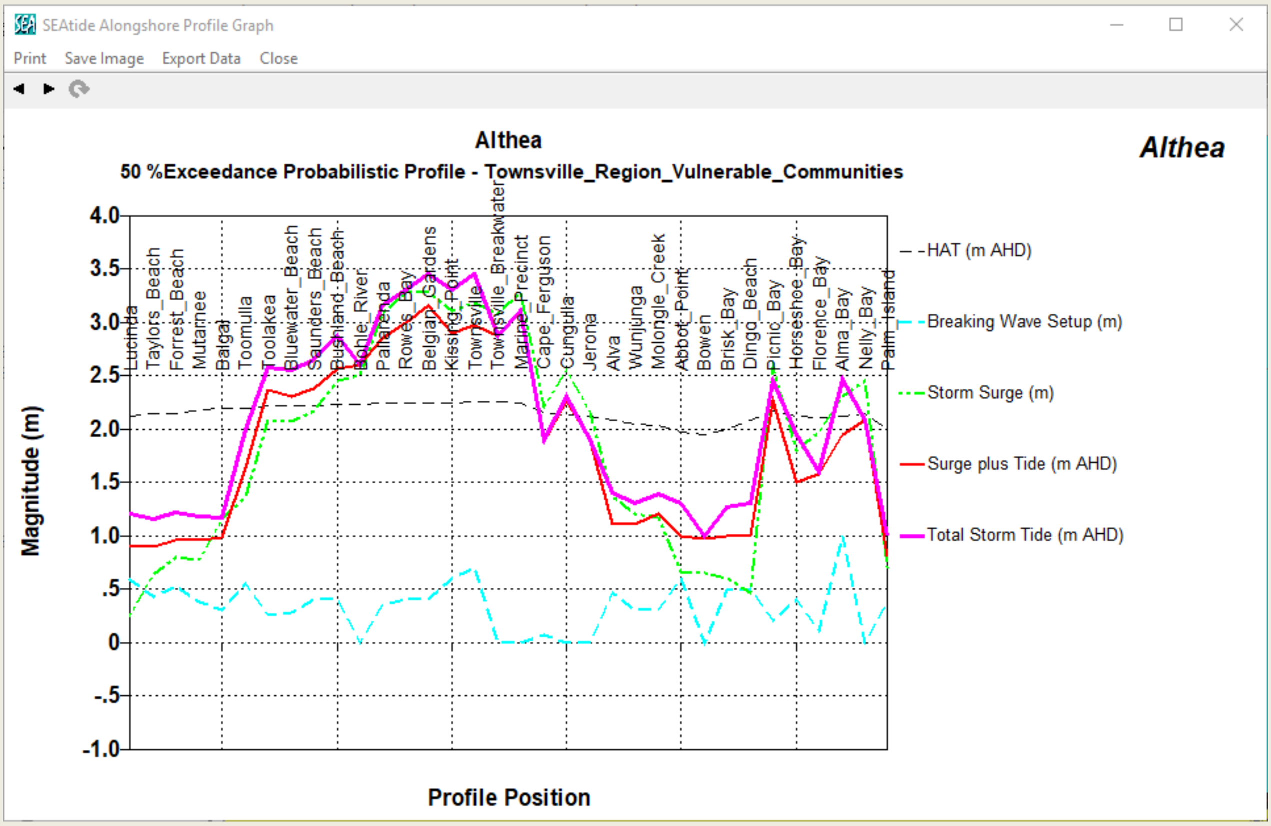



Returning to the view browser and choosing *Graph/Space* brings up a new selection window (below) that offers the choice between a spatial profile graph that shows various components at a common % exceedance level or else shows the % exceedance variation of a particular component.

In this situation, astronomical tide is not a stochastic output and is therefore not selectable but an *overplot* of the *deterministic* result is possible (as symbols). If an external model dataset is also available, the user will be offered the choice as to which result is to be overplotted.

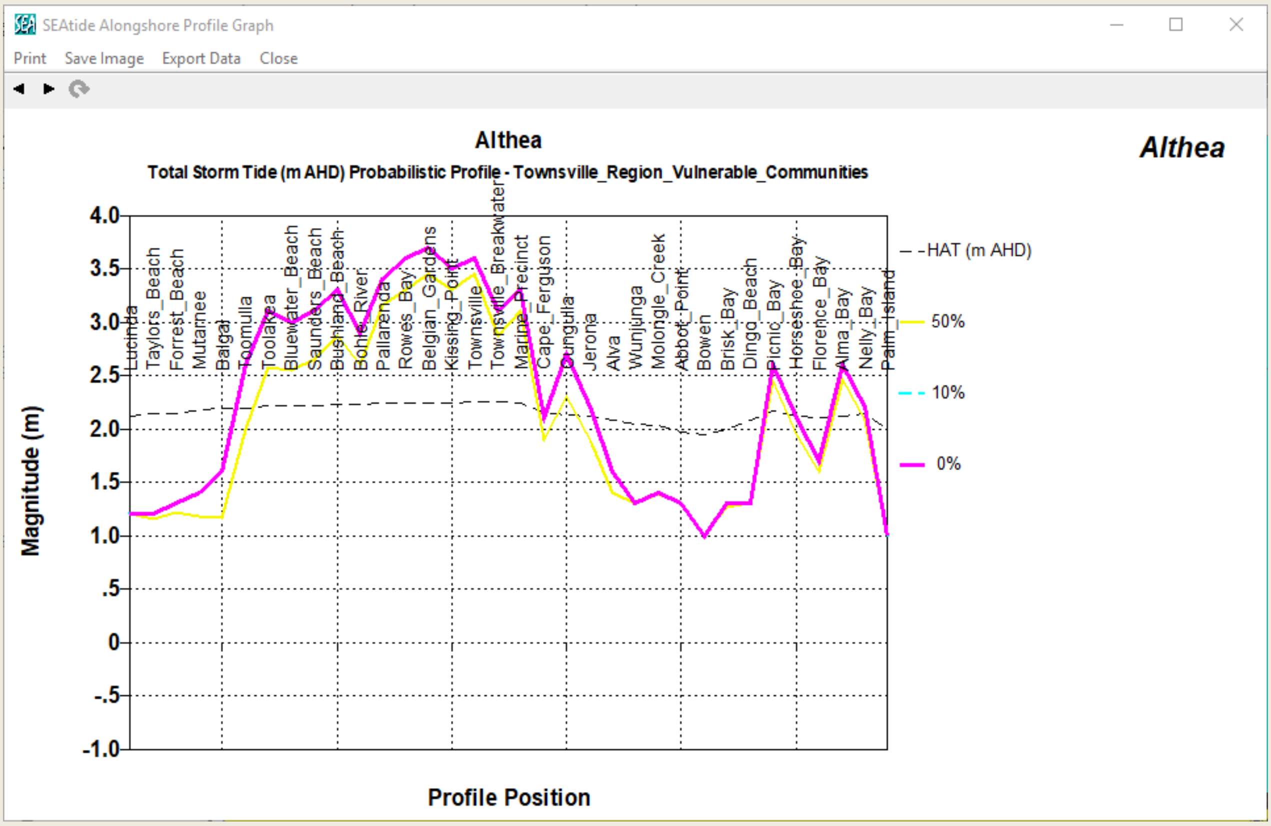


Choosing the *Selected Parameters* option produces:




The window arrow buttons in this case select other % exceedance values (10%, 0% etc).

Meanwhile, choosing the *% CDF Values* option produces:



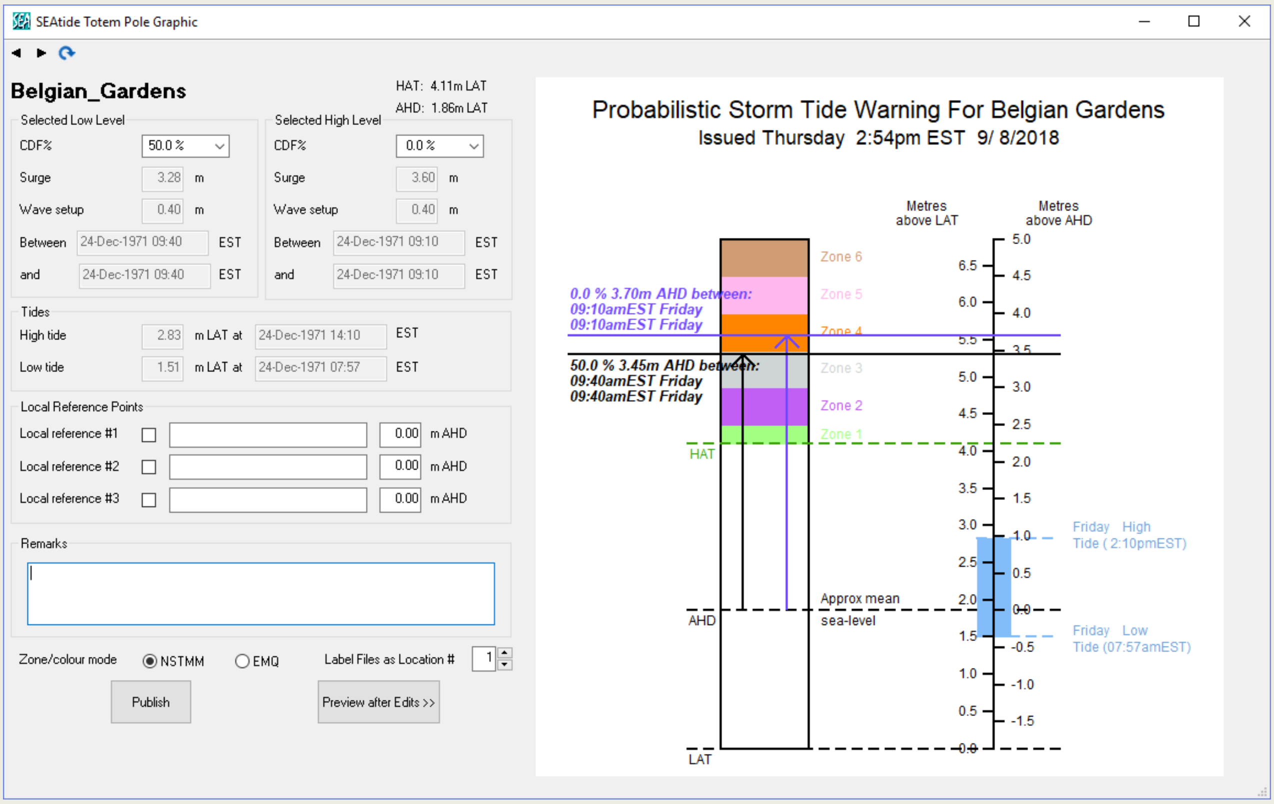

and the window arrow buttons will choose a different water level component to graph.

When the Totem View is selected after a probabilistic simulation it provides for up to two %CDF water level predictions to be displayed and then published.

In addition to the features available in the deterministic case, drop-down menus are available to enable selection of the chosen High %CDF value and a Low %CDF value. By default, these are set to “50%”, which is the “expected result”, and “0%”, which is the “not expected to be exceeded” case.

Editing of these values is not allowable or desirable because they are independent (not additive). For example, the indicated Surge value of 3.28 m is the 50% exceedance magnitude of all the simulated storm scenarios and the Wave Setup of 0.40 m is likewise the 50% exceedance magnitude. When each simulated surge and wave setup magnitude time history is combined with the varying astronomical tide timing (due to different landfall times) they produce a range of Total Water Level values, of which the 50% exceedance value is the value of 3.45 m AHD indicated on the totem graphic.

Furthermore, there is no specific time when the 50% value of exceedance occurs. The totem graphic shows the range of times over which this value is predicted to be exceeded.



### 5.11.1 Peak Probabilistic Scenarios

These results are accessible only by first selecting the 0% exceedance case from the drop-down menu on the storm tide browser and then selecting the *Peak Prob* checkbox that is adjacent to the *Probabilistic* button.

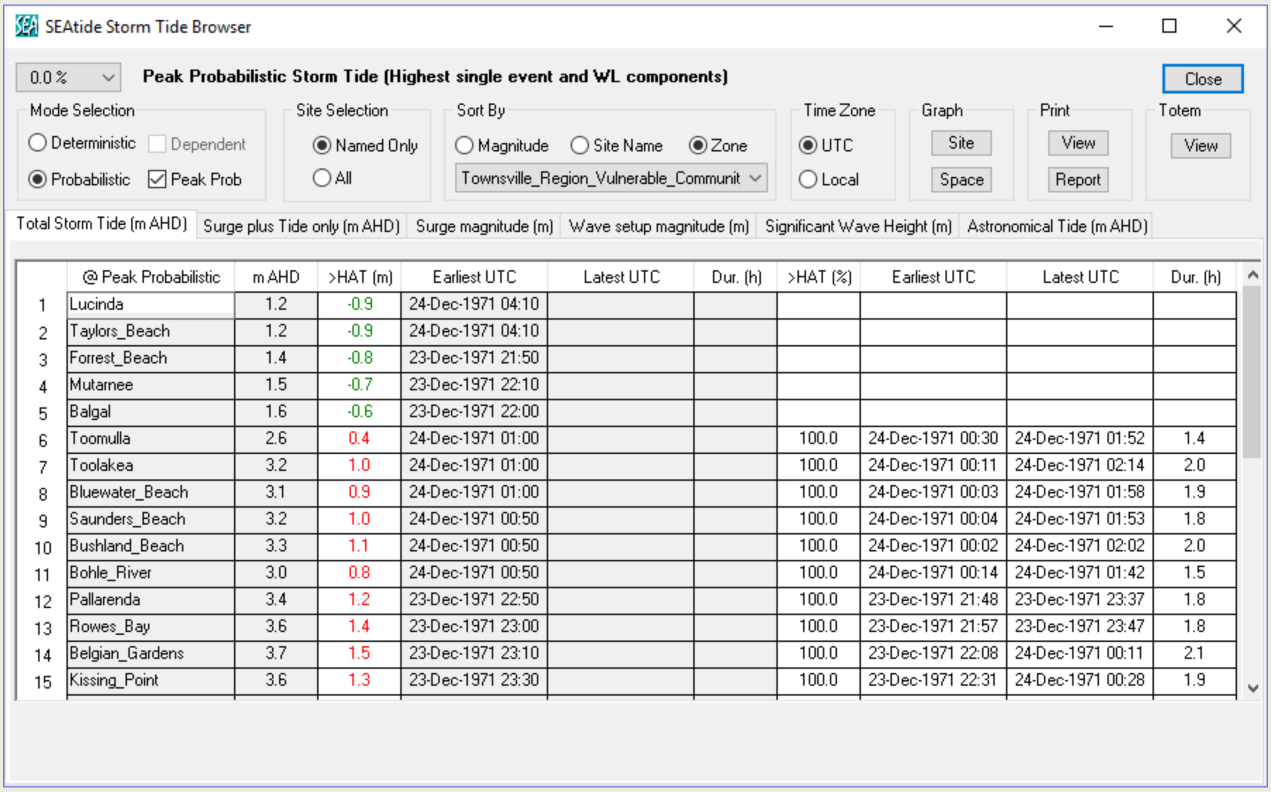
Selecting this checkbox changes the viewer display from a probabilistic context (the water level components across all sites that are not expected to be exceeded) into essentially a deterministic /dependent context (the single highest values expected at each site at the time of the single highest total water level).

In this display mode, the highest total water level event at each site is treated as a single deterministic scenario and the graphical outputs become time-based rather than probability-based.

The browser heading is now *Peak Probabilistic Storm Tide (Highest single event and WL components* and the first column is labelled "@Peak probabilistic". The *Townsville_Region_Vulnerable_Communities* zone is also active, which aligns the sites geographically.

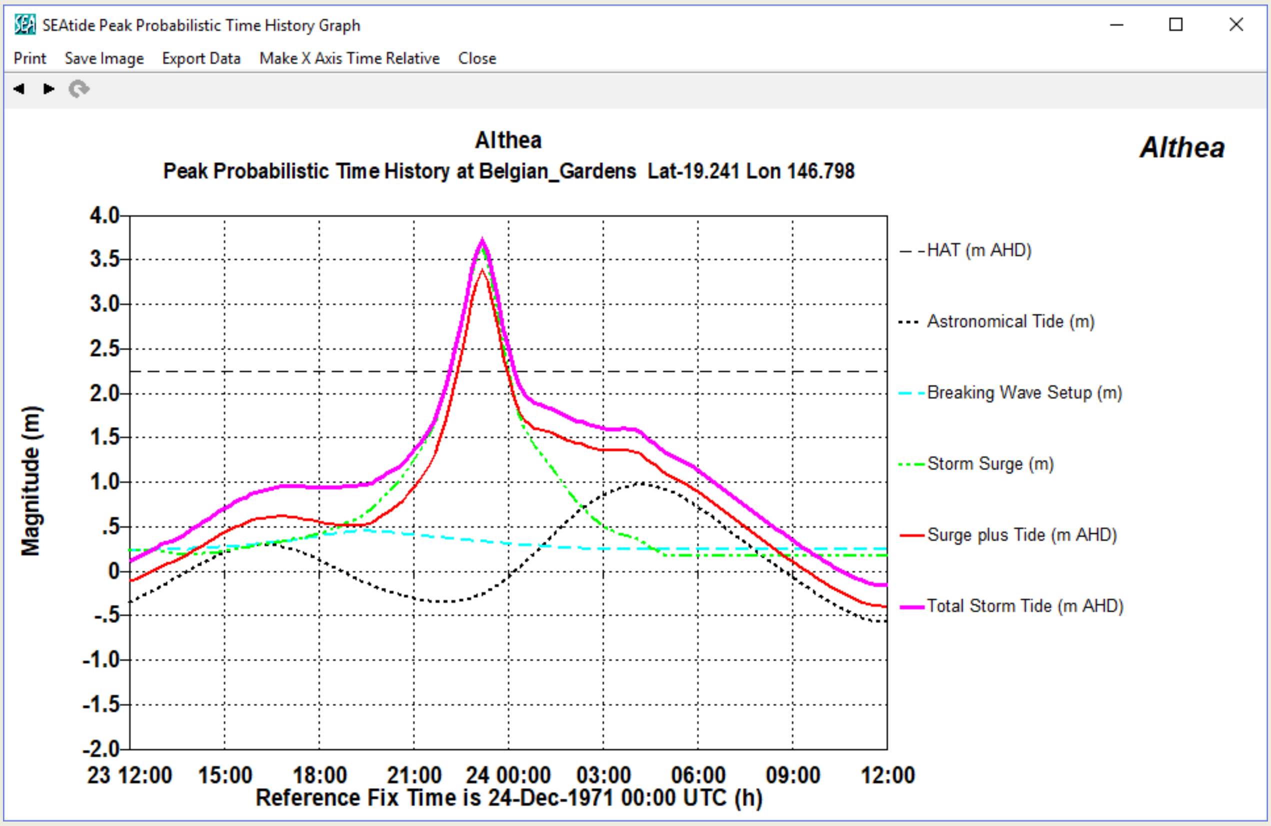
These results are now analogous to the *Deterministic* mode with the *Dependent* checkbox selected.

*Belgian_Gardens* (row 14 in this along-coast sequence) has the single highest predicted total water level of 3.7 m AHD in this peak probabilistic view and the *>HAT (m)* value is now 1.5 m. Scrolling down, this level can be seen to be shared with *Townsville*.

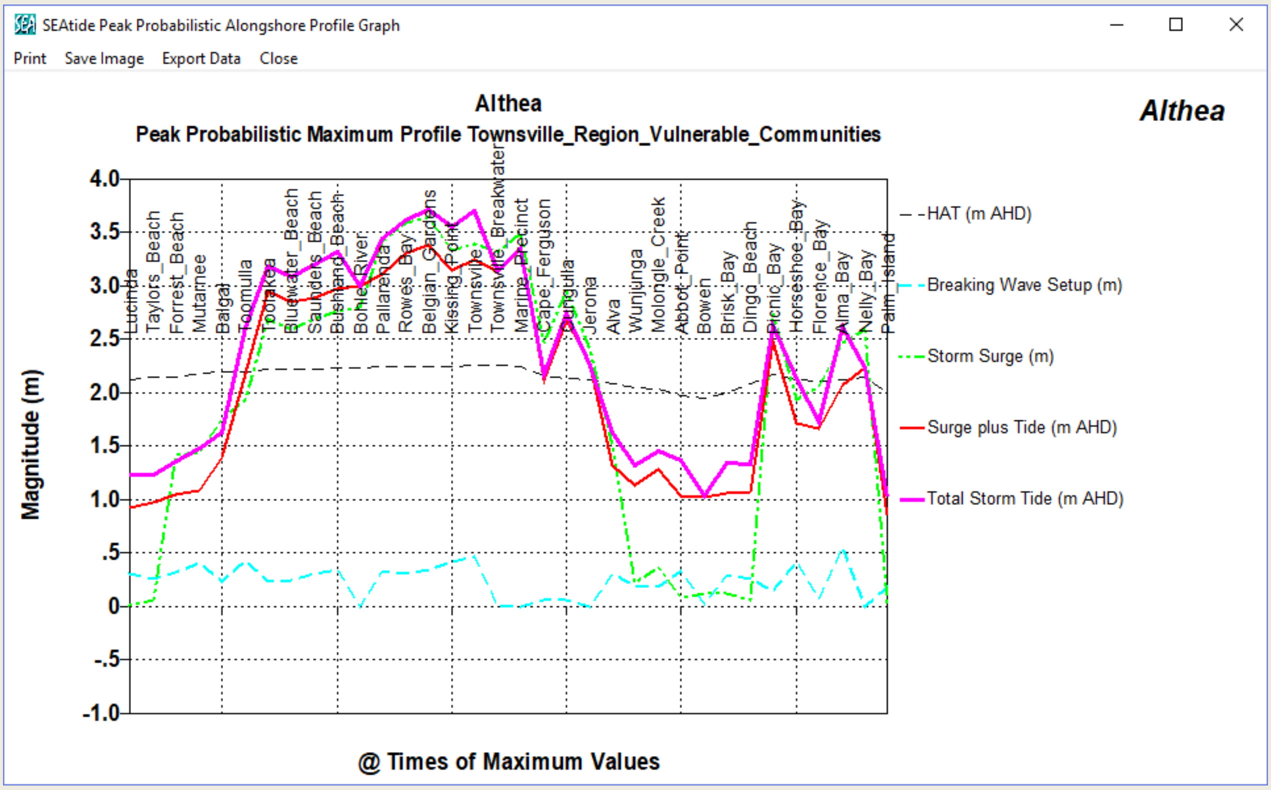



| | @ Peak Probabilistic | m AHD | >HAT (m) | Earliest UTC | Latest UTC | Dur. (h) | >HAT (%) | Earliest UTC | Latest UTC | Dur. (h) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Lucinda | 1.2 | -0.9 | 24-Dec-1971 04:10 | | | | | | |
| 2 | Taylors_Beach | 1.2 | -0.9 | 24-Dec-1971 04:10 | | | | | | |
| 3 | Forrest_Beach | 1.4 | -0.8 | 23-Dec-1971 21:50 | | | | | | |
| 4 | Mutarnee | 1.5 | -0.7 | 23-Dec-1971 22:10 | | | | | | |
| 5 | Balgal | 1.6 | -0.6 | 23-Dec-1971 22:00 | | | | | | |
| 6 | Toomulla | 2.6 | 0.4 | 24-Dec-1971 01:00 | | | 100.0 | 24-Dec-1971 00:30 | 24-Dec-1971 01:52 | 1.4 |
| 7 | Toolakea | 3.2 | 1.0 | 24-Dec-1971 01:00 | | | 100.0 | 24-Dec-1971 00:11 | 24-Dec-1971 02:14 | 2.0 |
| 8 | Bluewater_Beach | 3.1 | 0.9 | 24-Dec-1971 01:00 | | | 100.0 | 24-Dec-1971 00:03 | 24-Dec-1971 01:58 | 1.9 |
| 9 | Saunders_Beach | 3.2 | 1.0 | 24-Dec-1971 00:50 | | | 100.0 | 24-Dec-1971 00:04 | 24-Dec-1971 01:53 | 1.8 |
| 10 | Bushland_Beach | 3.3 | 1.1 | 24-Dec-1971 00:50 | | | 100.0 | 24-Dec-1971 00:02 | 24-Dec-1971 02:02 | 2.0 |
| 11 | Bohle_River | 3.0 | 0.8 | 24-Dec-1971 00:50 | | | 100.0 | 24-Dec-1971 00:14 | 24-Dec-1971 01:42 | 1.5 |
| 12 | Pallarenda | 3.4 | 1.2 | 23-Dec-1971 22:50 | | | 100.0 | 23-Dec-1971 21:48 | 23-Dec-1971 23:37 | 1.8 |
| 13 | Rowes_Bay | 3.6 | 1.4 | 23-Dec-1971 23:00 | | | 100.0 | 23-Dec-1971 21:57 | 23-Dec-1971 23:47 | 1.8 |
| 14 | Belgian_Gardens | 3.7 | 1.5 | 23-Dec-1971 23:10 | | | 100.0 | 23-Dec-1971 22:08 | 24-Dec-1971 00:11 | 2.1 |
| 15 | Kissing_Point | 3.6 | 1.3 | 23-Dec-1971 23:30 | | | 100.0 | 23-Dec-1971 22:31 | 24-Dec-1971 00:28 | 1.9 |

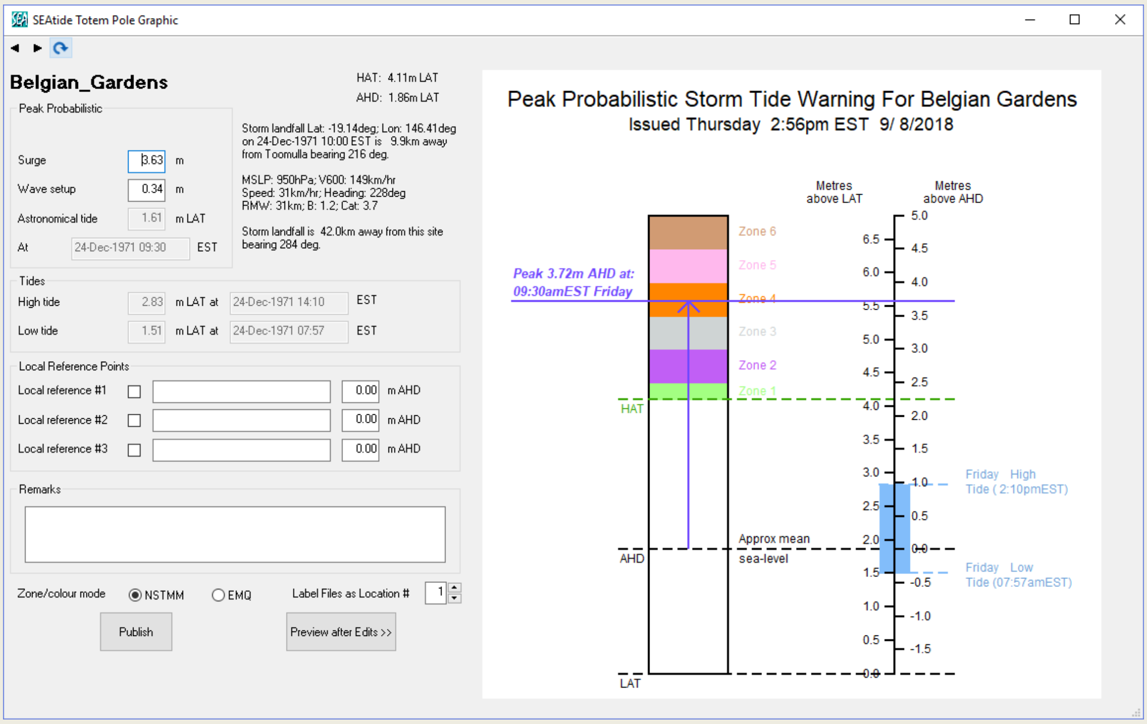
Now selecting the *Graph / Site* display option produces a specific prediction:




And selecting the *Graph / Profile / MEOW* option shows the specific water level profile that is produced by the storm that gives the highest total water level at *Belgian*_Gardens and Townsville:

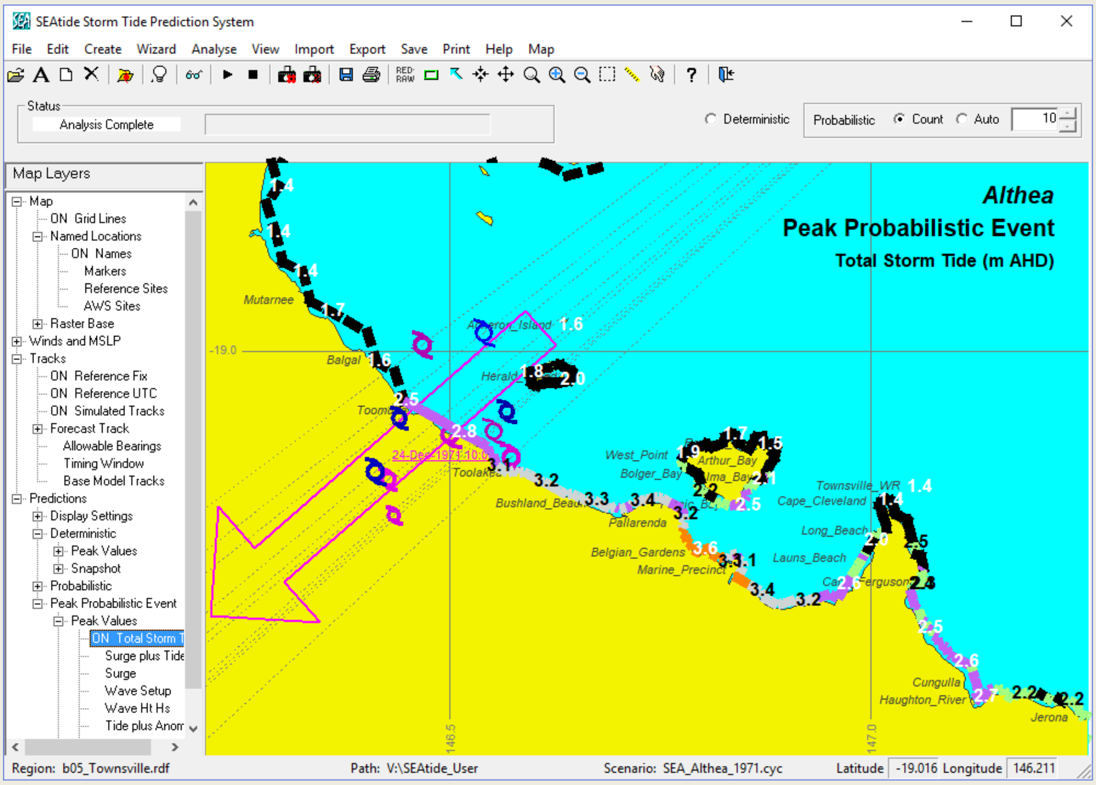


And selecting the *Totem / View* also produces a specific prediction:




In this case the information about the storm landfall position causing this result will likely vary between sites, even adjacent sites, because a different individual storm out of the many that are simulated may have caused the highest level at another nearby site.

In addition to the peak probabilistic event at each and every site being able to be determined, the hazard map can display the results for the single-highest-total-water-level-producing event during the simulation. The associated fix is indicated as an enlarged open arrow, e.g.



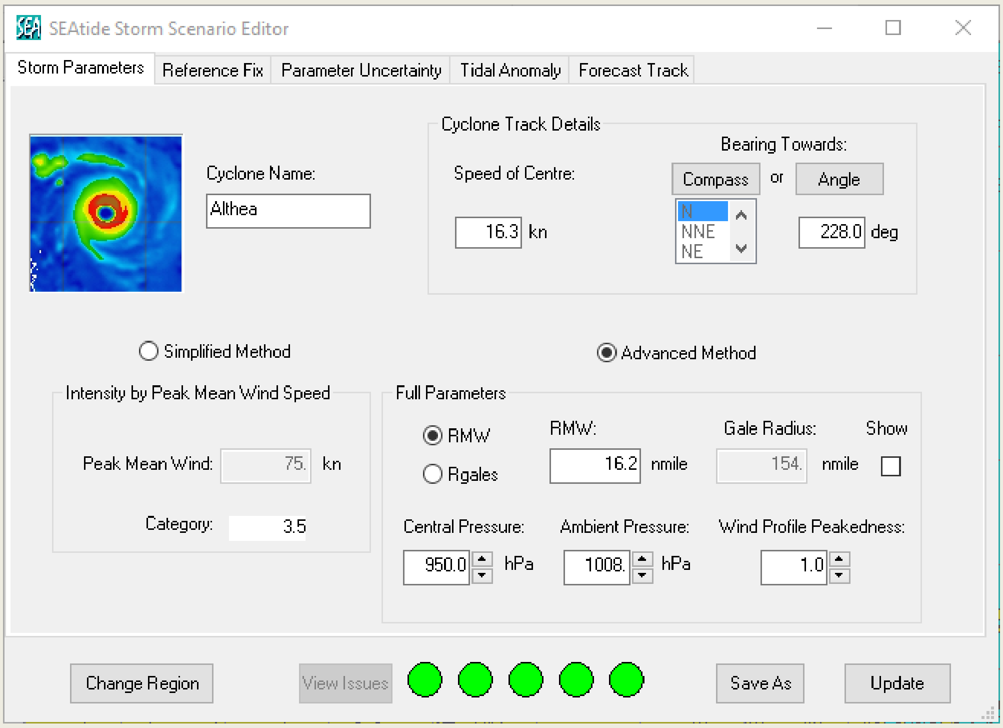
## 5.12 Edit or Create a Storm Scenario

Returning to the storm scenario editor window, the last remaining detailed aspect of *SEAtide* relates to the specifying of the storm (CYC file) details. Either the **A** button or the menu item *Edit/Scenario* can be used to edit an existing scenario if that window has been closed.

This displays a multiple tabbed dialog, with the first *Storm Parameters* tab allowing the specification of the TC specific parameters such as name, track and intensity information. Along the base of the window are options to *Change Region* (refer later), *Save As* and *Update*. The *View Issues* button and "traffic lights" display is discussed later below.

Two radio button options are provided for specifying the intensity: (1) a *simplified method* whereby only the estimated peak surface (+10m) mean wind speed is entered (for example derived directly from advisories) and a set of regional default parameters are generated that will match the specified peak mean wind speed or, (2) an *advanced method* whereby the user must provide all the required parameters. In either method, the track heading may be specified exactly as a motion bearing or approximately as a compass heading.

The actual modelled peak mean wind is always updated to reflect whatever option is active. When importing a Forecast Track file fix (refer later) the *advanced method* is always active. The default storm scale parameter is *RMW*, but *Rgales* can optionally be used via the button controls to override this. Changing *Rgales* manually will change *RMW* and vice-versa depending on the *B* value (with some round-off occurring because of the radius fitting method)[24]. The *Show* tick box, if enabled, will display a pop-up wind and pressure profile to assist the user in visualising the model structure[25]. In all cases the BoM TC intensity *Category* based on the peak mean wind will also be displayed[26].

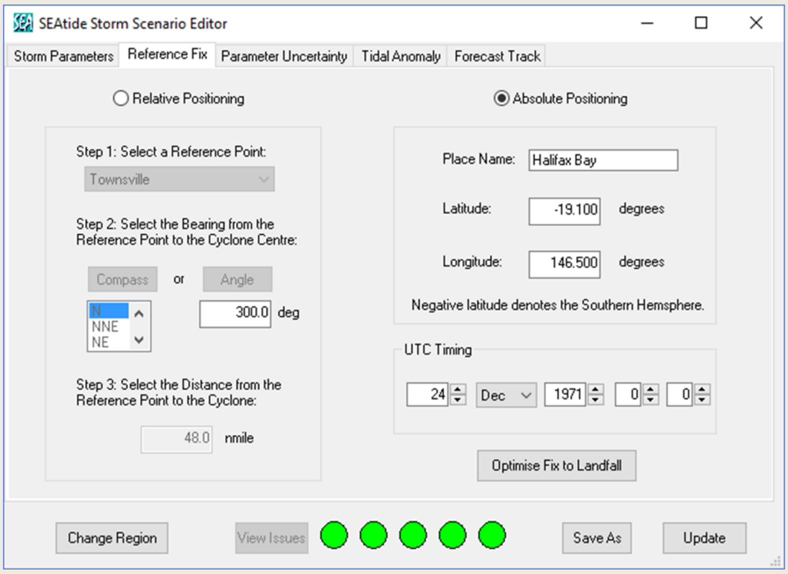



The View Issues button will be active if any parameter is creating a conflict and the user can choose to view those issues. If there are no issues on this tab, then the "go" symbol will be

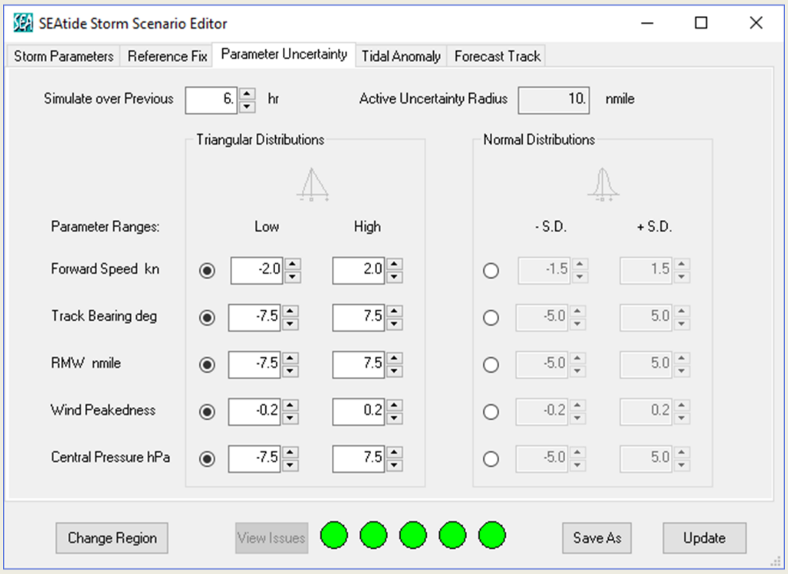
[24] The change in *RMW* that arises when *Rgales* is specified is transferred to the Parameter Uncertainty sheet.
[25] Refer Appendix B for a discussion about this feature.
[26] This is not capped at "Category 5" but permits extension assuming "Category 6" commences at the next logical division.

visible as the first in the “traffic light” tab sequence. If there is an active “warning” then the △ will be visible, else ■ for a potentially more serious error and ✕ for a critical error when the model cannot continue. The specific parameter fields in warning or error states will be similarly coloured for your attention.

The second *Reference Fix* tab allows specification of the location of the storm centre and the time reference (UTC) of the fix. There are also two separate options in this case. Either the storm landfall position can be given as a bearing and distance from a list of available regional sites or as an absolute position, which can also be named. The fix time must be specified in UTC.




The third *Parameter Uncertainty* tab is where the user can specify the uncertainty of each storm parameter in terms of either a triangular or normal probability distribution. The values entered here are relative to the previously supplied “expected” parameter values. In the case of a triangular distribution, the user is indicating the upper and lower limits of each parameter, which can be different to reflect a perceived bias in the estimates. In the normal probability option, the indicated value is the standard deviation.



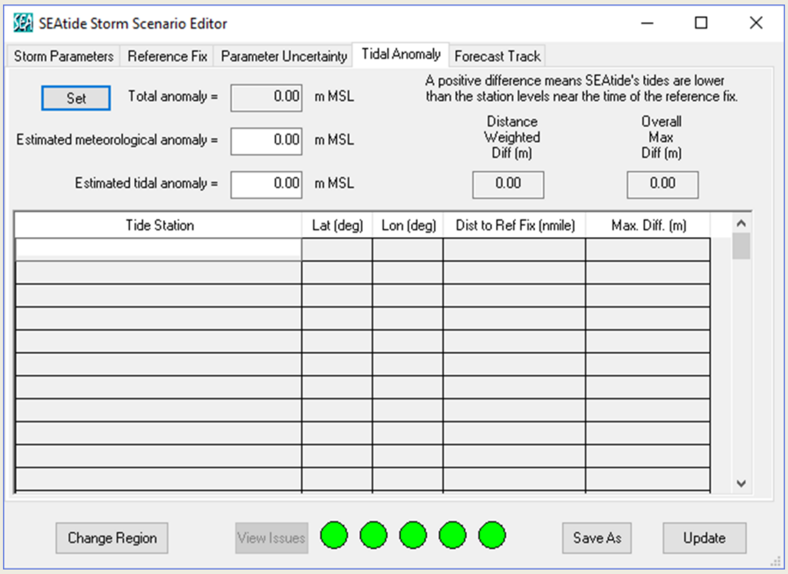

The default uncertainty values shown here are unbiased but can be skewed to reflect the expectation that the forward speed is not expected to be slower than the reference fix or that no storms are expected to be less intense than the reference fix. If this were applied, then any probabilistic simulation will produce a result whereby the reference fix deterministic storm tide levels will likely be less than the expected 50% values (depending on the tide stage also). Climatologically-derived error estimates could also be used.

The *Simulate Over Previous* value here is used during the probabilistic scenarios to facilitate the starting point for the Monte Carlo tracks (12 hr is the default). Details of this *t_pre_ref* value are provided in Appendix C.

The *Active Uncertainty Radius* field will be visible only if an uncertainty radius has been imported from a Forecast Track fix (refer later). In that case the forward speed and track bearing uncertainty will be automatically calculated so that all simulated centre fix positions will lie within the specified radius of uncertainty. Changing *t_pre_ref* in such circumstances will also automatically adjust the uncertainty limits to suit.

The fourth *Tidal Anomaly* tab allows the user to view any regional tide prediction anomalies and/or specify an anomaly value. So-called tidal anomalies are meant to represent effects that are outside the ability of the model to represent or are due to limitations in the assumed spatial distribution of the astronomical tide across a particular region. Provision is made for specifying a *purely meteorological* anomaly and a separate *purely astronomical* anomaly.

For the former, there might be pre-existing meteorological effects that could be already increasing the “predicted tide” level, such as a preceding strong and persistent onshore flow due to large scale ridging, unaccounted baroclinic effects near deepwater/shelf boundaries or even near-equilibrium effects from a near-stationary TC (e.g. in the Gulf of Carpentaria). This information might be obtained from a real time tide gauge that directly measures the anomaly.




The latter anomaly allowance is for accounting for actual tide prediction errors that might be present in some remote regions where the spatially varying tidal characteristics are uncertain. *SEAtide* can estimate this effect directly by considering differences between its regionally-interpolated tide predictions and published site-specific predictions for any tidal stations that are near to the prediction sites of interest[27]. The location of any active tidal stations can also be shown on the map layer. *SEAtide* assists by suggesting that the user apply the distance-weighted tidal prediction anomaly, which also allows for the likely accuracy of the regional tidal predictions

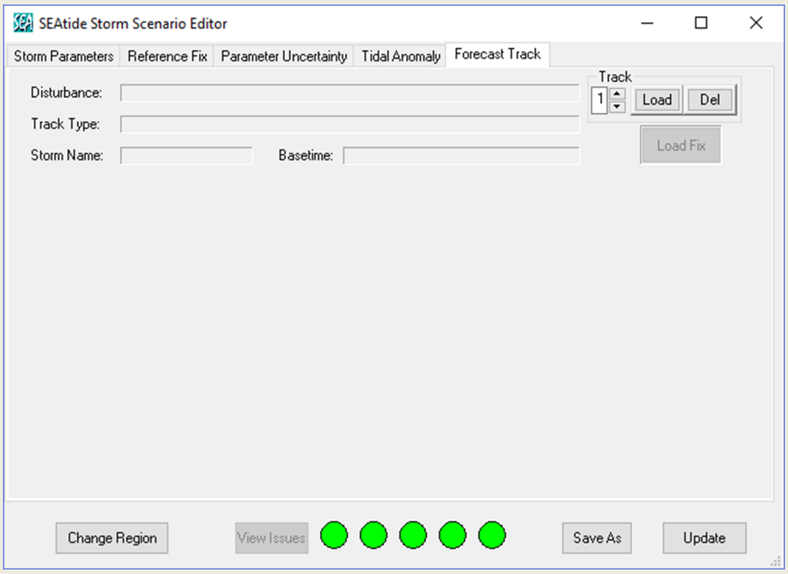
[27] This feature is not active in all regions but depends on the quality of the tide data in the regions. If published tide data is available at reasonable intervals then it is not used (e.g. Qld). If SEAtide relies on “modelled tides” over sparsely observed areas, then it may be used for guidance (e.g. NT). Appendix D provides further details.

themselves based on its knowledge of the number of tidal constituents that are available for each tidal station. For details on why a chronic tide prediction anomaly might exist, the user is referred to, for example, GHD/AMC (2014).

In any case, the user must make a manual assessment of each component and then *Set* the final combined anomaly value to be used by SEAtide, which will simply add this value to the generated tide levels for all sites.

The final *Forecast Track* tab in the Storm Scenario Editor shows any active imported agency storm tracks (or historical tracks). In this example there is no track file loaded, so the only option is to *Load Track* (refer next section). The spinner/counter indicates the currently selected track number. The available actions are *Load* and *Del*, which together allow management of the various tracks, which are then stored in the CYC file.

Selected tracks are not utilised/displayed until the *Update* button is selected (refer next Section). The symbol ■ will appear next to the *Update* button if it needs manual updating for a change to have effect.



## *5.13 Importing a Forecast Track File*

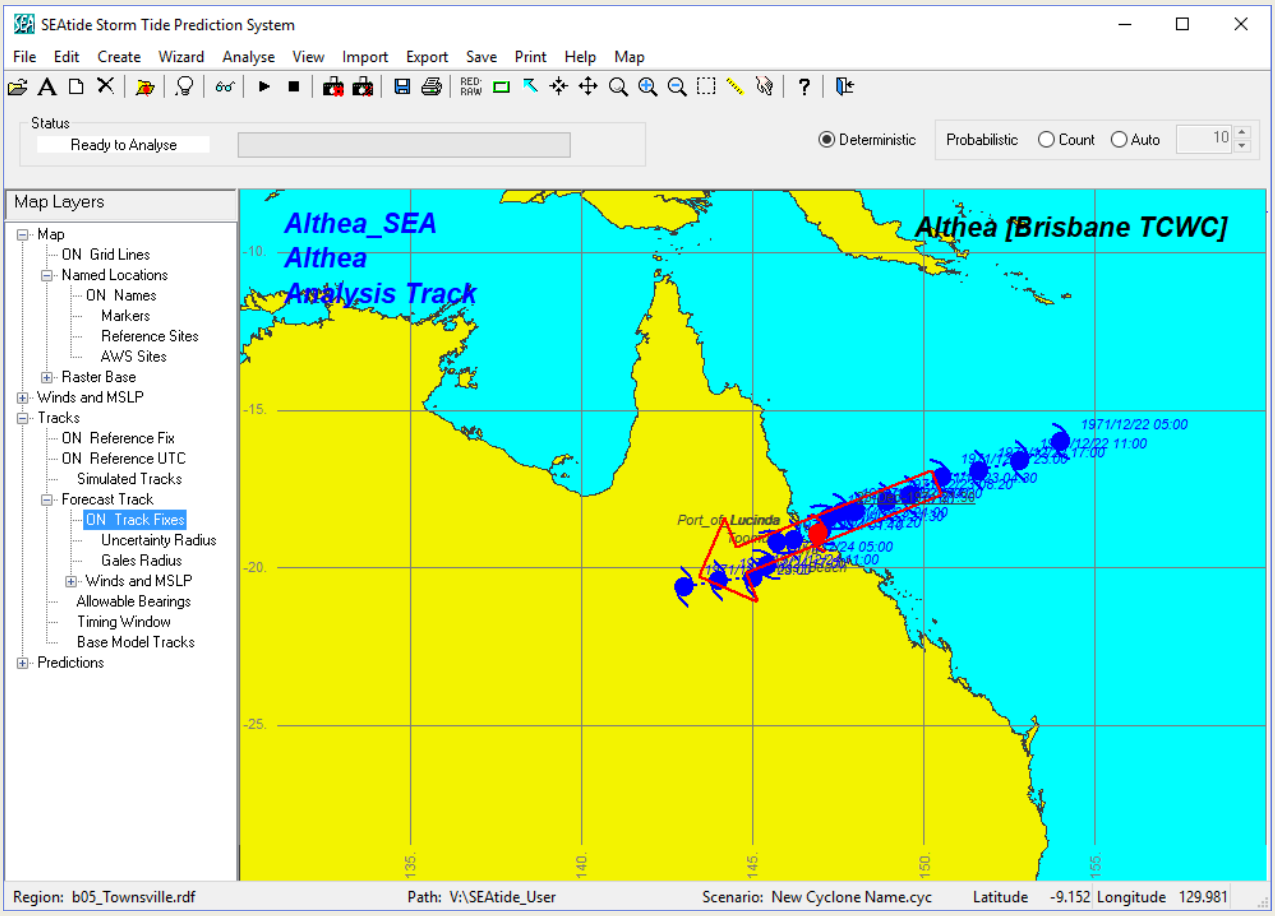
Up to 3 forecast track files[28] may be imported at any time into a CYC file.

This can be done in a number of different ways. A forecast track may be imported

- initially from the *Wizard* dialogue on start-up, or
- via the menu item *Import/Forecast Track File*, or
- via the toolbar button, or
- from the Scenario *Forecast Track* tab (discussed above).

A popup dialog will then ask if you wish to download a real-time BoM Technical Bulletin forecast track[29]. If not, then the necessary file is expected to be available locally. In all cases the user may browse directories and make a selection from the available agency forecast track files.

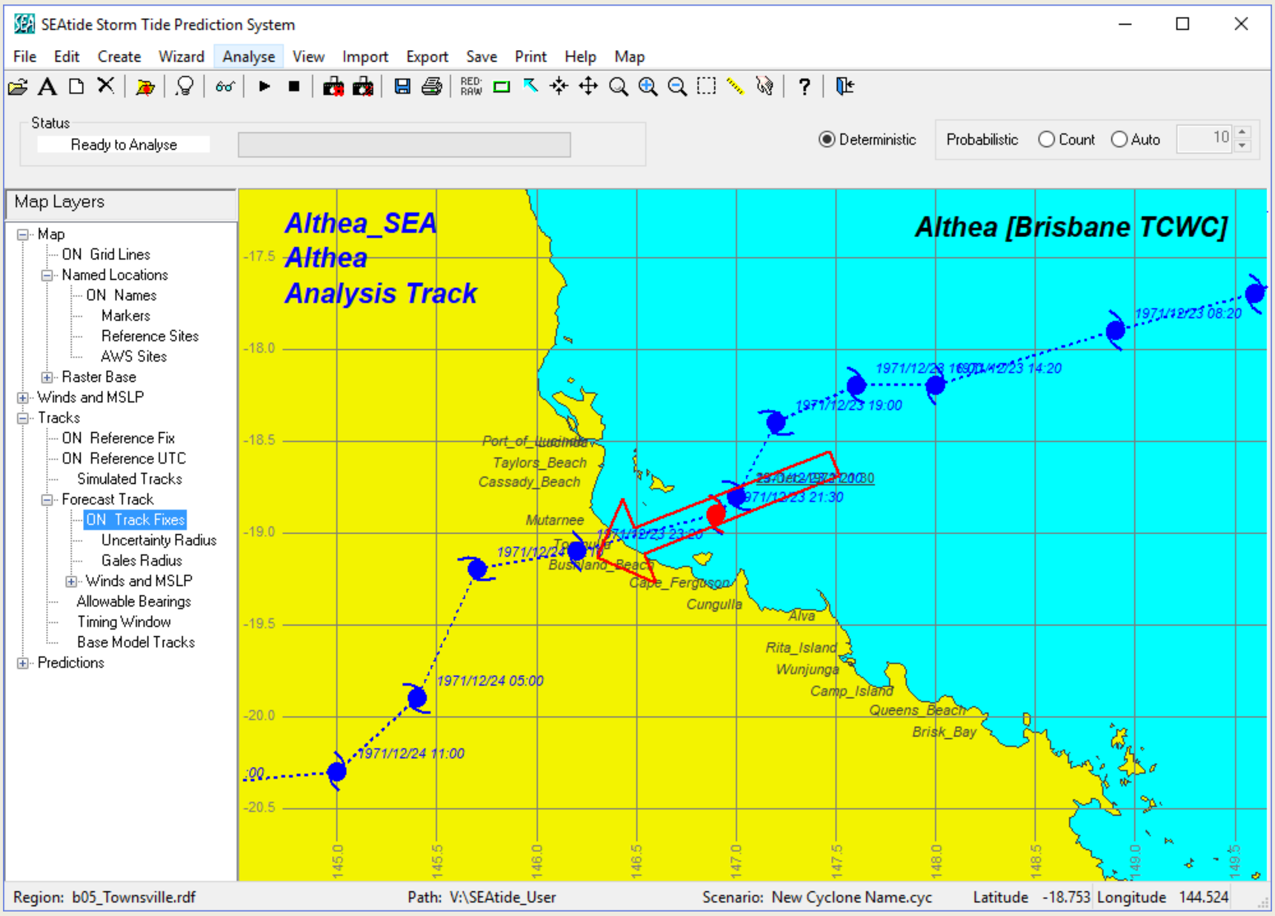
In this example the previous scenario has been closed and the toolbar button option used to import the example BoM Forecast Track file *SEA_Althea_Track_Example.csv*. The model will prompt for a name for a new CYC file and then display the *Storm Scenario Editor* window (overleaf). The most appropriate model region is automatically selected by the model as being Townsville and it has chosen the closest available fix from the track file that is immediately before the landfall crossing point as the *Reference Fix*. When the track is loaded (below) the map is expanded to show the available model area.



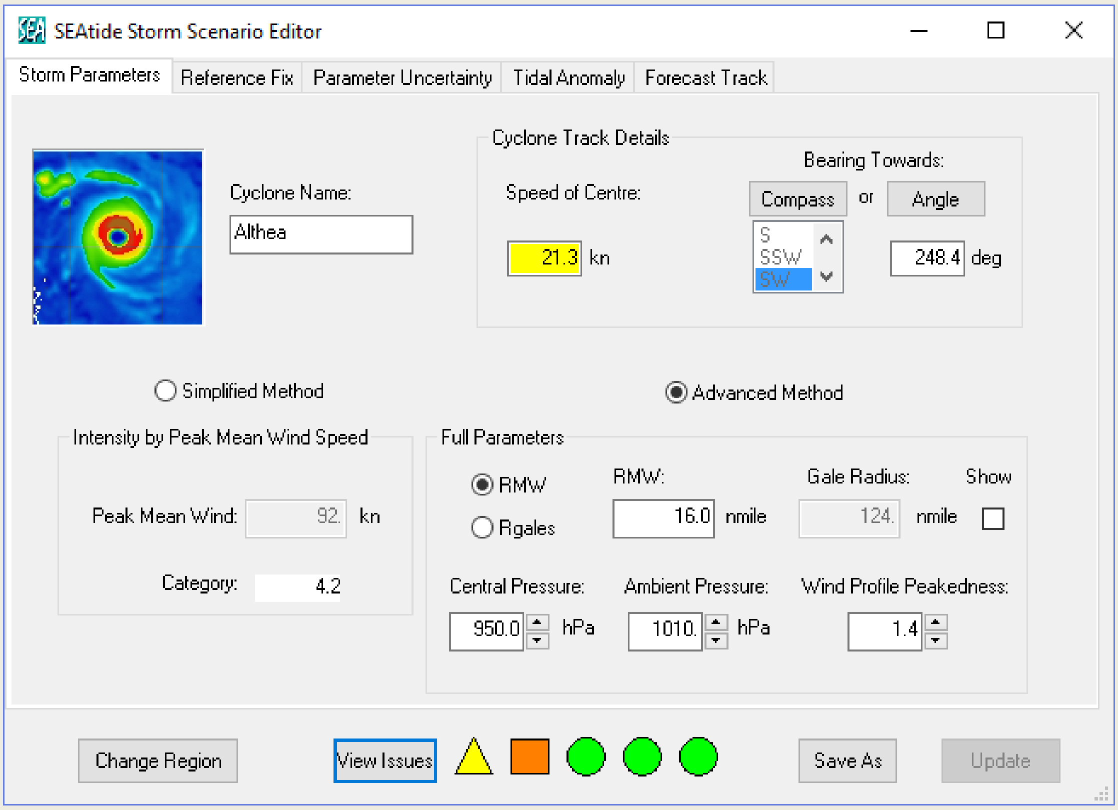

[28] These are sourced from the *TCT_Filepath* as specified in the INI file (Appendix A).

[29] Only BoM will normally have direct access to the official forecast track file.

The map window (below) is then zoomed into the chosen region as shown below.



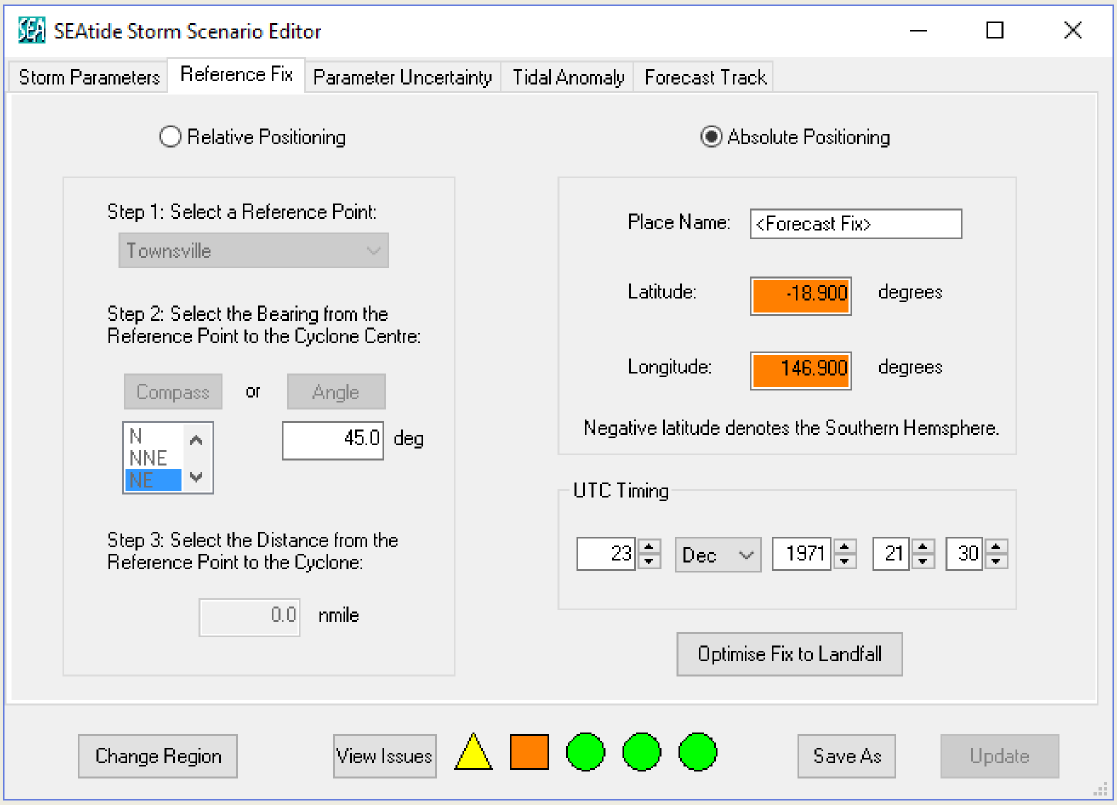

However, the "traffic lights" in the Storm Scenario Editor show that there some warnings or suggestions regarding this automatically chosen reference fix:



None of these issues are "critical" and so will not prevent a simulation proceeding, but the *View Issues* button should be consulted to provide more information.

The *Speed of Centre* field is highlighted in yellow on the first tab, which matches the first "traffic light" . This is because the speed calculated from the track file fix exceeds the modelled range of values[30] and will be truncated at the upper limit for this region. Often, unreasonably high speeds result from apparent jumps in the radar centre. This is easily fixed, after inspection of the issues, by manually overriding with the value used earlier in the Althea CYC file example of 16.3 kn and pressing *Update*.

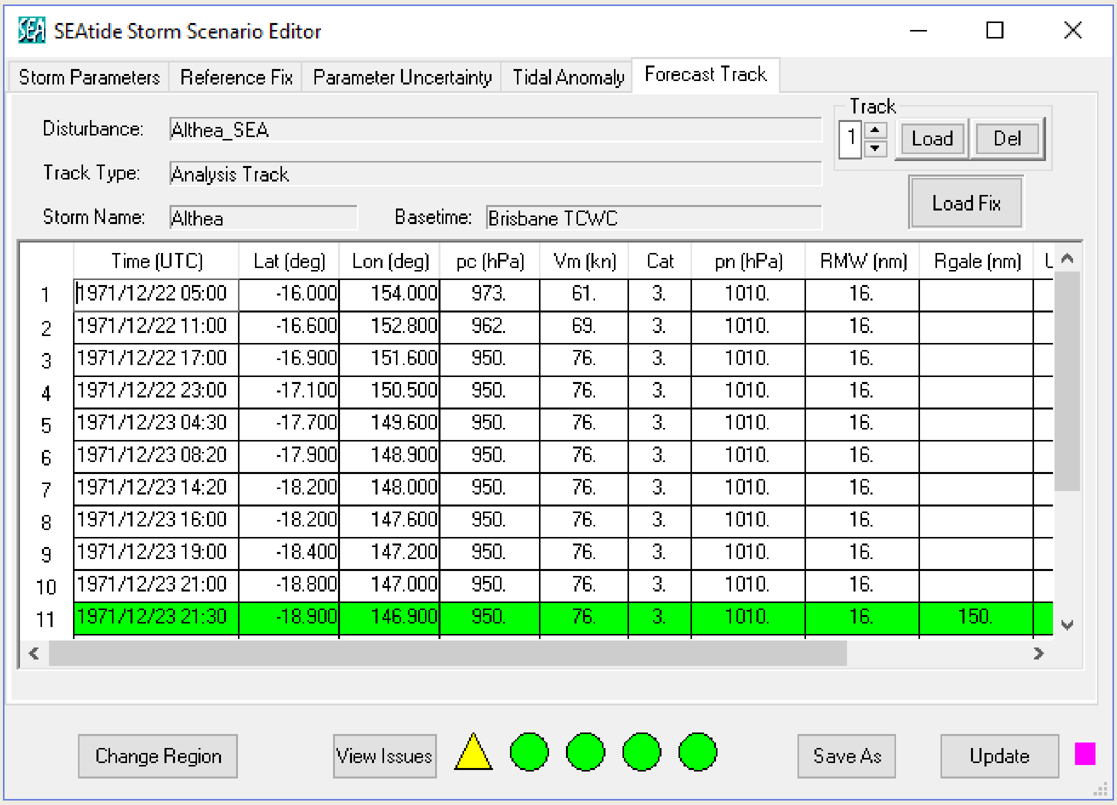
The symbol is associated with the second tab and refers to the fact that the chosen storm fix could be usefully moved closer to "landfall". This will ensure that the model prediction can cover a slightly wider time period. It is not really a problem in this case but pressing the *Optimise Fix to Landfall* button will do this automatically.




Meanwhile the Gale Radius field on the first tab remains highlighted and the *View Issues* button notes that model Gale Radius differs from the forecast value by more than 20%. This check is done because *Rgale* is not imported into *Storm Parameters* but is instead calculated based on the model's (now fully specified) "double Holland" profile. Differences between the calculated *Rgale* and the estimated/forecast fix *Rgale* can then be interpreted as a measure of how the fix parameters differ from SEAtide's idealised model wind profile that is a function of *RMW* and *B*. The *Show* checkbox, described in detail in Appendix B, provides a way of visualising the difference between the model view of the wind profile and the incoming fix information.

Turning attention to the *Forecast Track* tab (below) it can be seen to provide a listing of the track file data and the row that is coloured green is the fix that was originally loaded automatically, showing an *Rgale* of 150 NM.

[30] Because the BoM track fixes are normally only specified to 0.1 degree resolution this can create periods of apparently high storm speed.




The fix values for $p_c$, $p_n$ and RMW are imported directly to the *Storm Parameters* tab. If not provided (which is the expected situation), SEAtide also calculates a Holland *B* value based on the supplied $V_m$ and ($p_n$-$p_c$) in the imported track fix. Because of the expectation of $V_m$ coming from a Dvorak approach, is assumed to not include a forward speed component (i.e. it is the estimated axisymmetric mean surface wind or “vortex strength”). The total *Peak Mean Wind* that includes the forward speed (i.e. the asymmetric mean surface wind) is then calculated and displayed on the Storm Parameters tab (in the *Simplified Method* section).

The user may now choose a different fix if desired and, after selecting *Load Fix,* this will transfer the various values into the other tabs. Alternatively, another track file can be loaded (e.g. perhaps another agency’s view) as Track #2 for example, and the *Load Track* button will display the new track with the recommended fix coloured yellow. Whichever fix is selected by the user then becomes green. The *Update* or *Save As* button must be used to ensure that any Track # changes are saved in the CYC file and for the hazard map to reflect the different track path. The symbol will appear next to the *Update* button if it needs manual updating for a change to have effect. After updating a Track # change any displayed hazard map forecast track details and/or wind fields will update to reflect that change.

If a fix is manually chosen that is not very close to “landfall” then the traffic light noted by a ■ may be displayed applying to the second *Reference Fix* tab. Selecting the *Optimise Fix to Landfall* button here will move the selected fix accordingly and perform an *Update*. This will ensure that the full model “time window” will be available for the simulation. The *Place Name* will be renamed “<auto landfall>” by default to reflect this intervention but may be manually overridden if desired.

In addition to the ability to manage up to 3 tracks in this way, the user may also edit any data field in any of the tracks. This might be desirable because often the forecast tracks could be missing some information that is of interest and could be used to improve the matching between the forecast and the SEAtide wind model’s “view of the world”. For example, *Rgale*, which is often available from real-time scatterometry, can be useful in finding a balance between the various competing “intensity” parameters (refer Appendix B). Also, because any missing values are simply interpolated in time between available data when the *Load Fix* is executed, it may be desirable to add intermediate values that will have the desired effect. For example, users can also specify the *B* value if desirable, which will prevent SEAtide from calculating a value based on $V_m$ and ($p_n$-$p_c$). Appendix B provides insight into the "double Holland" model wind and pressure profile parameters to assist users in this regard.

The *Reference Fix* tab receives the landfall coordinates and UTC time from the selected track fix and *SEAtide* calculates the forward speed and bearing over the preceding period for specifying on the *Storm Parameters* tab.

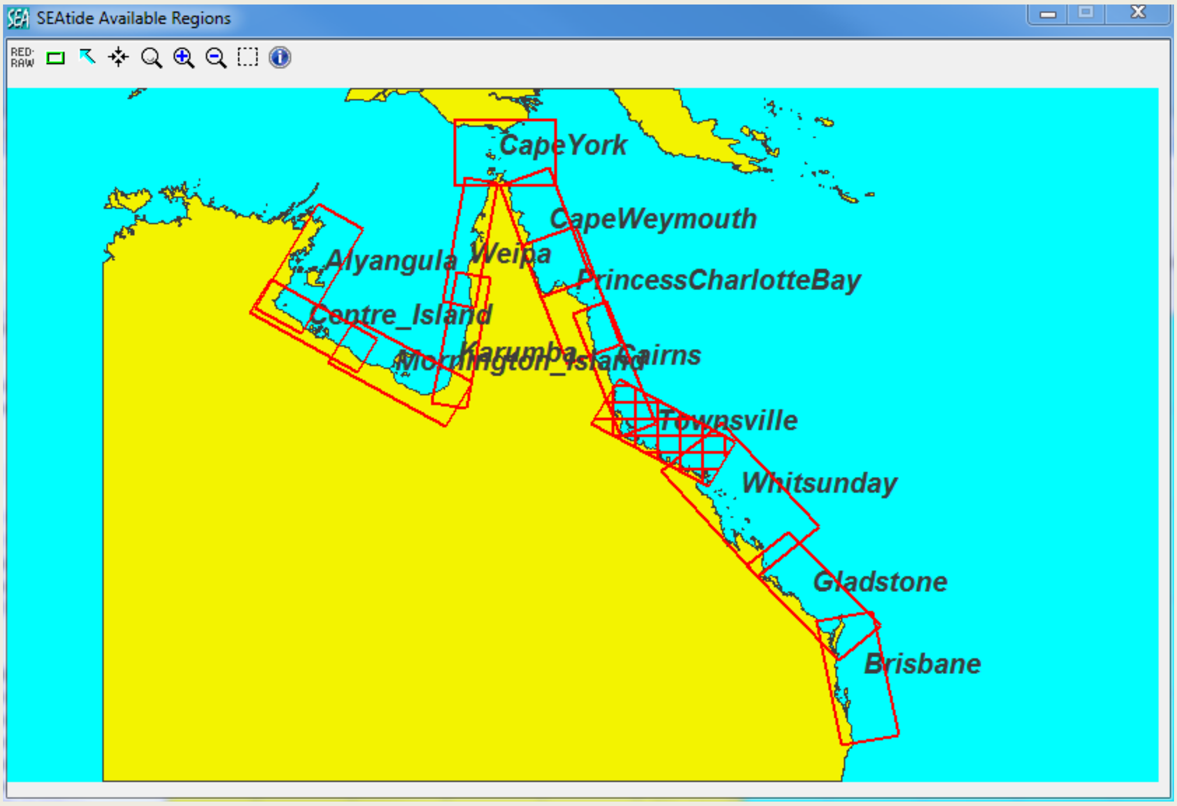
The *Parameter Uncertainty* tab can also be seen to have obtained a value for the *Active Uncertainty Radius* from the specified track data *Fix Uncertainty* of 10 NM.

Returning to the *Storm Parameters* tab, in this example, we can improve the profile fit by adjusting the *Wind Profile Peakedness* value downwards to 1.0, which matches the SEA-calibrated value from the CYC file. This increases the modelled *Gale Radius* to 162 NM.

All the "traffic lights" are now **green** as a result of addressing the issues with that original fix and at this point an *Analysis* can be performed that fully complies with the model requirements and also produces a closer model-forecast fix result.

# 6 Working with Model Regions

Without having an active storm scenario, the regions that are available for modelling can be easily viewed either from the *Wizard's View Maps* option or from the menu *View* option. This brings up the following additional window:




This shows all the available regions and that the Townsville region (hatched) is currently active[31]. Selecting any other region will correspondingly change the view in the Map Hazard window, where the user can navigate and explore.

Whichever region is currently active will be where any new scenario is manually created, unless it is initialised by loading another Forecast Track. Existing scenarios (CYC files) will load the region that they require.

## *6.1 Changing Regions*

When a storm scenario is active, the user can select another suitable region simply by using the *Change Region* button in the *Scenario Editor* window and then the *Choose Selected Region(s)* menu option.

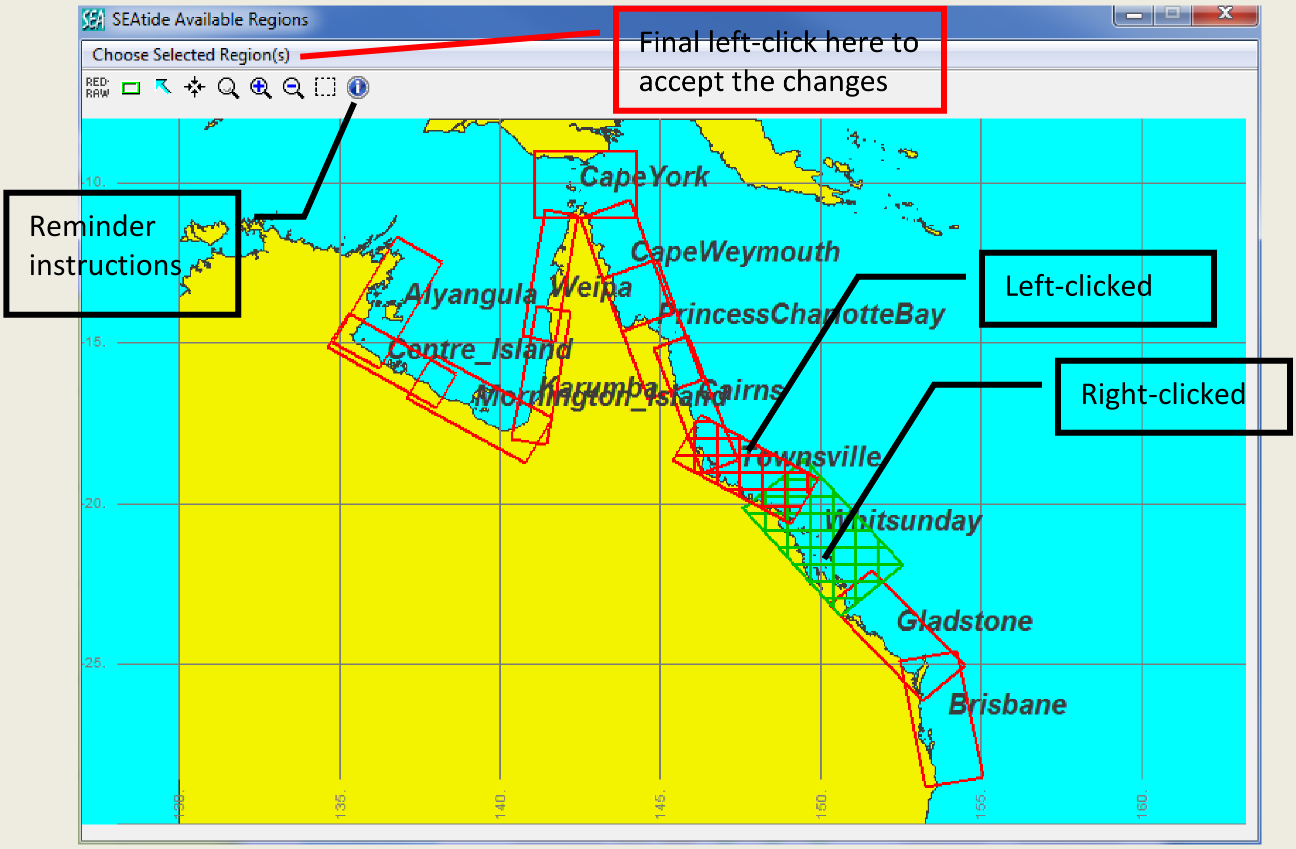
However, this needs to be done with some consideration and care, noting that the model can only model situations where the *Reference Fix* is either within or "close" to a region. Choosing inappropriate regions far from the fix will simply result in a critical issue, as notified by the ✕ symbol. Please refer to Appendix C, which provides technical insight into such situations.

[31] Cairns region is the default for the Qld-Gulf model; refer Appendix A.

In that case a new scenario either needs to be started in that selected region or the existing fix coordinates must be edited to be representative of that region.

## 6.2 Multiple Region Modelling

When a scenario is active, and the Scenario Editor *Change Region* button is used, the user can also create a "multi-region" model by choosing another region that is adjacent to any currently selected region. This is shown below, whereby the "left mouse button" is used for selecting the *primary region* and the "right mouse button" can be used to select the *secondary region*, shown in green hatching. Next the *Choose Selected Region(s)* menu option must be selected to update that information in the Storm scenario, otherwise the selections will be ignored (i.e. cancelled).




Sensibility rules will be applied in deciding whether these two regions can be modelled or if a critical error will result, requiring revised selection. In the event of an error this will also show the available model "timing window" to assist in region selection. The *Map/Tracks/Timing Window* layer can be used to visualise the available "reach" of a particular storm scenario. If the timing window does not intersect the "coast" for a "coast crossing" event, then it will not be able to be simulated (refer Appendix C).

When creating a new *Scenario* or when loading a *Forecast Track*, if the *Reference Fix* is suitably located between two adjacent regions the user is always given the opportunity of choosing a "multi-region" simulation.

# 7 Surface Wind and MSL Pressure Visualisation

This is an optional SEAtide component and may not be available in all installations if not licenced.

This feature assists the user in matching the parameters of the forecast TC system to that available in the parametric storm tide modelling system (refer Appendix B for discussion). It extends the utility offered in the Scenario Editor and the pop-up wind and pressure profile feature triggered by the Show option, whereby the Holland *B* value can be manipulated in association with *Vmax* and *Rgales* in order to obtain the best overall correspondence between what "SEAtide can represent" and "what the forecaster is predicting" based on the adopted intensity estimation method (e.g. Dvorak 1984 etc).

## 7.1 Wind and Pressure Values

The following mapped values are available:

Open Sea Surface Wind Metrics (+10m):

- 10 min mean ($V_{600}$) as per BoM/WMO standard;
- 1 min peak gust ($V_{60,600}$) as per preferred US "sustained wind";
- 3 sec peak gust ($V_{3,600}$) as per BoM/WMO standard;
- 0.2 sec peak gust ($V_{0.2,600}$) as per Standards Australia (2011).

Wind Units (display):

- Knots (wind barbs, plus contours)
- Km/hr (vectors, plus contours)
- m/s (vectors, plus contours)
- BoM TC intensity category (colour-coded vectors, plus contours)

Mean Sea Level Pressure (display):

- hPa (contours)

These wind speed metrics follow the Harper, Kepert and Ginger (2010) WMO-endorsed recommendations for the "At Sea" exposure and should be directly comparable to observations from low-lying, well-exposed and flat offshore islands (e.g. AWS on coral cays, the positions of which are available as a Map Layer). Where available, visualising the match between modelled and measured real time wind speeds and pressures will assist (noting allowance for future changes) in specifying the most appropriate model parameters to specify near the point of anticipated landfall.

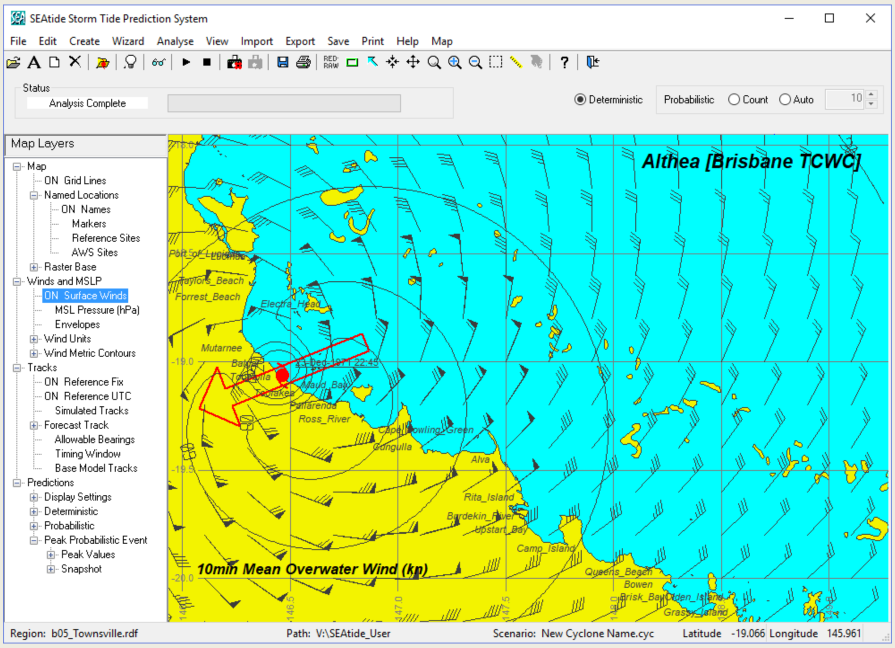
## 7.2 Map Layer Operations

There are separate but analogous controls depending on whether it is the *reference fix* (i.e. the *parametric* TC track representation) or the imported *forecast* TC track that is of interest. Both the reference track and the forecast track winds and pressures can be displayed together if required. The map layer is branded by the selected wind or pressure metric.

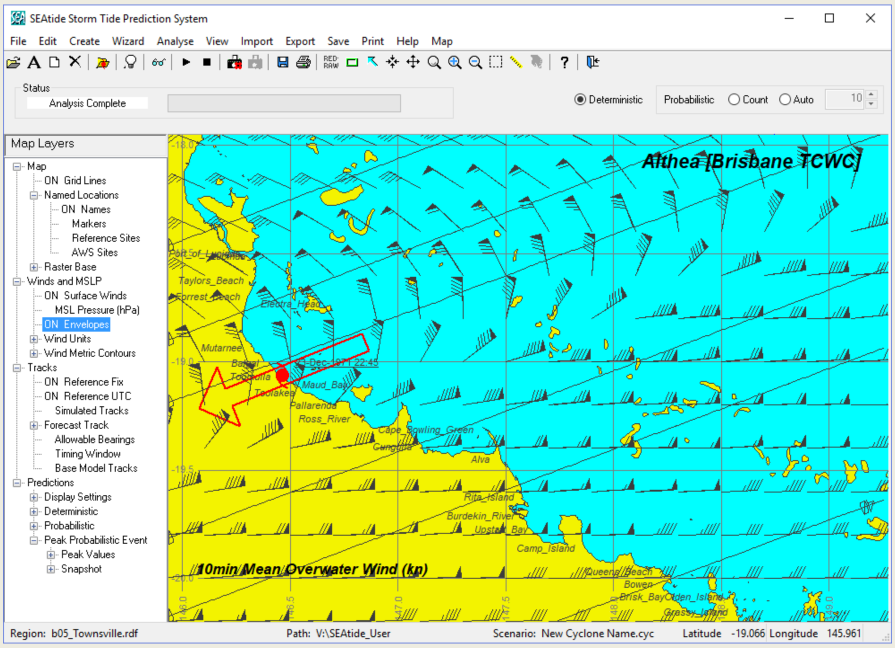
### 7.2.1 Reference Fix Track

If this feature is available, a new *Winds and MSLP* map layer control will be visible and by default the *Surface Winds* layer will be activated for 10 min mean winds displayed in knots (wind barbs). Other layers can then be manipulated as desired.

Whenever a *storm scenario* is active the winds and pressures for the *reference fix* parameters will be available for display as a *snapshot* view. Using the *Predictions* | *Deterministic* | *Snapshot* map layer controls, the user can also display the winds and pressures at other fix times.



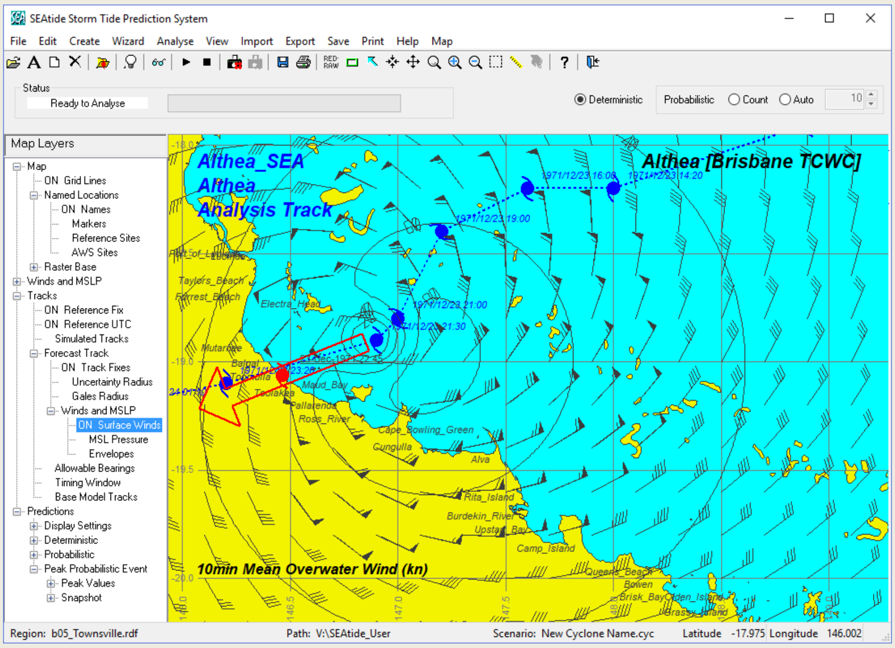

An envelope can be obtained by using the *Envelopes* map control directly. The user can then toggle between the *snapshot* and the *envelope* displays as required.




After a *deterministic* simulation, the maximum *envelope* of winds and pressures will automatically be available for display.

### 7.2.2 Forecast Tracks

If a *forecast* track is available and selected from the *scenario editor* tab, then a *Winds and MSLP* map layer control will be visible in the *Tracks* | *Forecast Track* layer controls. This is only activated if the *Tracks* | *Forecast* | *Track Fixes* branch is also activated. The default *snapshot* view is close to the *reference fix*[32] time. The user can display any other fix *snapshot* by selecting that fix from the scenario editor *Forecast Track* tab.




An envelope of the winds and pressures throughout the entire forecast track is obtained by activating the *Envelopes* map layer control.

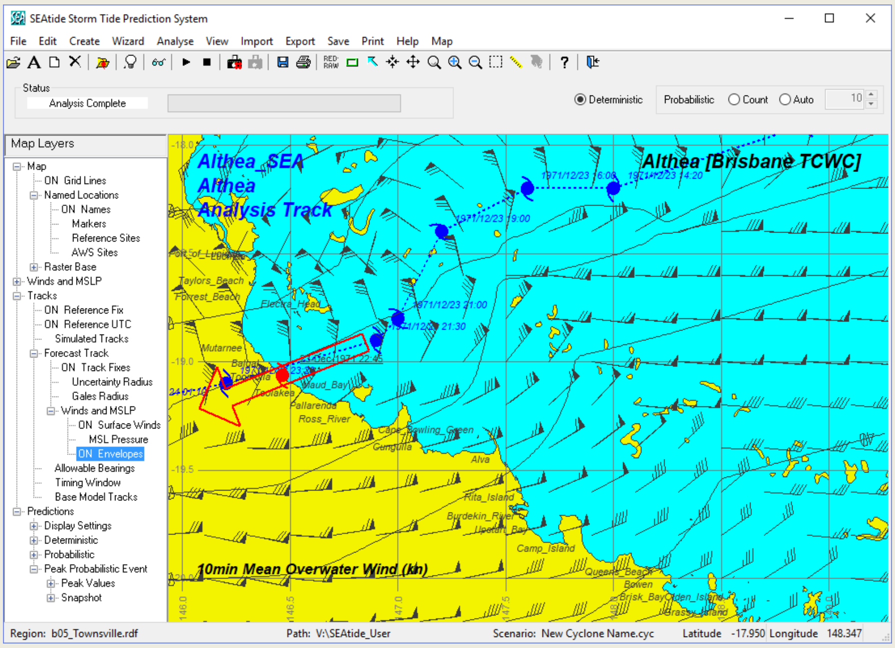
### 7.2.3 Wind and Pressure Field Export

The currently selected wind and pressure field view can be exported to CSV files in the current *REP_filepath* folder by the Export | Wind and MSLP Fields menu option.

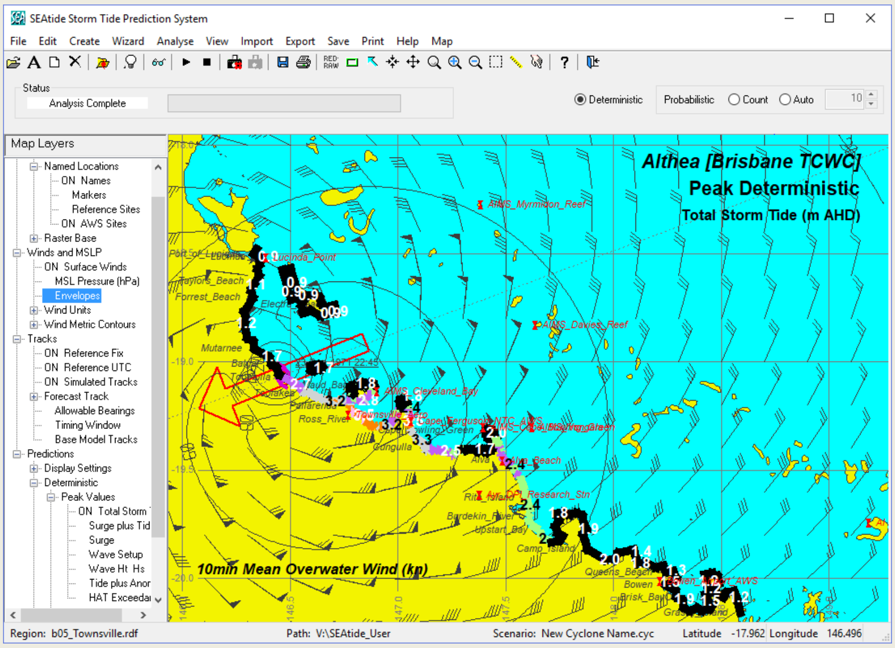
Exported wind and pressure field files are automatically named as follows:

| | |
|---|---|
| <scenario>_Wind_Contour_Values.csv | <lon>,<lat>,<wind_contour_value> |
| < scenario >_Wind_Values.csv | <lon>,<lat>,<wind_ _value> |
| < scenario >_MSLP_Contour_Values.csv | <lon>,<lat>,<MSLP_contour_value> |
| < scenario >_MSLP_Values.csv | <lon>,<lat>,<MSLP_value> |

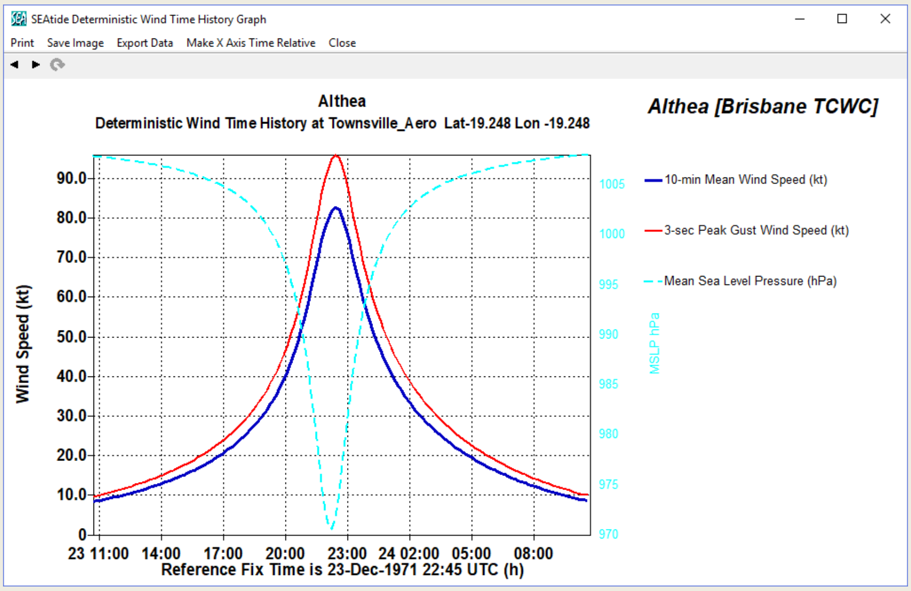
[32] It is possible for non-contemporaneous TC forecast tracks to be available and displayed in the hazard map (e.g. TC *Althea* in 1971 and TC *Larry* in 2006). In that case the displayed winds fix will be at the start or end of the forecast track if it is not contemporaneous with the current reference fix.


SEAtide Storm Tide Prediction System
File Edit Create Wizard Analyse View Import Export Save Print Help Map
Status
Analysis Complete
Deterministic
Probabilistic
Count
Auto
Map Layers
Althea_SEA
Althea
Analysis Track
Althea [Brisbane TCWC]
10min Mean Overwater Wind (kn)
Region: b05_Townsville.rdf
Path: V:\SEAtide_User
Scenario: New Cyclone Name.cyc
Latitude -17.950 Longitude 148.347

Users can additionally select displayed AWS sites from the hazard map using the button to select the relevant cursor. This will invoke a time-series graph of modelled wind speed, direction and/or pressure. If real-time data is also available, model and data can be compared.

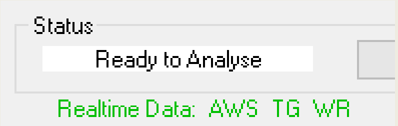



The following graph provides the modelled time history of wind and pressure at the Townsville Airport.



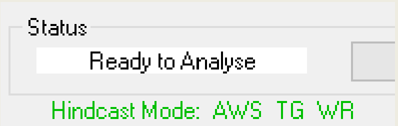
# 8 Real-Time Data Display

If internet access is available and the model region has defined real-time data links,[33] then the available data will be automatically downloaded and displayed in the relevant time-series graphical context. To achieve this the CYC file **UTC** *Reference Fix* time must be such that data will appear within the ±12 h display view. This will be confirmed by a status notification:

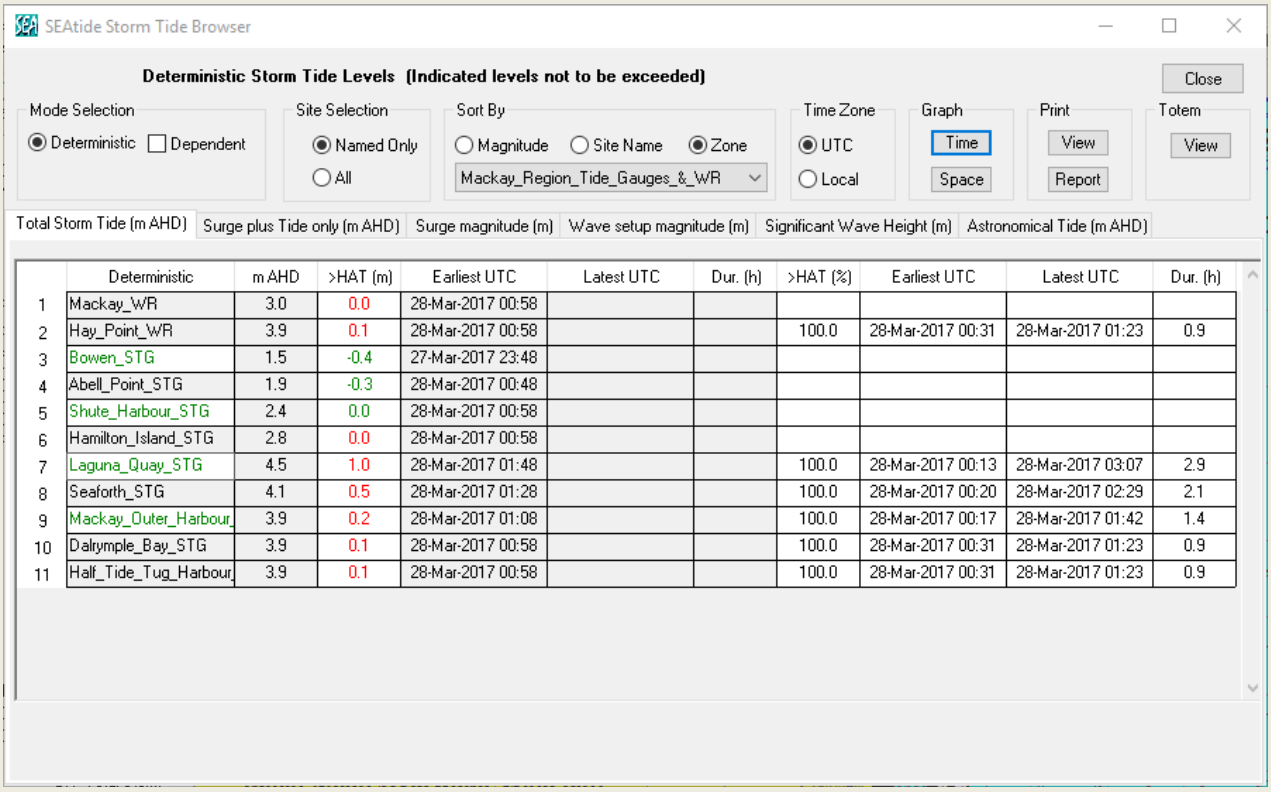



where AWS refers to wind sites, TG refers to tide gauges and WR to waveriders. The *Help* | *Error Log* can be used to check the status of the real-time data downloads, which may be subject to operational issues during extreme events or maintenance periods.

In the example that follows, a special "hindcast" mode (refer Appendix A) has been invoked to enable the replay of historical events, such as TC Debbie from 2017, where the original real-time data files have been previously saved to a specific folder. The status notification will be:



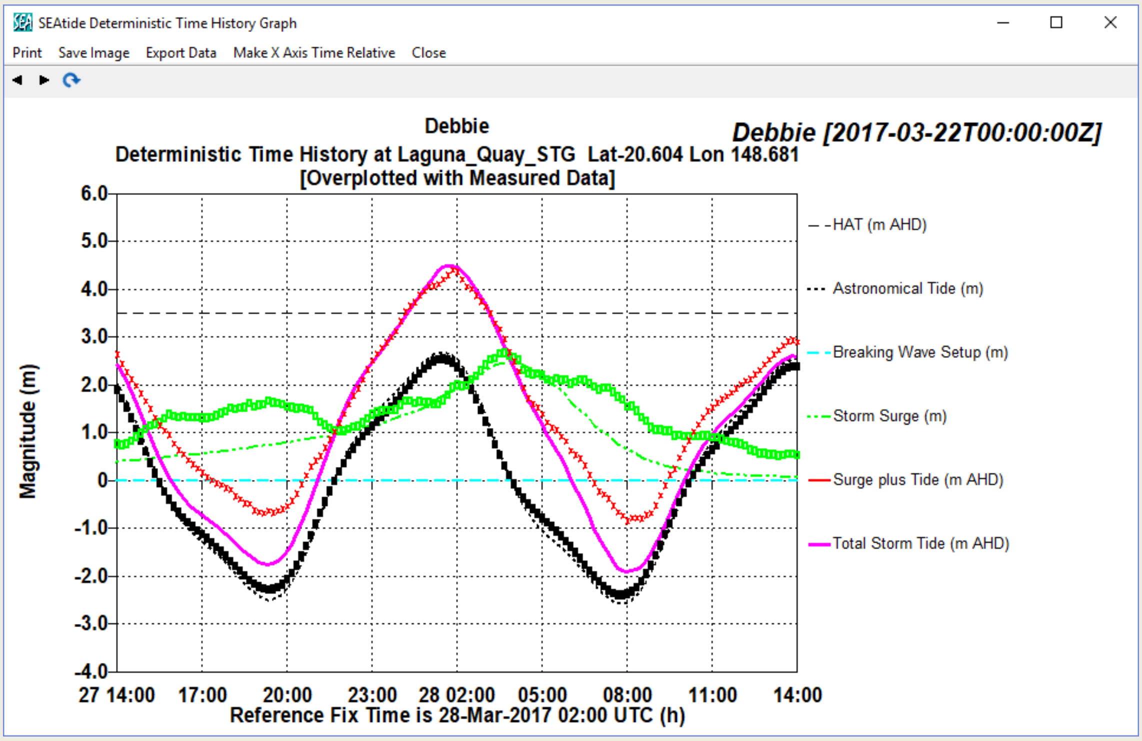

If there is an *Active Analysis*, then the *View Browser* will indicate any site that has real-time or hindcast data available with its name coloured green. To facilitate locating real-time data sites each region has a specific *Zone* where such sites are already grouped, as per example below:



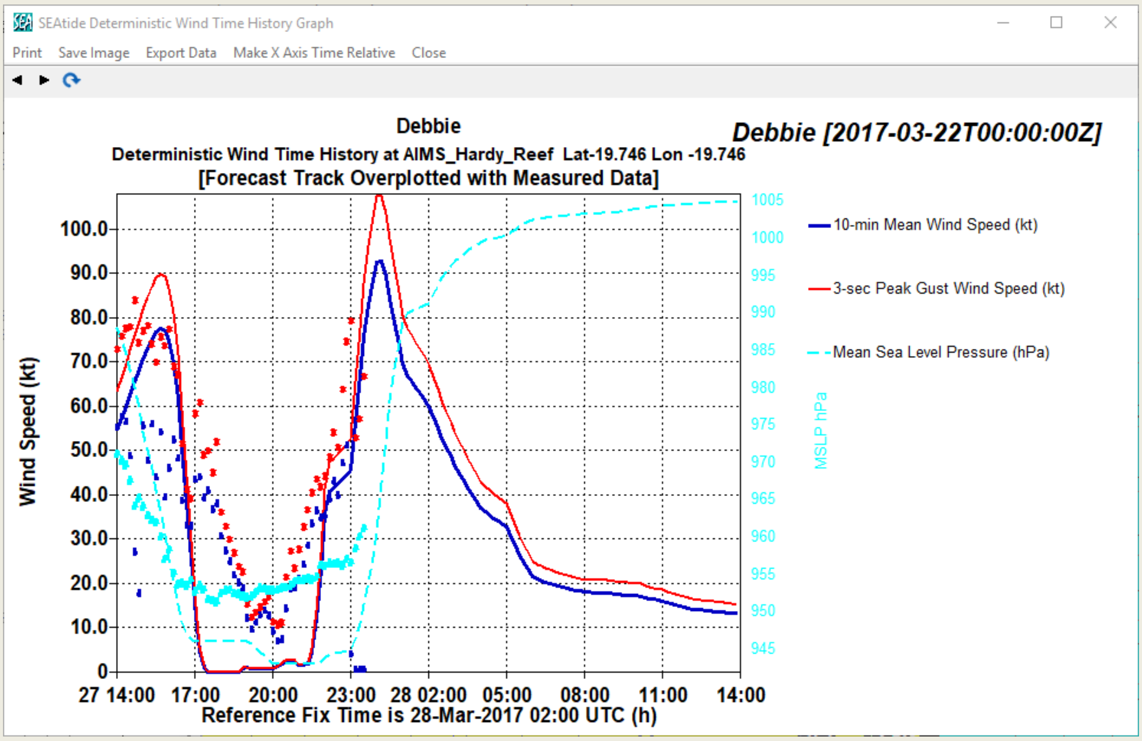

| | Deterministic | m AHD | >HAT (m) | Earliest UTC | Latest UTC | Dur. (h) | >HAT (%) | Earliest UTC | Latest UTC | Dur. (h) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Mackay_WR | 3.0 | 0.0 | 28-Mar-2017 00:58 | | | | | | |
| 2 | Hay_Point_WR | 3.9 | 0.1 | 28-Mar-2017 00:58 | | | 100.0 | 28-Mar-2017 00:31 | 28-Mar-2017 01:23 | 0.9 |
| 3 | Bowen_STG | 1.5 | -0.4 | 27-Mar-2017 23:48 | | | | | | |
| 4 | Abell_Point_STG | 1.9 | -0.3 | 28-Mar-2017 00:48 | | | | | | |
| 5 | Shute_Harbour_STG | 2.4 | 0.0 | 28-Mar-2017 00:58 | | | | | | |
| 6 | Hamilton_Island_STG | 2.8 | 0.0 | 28-Mar-2017 00:58 | | | | | | |
| 7 | Laguna_Quay_STG | 4.5 | 1.0 | 28-Mar-2017 01:48 | | | 100.0 | 28-Mar-2017 00:13 | 28-Mar-2017 03:07 | 2.9 |
| 8 | Seaforth_STG | 4.1 | 0.5 | 28-Mar-2017 01:28 | | | 100.0 | 28-Mar-2017 00:20 | 28-Mar-2017 02:29 | 2.1 |
| 9 | Mackay_Outer_Harbour | 3.9 | 0.2 | 28-Mar-2017 01:08 | | | 100.0 | 28-Mar-2017 00:17 | 28-Mar-2017 01:42 | 1.4 |
| 10 | Dalrymple_Bay_STG | 3.9 | 0.1 | 28-Mar-2017 00:58 | | | 100.0 | 28-Mar-2017 00:31 | 28-Mar-2017 01:23 | 0.9 |
| 11 | Half_Tide_Tug_Harbour | 3.9 | 0.1 | 28-Mar-2017 00:58 | | | 100.0 | 28-Mar-2017 00:31 | 28-Mar-2017 01:23 | 0.9 |

[33] The real-time tide gauge, waverider and AWS wind data links are specified in the region RDF file.

The time series graph options dialog will then display the option of over-plotting the available real-time data, as shown in the following example for *Laguna_Quay_STG*.




Users with access to the optional wind feature can additionally select any displayed AWS sites from the hazard map using the  button to invoke the site selection cursor. This will provide a time-series graph of wind speed, direction and/or MSL pressure where model and data can be compared. In each case the displayed modelled winds are adjusted to represent likely wind speeds at the site. The example below compares modelled wind and MSLP based on BoM forecast track parameters with real-time data from *AIMS_Hardy_Reef*, which failed after the eye passage:



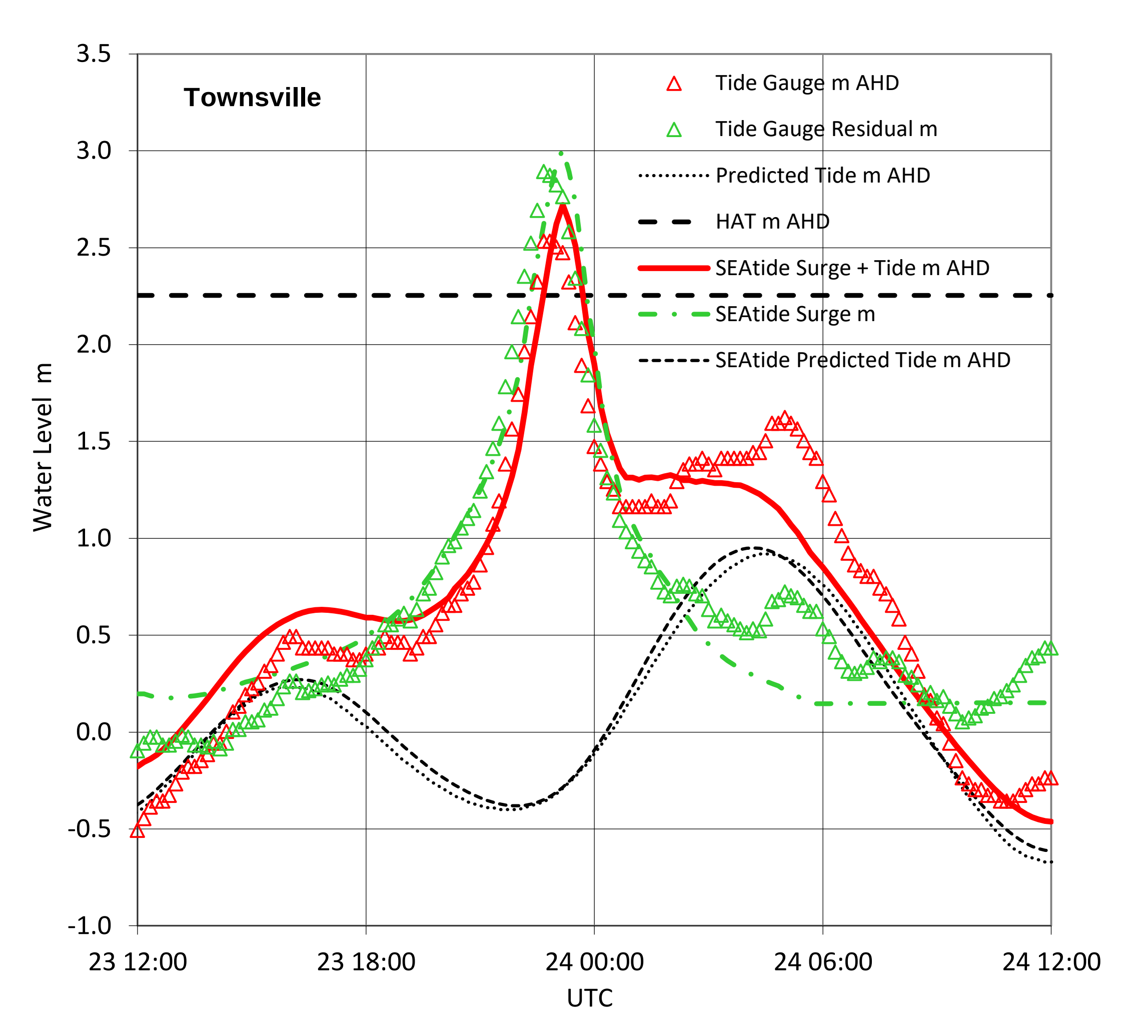
# 9 Example Storm Tide Validations

This section provides several examples of *SEAtide* capability based on hindcast analyses of specific historical storms where there were measured water levels from reliable tide gauges, regional wind speed, or MSLP observations to inform model parameter selections. Each of these events is described by the provided example SEA_<storm>.CYC files.

## *9.1 Tropical Cyclone Althea (Dec 1971)*

This storm, which precipitated an awakening to the potential storm tide hazard in Queensland, has been extensively investigated over time (e.g. Harper 2001, Harper et al. 2001) using a variety of wind and hydrodynamic modelling approaches. While critical observations of its intensity while approaching the coast some 35 km north of Townsville are not available, the wind and pressure data from Townsville Airport has provided a calibration point that enables a realistic reconstruction of the likely regional wind and pressure field and the Townsville tide gauge provides an accurate water level that is unaffected by wave setup.

The following compares the SEAtide predictions of Tide, Surge and Surge plus Tide at the *Townsvile_STG* location with the measured gauge water levels, the official predicted tide and the resulting residual (or anomaly) water level comprising the surge component.

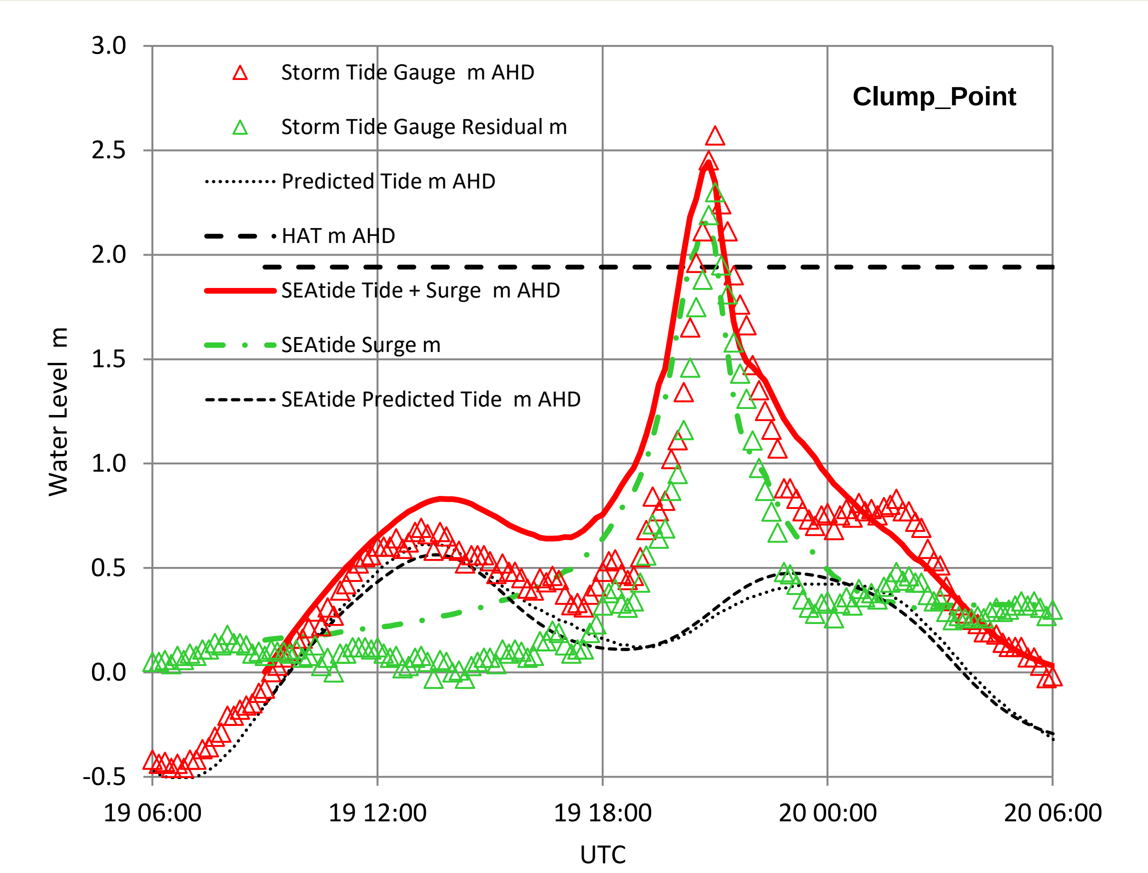


It can be seen that *SEAtide* slightly overpredicts the peak surge magnitude (+0.19 m) and the total water level (+0.15 m) compared with the tide gauge peaks, but the timing is within 0.5 h. It does not capture the shape of the trailing surge quite so well after the storm has crossed the coast but overall is an excellent example of what can be achieved by the model. The regional winds also well match the mean and gust winds recorded at Townsville Airport (refer references).

## 9.2 Tropical Cyclone Larry (March 2006)

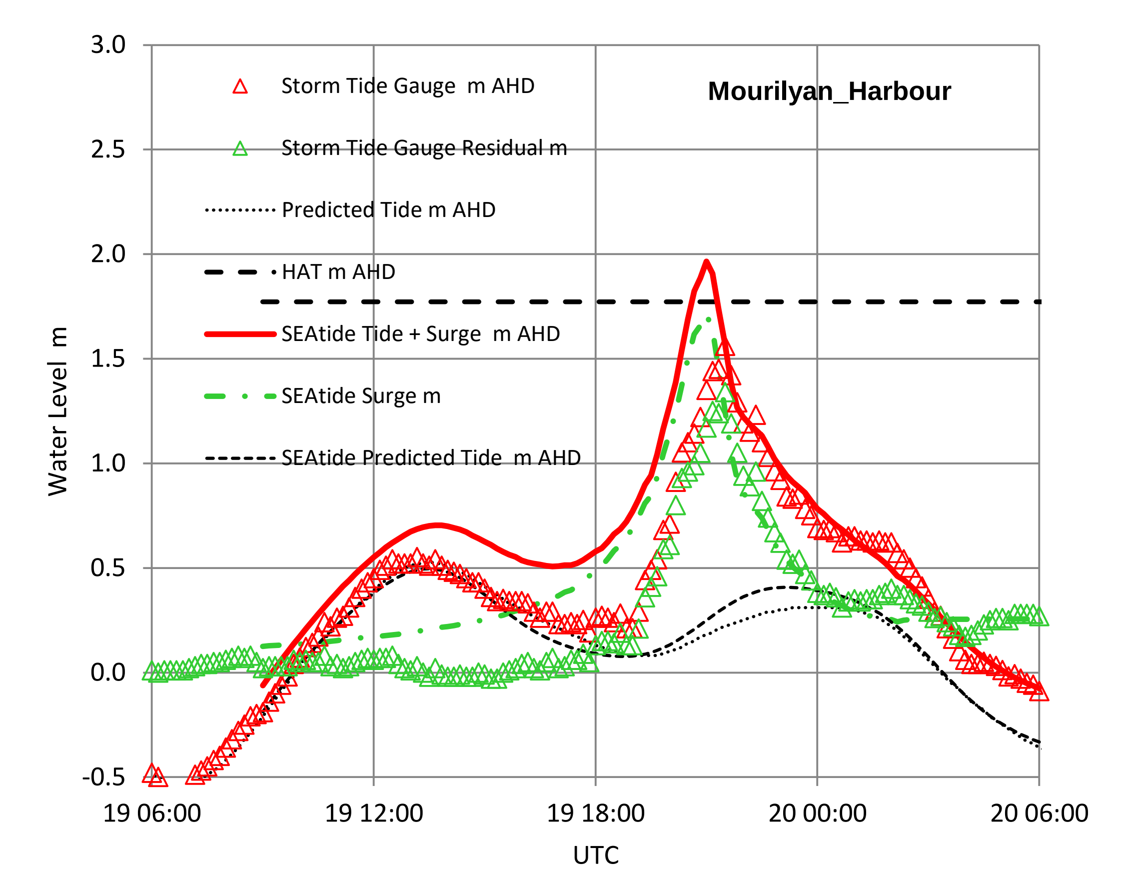
This storm also evaded coastal AWS when it made landfall near Innisfail but several MSLP and inland wind observations have enabled a reasonable reconstruction of the windfield from this event and the two tide gauges in the area (MSQ and EPA) captured the ocean response.

*SEAtide* winds in this case match the region of estimated peak gusts of about 65 m/s ($V_{0.2,600}$) from the damage survey undertaken by JCU-CTS (2006), as well as the various MSLP readings across the area.




The above comparison with *SEAtide* at *Clump_Point* shows a very good agreement, being a slight underprediction of about 0.15 m but excellent timing. Details of the rising and falling surge are again less well represented but the overall result is generally slightly conservative.

The below comparison with the *Mourilyan_Harbour* tide gauge, which was closer to the landfall point and experienced a lower surge, shows a slight overprediction by SEAtide of about 0.4 m. It can be noted that the tide prediction accuracy during this period is less than what can typically be achieved, being related to the sometimes-complex neap tides inside the Barrier Reef at this location.




## 9.3 Tropical Cyclone Yasi (Feb 2011)

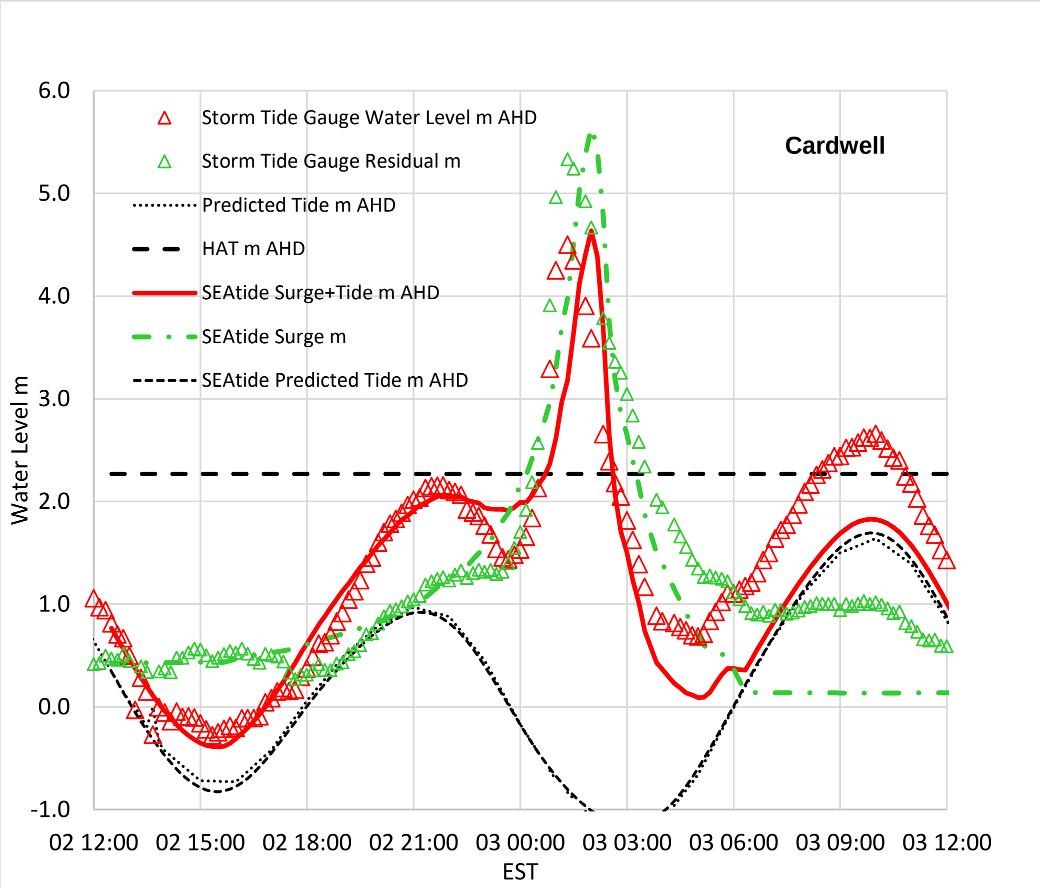
This storm crossed the coast near Clump Point some six years after TC Larry and was a larger system capable of generating a greater storm tide impact. A peak surge of over 5 m was measured at the Cardwell storm tide gauge (DERM), which occurred near low tide but was still capable of causing significant inundation across the Rockingham Bay area between Hull Heads and Cardwell.

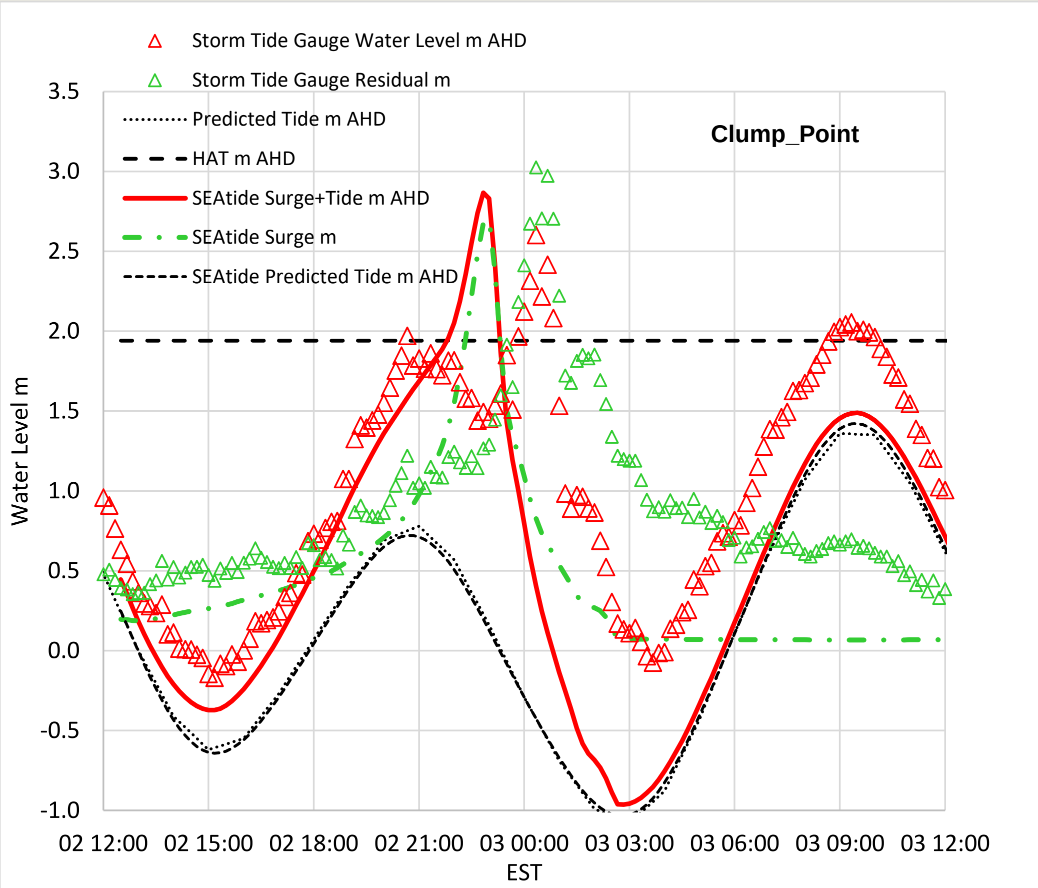
Again, peak winds in the area were not measured directly due to lack of AWS coverage, although the DERM gauge at Clump Point measured an MSLP of 930 hPa during the eye passage. The JCU-CTS (2011) report assessed peak wind gusts based on damage surveys as being in the range of 65 to 70 m/s ($V_{0.2,600}$) and the adopted *SEAtide* storm parameters match these values well.

The following comparisons of modelled and measured storm tide components at *Cardwell_STG* and *Clump_Point_STG* show that *SEAtide* matches within 0.15 m of the peak at Cardwell and within 0.3 m at Clump Point. The timing at Cardwell is very good (0.7 h) but it leads the measured peaks at Clump Point by about 1.5 h.

The BoM Murray Flats ALERT gauge some 12 km inland between these two sites registered a sharp rise in water level to above 6.5 m AHD at a time consistent with these gauges.

Using these storm parameters, the predictions at the more remote Cairns and Townsville gauges are less accurate but within 0.5 m. This emphasises the need for a forecast to consider a wide range of potential storm scenarios (intensity, size, speed) so that the threat to all communities can be reasonably assessed.


Storm Tide Gauge Water Level m AHD
Storm Tide Gauge Residual m
Predicted Tide m AHD
HAT m AHD
SEAtide Surge+Tide m AHD
SEAtide Surge m
SEAtide Predicted Tide m AHD
Cardwell
Water Level m
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
02 12:00
02 15:00
02 18:00
02 21:00
03 00:00
03 03:00
03 06:00
03 09:00
03 12:00
EST

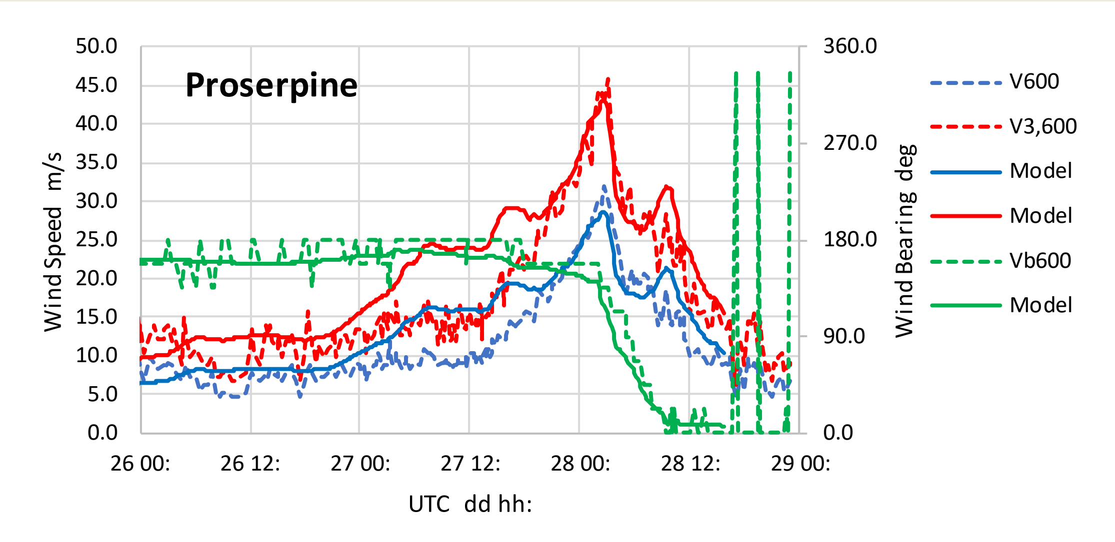

Storm Tide Gauge Water Level m AHD
Storm Tide Gauge Residual m
Predicted Tide m AHD
HAT m AHD
SEAtide Surge+Tide m AHD
SEAtide Surge m
SEAtide Predicted Tide m AHD
Clump_Point
Water Level m
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
02 12:00
02 15:00
02 18:00
02 21:00
03 00:00
03 03:00
03 06:00
03 09:00
03 12:00
EST

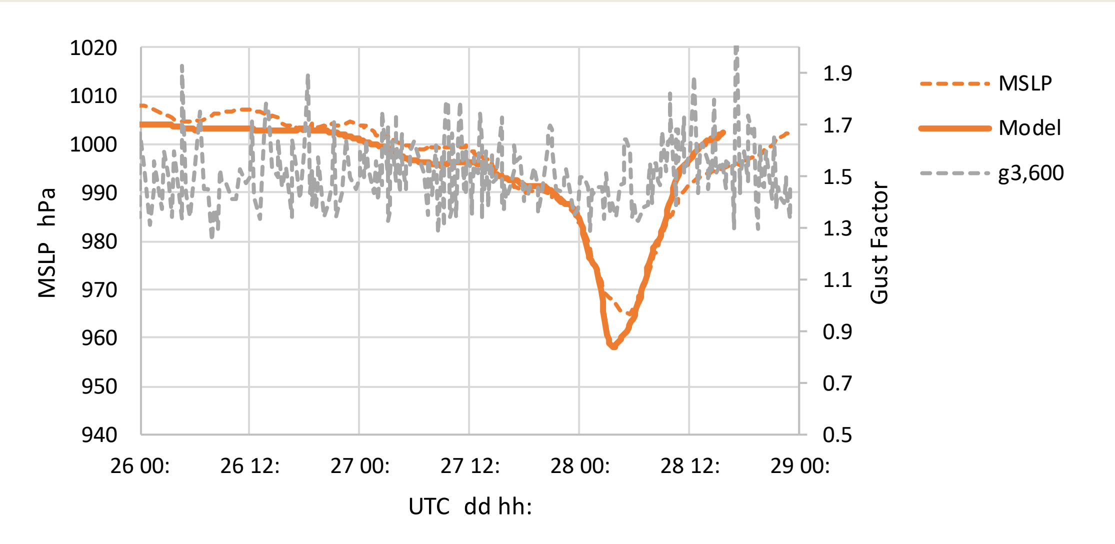
## 9.4 Tropical Cyclone Debbie (Mar 2017)

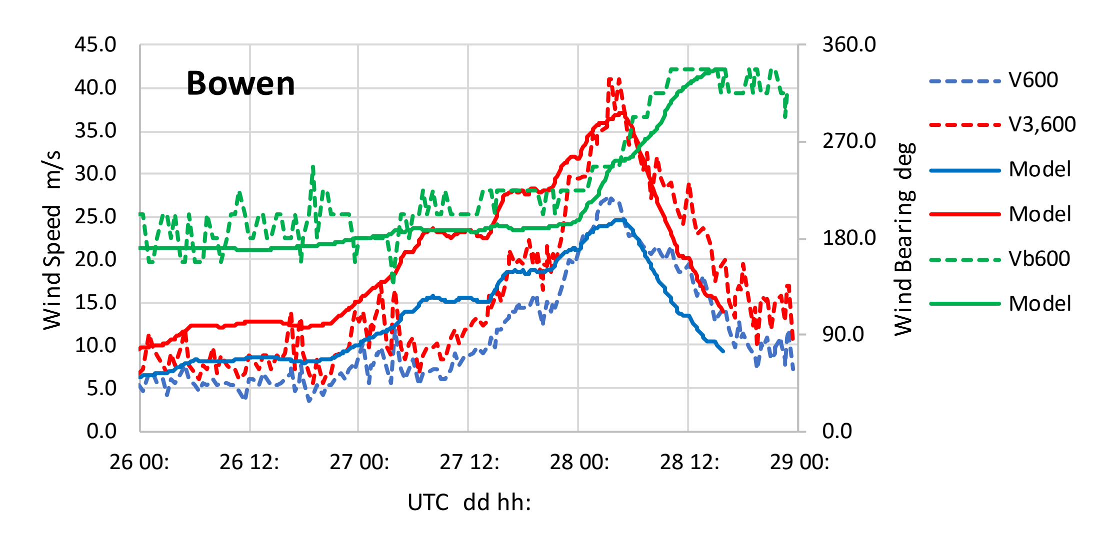
This storm, classified by the Bureau of Meteorology (BoM) as a Category 4 event, crossed the coast north east of Airlie Beach around midday on Tuesday 28 March 2017 (JCU-CTS 2017).

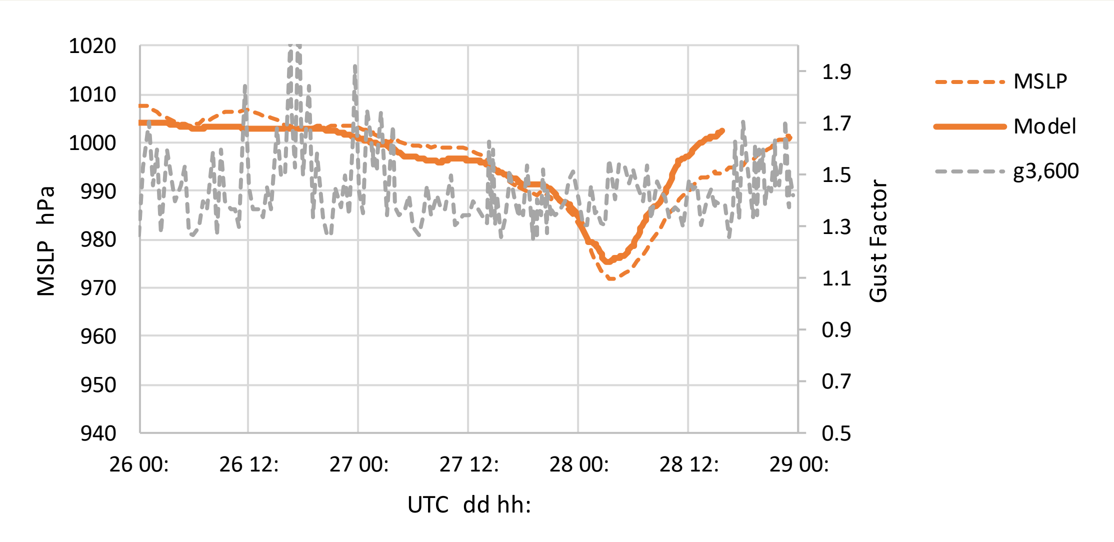
A peak surge of 1.2 m was recorded at Shute Harbour STG (DSITI) with 2.7 m at Laguna Quay, which occurred around 2 to 3 hours after the high tide, resulting in total water levels of 2.6 m AHD and 4.5 m AHD respectively. This was over 1 m higher than HAT at Laguna Quay, with evidence of even higher inundation in the northern part of Repulse Bay at Wilsons Beach (JCU-CTS 2017).

Surface wind and pressure across the impacted area were measured by BoM AWS at Proserpine Airport, Bowen Airport and Hamilton Island, although the latter site is significantly impacted by topographic effects. An AIMS weather station at Hardy Reef experienced the eye passage with a MSLP of 951 hPa and a peak V600 of 29.7 m/s. Using this to calibrate the BoM forecast intensity and storm scale enabled reconstruction of winds across the region that well match the recorded values at Proserpine and Bowen (refer below).



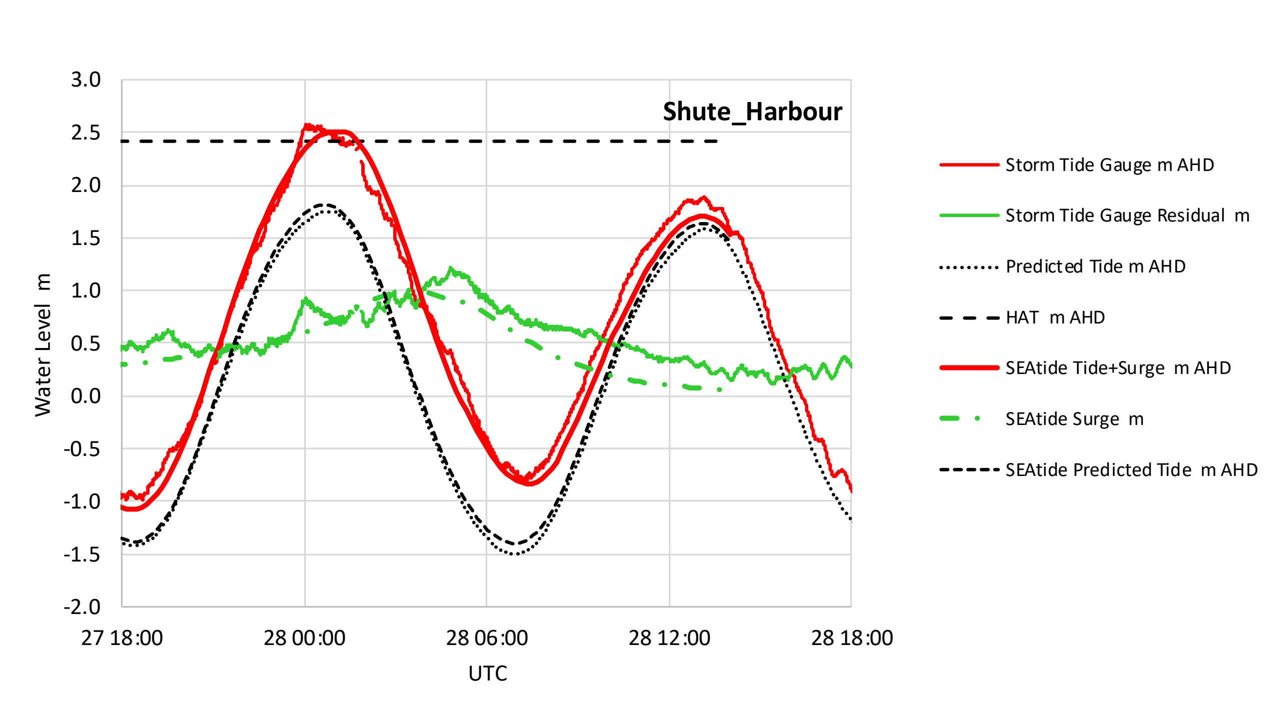


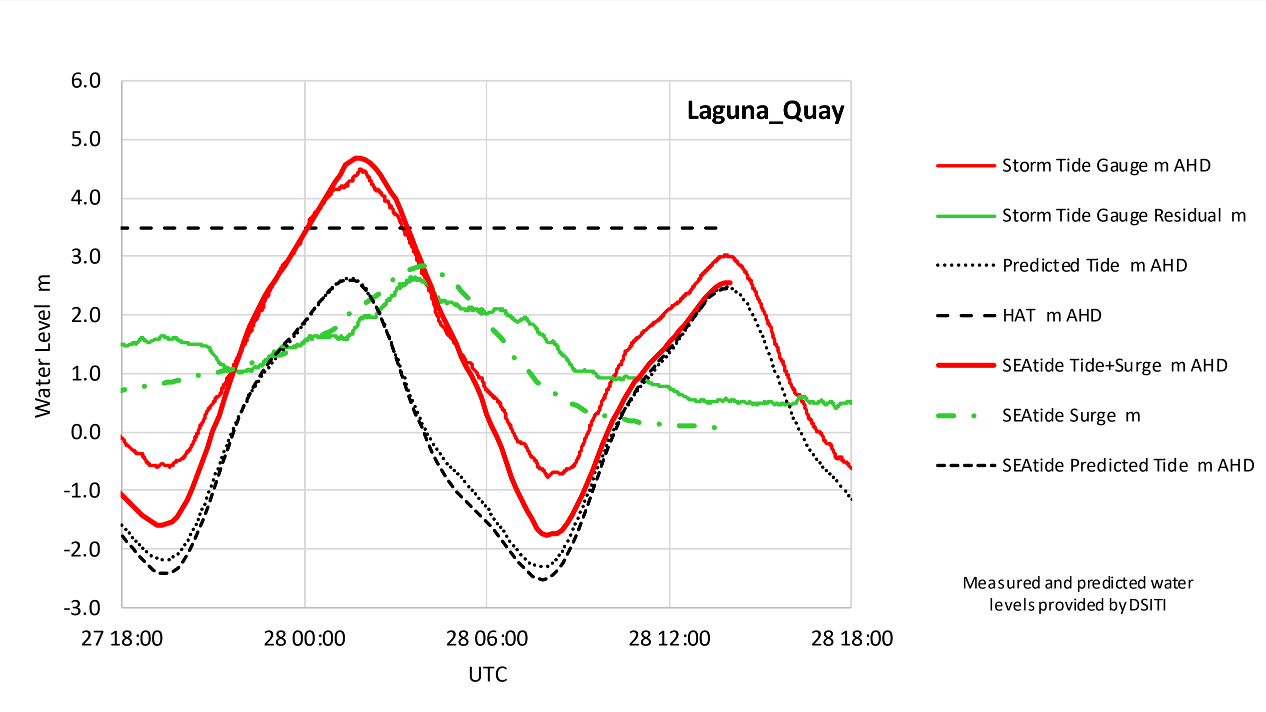




The above-calibrated storm parameters were then converted into a steady-state SEAtide CYC file representation to permit modelling of the storm tide by *SEAtide*.

The following comparisons of modelled *SEAtide* and measured[34] storm tide components at *Shute Harbour_STG* and *Laguna Quay_STG* show that *SEAtide* matches within 0.10 m of the peak at Shute Harbour and within 0.20 m at Laguna Quay. The timing at each location is also very good.

[34] Measured STG data provided by DSITI.


Shute_Harbour
Water Level m
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
27 18:00
28 00:00
28 06:00
28 12:00
28 18:00
UTC
Storm Tide Gauge m AHD
Storm Tide Gauge Residual m
Predicted Tide m AHD
HAT m AHD
SEAtide Tide+Surge m AHD
SEAtide Surge m
SEAtide Predicted Tide m AHD


Laguna_Quay
Water Level m
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
27 18:00
28 00:00
28 06:00
28 12:00
28 18:00
UTC
Storm Tide Gauge m AHD
Storm Tide Gauge Residual m
Predicted Tide m AHD
HAT m AHD
SEAtide Tide+Surge m AHD
SEAtide Surge m
SEAtide Predicted Tide m AHD
Measured and predicted water levels provided by DSITI

# 10 Assumptions and Limitations of the Predictive System

The foregoing validation examples demonstrate that *SEAtide* is capable of deterministically matching measured water levels during real storm tide events to an accuracy of 5% in magnitude and ± 1.0 h. Generally, however, the accuracy might be considered as likely of the order of ± 0.5 m near the peak of a storm. As always, the greatest uncertainty stems from the forecast storm intensity and wind structure, but the parametric model assumptions also limit the attainable accuracy for locations across a wide region.

The *SEAtide* system specific assumptions and limitations have been variously discussed throughout the description of the model development and calibration (e.g. SEA 2002, GHD/AMC 2014). Notwithstanding the significant efforts to minimise adverse outcomes and maintain a conservative prediction, these assumptions and limitations should be understood by all persons operating the predictive system, *inter alia*:

- The underlying TC wind and pressure fields used to establish the ocean forcing are based on idealised representations that will not always provide a good fit to a specific storm event;
- The underlying wind model has no knowledge of land and may overestimate wind forcing and/or direction in complex near-coastal environments. Users can approximate decay over land if deemed a significant factor by using a stepped time sequence having different intensities;
- The underlying hydrodynamic storm surge and spectral wave models, while representing best practice standards, are affected by the resolution and accuracy of the bathymetry data that is available;
- The total storm tide prediction will depend on the accuracy of the tidal prediction at any site, which varies across the regions (published HAT levels are reproduced where available);
- The underlying tide, storm surge and spectral wave models have not been "coupled" but rely on linear superposition of effects and may therefore not reproduce some specific characteristics in some situations;
- The modelling assumes that the storm tide response at any site and at any time can be adequately described by the assumption of constant storm parameters (including track) over the preceding 12h of storm approach (i.e. an equilibrium or steady assumption);
- The parametric storm tide model is a further approximation to the models that have been used to construct it and only produces predictions at locations <u>adjacent</u> to "coasts" – it does not consider how far storm tides might penetrate inland in specific situations and generally coastal levels should be transferred inland assuming no degradation;
- The parametric model does not reproduce negative storm tide events or (generally) potentially multi-peaked events and will tend to smooth out such situations;
- The parametric model will perform best on relatively open coast sites where typical depths are 10m or more; in areas where depths are very shallow over large regions (say <5 m for 50 km offshore) or where the coastal features are very complex, the model performance may be degraded;
- The model accuracy is likely to be greatest closest to the centre of the storm and may be reduced at more remote locations;

- There may be cases where the parametric model is not fully able to generate a prediction either away from land or at the extremities of some regions, due to specific combinations of storm speed and distance etc;
- There may be cases in areas of overlapping regions where the predictive model provides slightly differing guidance due to changes in representation between each region (e.g. a specific track may be treated as "parallel" in one region and "crossing" in another) and operator interpretation may be needed;
- The model may be less reliable at locations that do not lie on the "assumed line of coast" for a specific region (viewable from the *SEAtide* system) where the predictions are referred from the modelled storm events crossing the assumed line of coast – an overlapping region may provide a better representation, or the prediction should be more carefully scrutinised;
- The wave setup interaction is partly reliant on the specified height of the coastal lands, which are often unknown except where high resolution data has been made available. In other areas, only approximate values are available, and the *Dune Crest Height* may have been set at a nominal elevation relative to HAT (refer Release Notes);
- Wave runup is not presently included but may add a further 1 to 2 m or more of intermittent vertical elevation in specifically exposed locations capable of creating runup. Inclusion of wave runup in the model is technically possible but accuracy will always be limited by a lack of local data on beach slope and (as noted regarding wave setup), the actual height of the coastal lands and the type of bedform and vegetation.

**Operators of the predictive system are therefore required to check and test the model predictions in as many ways as the system allows and to use their own knowledge, judgement and understanding as to the likelihood that any specific model prediction might be erroneous. The system allows for the import of an independent external deterministic model prediction that can always be used to provide further confidence if required.**

Some of the above limitations can be reduced or alleviated by access to better data and the predictive system provides means by which, for example, tidal information, surge-tide interaction and dune crest heights can be modified through the various input data files.

# 11 Help and Support

The system Help menu provides the following:

- Access to an online help file
- Access to this user guide
- The ability to send an email[35] to report issues or to request assistance via seatide@systemsengineeringaustralia.com.au
- The ability to view the session Error Log
- Details of Third Party Data used by SEAtide

The best way to report an issue that has occurred in the present session is via the *Help | Send Email* feature, which will include details of the licenced site, the user and the PC as well as a copy of the current CYC file and the Error Log file that may contain useful information on the problem.

Please refer to the agreed Licence conditions to determine the extent of help that might be available and the amount of training that is included in the annual fee.

[35] Due to a MS Windows™ limitation, if your email client is not of the same "bit type" as the SEAtide version, you will at first see an error. For example, the 64-bit SEAtide will only be able to directly communicate with a 64-bit MS Outlook™ client. If you have a 32-bit email client, then after receiving the initial error, SEAtide will invoke a special 32-bit emailer as a work-around for you to complete the process, which may take a few more seconds to launch.

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# Appendix A *SEAtide* Installation, Renewal and Removal

The *SEAtide* model comes complete with an automatic installer/uninstaller that can be used to install the modelling system either on a system-shared networked folder or on a single personal computer, and to selectively uninstall as required. The supplied Readme.txt and Release_Notes.txt should always be consulted for more up to date installation information.

The supplied Licence.txt must be agreed to by the user during installation.

**(a) Model Installation**

To install *SEAtide*, simply locate and execute the *Install.exe* file on the distribution medium. The installation wizard will then ask for the installation root directory (default suggestion is *c:\Program Files\SEAtide* but only if the end users have the necessary privileges[36]). The installer can browse to find or create any suitable local or networked directory.

All the necessary files will be copied over and the model will be ready to execute[37]. An option during installation will also add a *SEAtide* shortcut to the *Start Menu* and/or the desktop if required. This is only immediately useful if the installation machine will also be a user machine. Example Scenario (*.cyc) and Forecast Track files are provided in a sub-directory of the install directory *\SEAtide_User*.

**(b) Model Initialisation**

To execute the model from a non-installation machine (e.g. from a network) it will first be necessary to locate the executable on the installation path and, if desired, create a local desktop shortcut or add the shortcut manually to the local machine *Start Menu*.

It then may be desirable that each user machine first create a copy of the installation sub-directory *\SEAtide_User* and its contents to use as a local machine/user work area. This directory can be located anywhere and may be renamed or shared to suit specific applications. Any folder can be selected for data input and that will become the new default folder for future use for that user/PC until it is again changed.

The first time the model is executed at any personal computer by any specific user (including the machine that holds the installation) it will ask for an *Unlock Code*, which may be supplied in the file *Unlock_Code.txt* or via email. If the validity period has expired another must be obtained from Systems Engineering Australia Pty Ltd. This is client-specific and will have a validity period and expiry date that will be patched into the executable file.

To facilitate unlocking by any user the runtime parameter *unlock=<unlock_code>* can be specified in a shortcut, which only then requires the user to OK at the licence screen. If the unlocking user has suitable Administrator privileges it is possible to unlock that PC for all users rather than just the current user at that time. This could be desirable to avoid the code validity period expiring.

Next, the model will expect to find its essential files (e.g. SEAtide.ini) on the same path as the executable, unless otherwise directed.

This is the last step of the unlocking process when the model looks to locate its “model data” folder and the other default installation sub-directories. The INI file is useful for this purpose and

[36] MS Windows users should also be aware that installing into the c:\Program Files or %systemroot% area is liable to automatically create a “virtual store” of compatibility files unless the users are given permission to write to the default file directories. This can become confusing as Windows will seamlessly show original and changed files as though they are in the same physical directory. Consult your system administrator to avoid this issue.

[37] Instances of problems installing to network drives have been reported, potentially related to directory latency issues. In this case a workaround is simply to copy the entire distribution structure via file manager. This is possible because no registry changes are made during the install process.

can especially assist deployment if the model is to be installed to a non-default area or shared file structure. While the default file is SEAtide.ini in the EXE folder, a runtime parameter ini=<ini path> can be used to point to any specific INI file[38].

The shipped default SEAtide.ini file specifies the model regional data file (RDF) path in a relative sense, expecting it to be a child to the EXE folder. Blank paths are specified for any default directories, which will become \SEAtide_User as a child to the EXE folder.

The system Administrator can pre-edit this file to reflect the operational context by substituting the appropriate quoted paths, e.g. this is the supplied INI file specification:

| | |
|---|---|
| *RDF_Filepath=' SEAtide_Qld-Gulf'* | is the required model region EXE-relative data path |
| *CYC_Filepath=' '* | is the desired input/output path for all CYC files |
| *TCT_Filepath=' '* | is the desired input Forecast TC Track file path |
| *REP_Filepath=' '* | is the desired report output path (totems are published here) |

Example:

*CYC_Filepath='S:\Qld-TCWC\SEAtide'*

These paths are used explicitly unless they are blank (defaults apply) or are assumed relative to the EXE folder if they do not contain a "\".

If *SEAtide* cannot find any of the default or specified paths on initial start-up then the user will be prompted to locate all the paths (which can be tedious). This process only happens once during the unlock process on each PC. To refresh this outcome would require an uninstall and then another install, or experienced users can edit the registry keys (below).

After *SEAtide* has been used for the first time and closed normally, it will write details of the current paths and licence information into the specific user's machine registry for future use, as follows:

*HKEY_CURRENT_USER\Software\Systems Engineering Australia\SEAtide*

If the model has been installed by an Administrator, it may also make changes to the following registry entry:

*HKEY_LOCAL_MACHINE\Software\Systems Engineering Australia\SEAtide*

The INI file also allows specification of the default model start-up region, e.g.

*Default_Region='Cairns'*

Which can be any of the map names declared in the SEAtide_master.rdf \SHAPE_NAME definitions.

There are other INI parameters that will be actioned each time the model is started that change various default model settings, e.g.

| | |
|---|---|
| *Prompt_During_Region_Suggest='true'* | auto region selection is default |
| *Preference_Time_Axis_Relative='true'* | absolute time axis labelling is default |
| *Preference_Graph_Size_percent=30.* | 50% of screen size graph windows is default |
| *Tide_Stations=' '* | regional tides file for checking |

These have been deactivated by comment in the shipped INI file.

[38] If the file path has imbedded blanks then the whole runtime parameter must be enclosed in "", e.g. "ini=file path with blanks".

It can be noted that individual users can create their own customised INI file and invoke SEAtide from a desktop shortcut that sets the ini= parameter to whatever is the path to their INI file. In this way the experience can be tailored to specific devices, especially such as setting the default graph size (e.g. laptops, multi-screen etc). Likewise, if multiple SEAtide installations are present (Qld-Gulf, NT, WA etc) then different INI files can be specified when wishing to activate a specific region. This why a default SEAtide.ini is installed in addition to an installation-specific one (e.g. SEAtide_Qld-Gulf.ini).

**(c) Licence Renewal or Upgrade**

When the installation expiry date nears, a popup reminder will appear that provides an opportunity to enter a renewal code. After the expiry date a short period of grace is provided to enter a renewal code before the model will cease operating.

Users must be aware of any impending renewal dates when relying on the availability of the model. Renewal dates opposite to the TC warning season are therefore recommended.

Adding the runtime argument “upgrade” when starting SEAtide (e.g. via a dedicated shortcut) will invoke an opportunity to enter a renewal <unlock_code> without a reinstall.

**(d) Updates**

From time to time there may be maintenance updates (refer Licence conditions) that will be accompanied by instructions for installation. These may or may not require an uninstall or may simply require updating the EXE file or one or more data files.

**(e) Uninstalling**

To uninstall, simply locate and execute the *Uninstall.exe* file on the distribution medium or in the installation directory.

This will offer to either (1) uninstall *SEAtide* from the system, in which case the installed model and all its data files will be removed, or (2) to uninstall from a local user machine, in which case only the registry entries will be cleared, and no data files will be affected.

A user with Administrator privilege is required to perform the “system uninstall”.

Note that if *Uninstall.exe* is located on the installation directory then it may interrupt a full system uninstall and the installation directory may need to be removed manually.

If changing from a 32-bit version to a 64-bit version the *CLEAN* utility can be supplied on request to first remove old registry entries without having to do a complete *UNINSTALL* and *INSTALL*.

**(f) The User Error Logging File**

This file maintains a session-specific user error log that can be useful in tracing unexpected behaviours. It is written to the directory defined by the system environment variable %temp%, which is normally attached to the default USER path. This file has a name of the form *<user>_<#>_<PC>_SEAtide.log* and will be automatically attached to any *Help | Send Email* action by the user[39]. These files are removed at subsequent model restarts. The <#> is a “user code” from 0 to 9 that allows up to 10 models to coexist (subject to user care and available PC capacity).

**(g) Temporary Scenario Output Files**

The model also needs to write another temporary file each time a prediction is performed. This uses the user error logging filename as a prefix and appends “.scenario”. This file is always

[39] As described in Section 11, if the MAPI client is 32-bit, this will invoke an error-trapping workaround to bridge between the 64-bit SEAtide and the 32-bit mail client that might prompt security checks.

deleted after each analysis but during some simulations with large storm counts in a multi-region setting, may exceed several GB in size. The %temp% path can be permanently changed via Control Panel | System | Advanced | Environment Variables or specified as a runtime parameter.

**(h) The SAS File**

Each region has a “*SEAtide* Active Sites” or SAS file, which is an ASCII file capable of being edited by an authorised/qualified/trained person.

It enables:

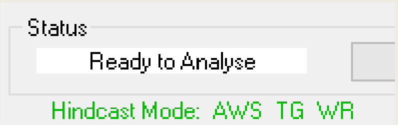
- Assigning of sites to Zones for display
- Changing the plotting order of the mapped site output
- Renaming of sites, removal of sites
- Adjusting of surge-tide interaction or wave setup parameters or beach classifications
- Specifying local reference water levels for display on totem graphs

Importantly, values in the column labelled “Raw#” **must not** be altered

Systems Engineering Australia Pty Ltd takes no responsibility for model operation if any of these files are altered but will offer training in the details of this process.

**(i) Hindcast Mode**

Adding the runtime argument “hindcast=<user_path>” when starting SEAtide (e.g. via a dedicated shortcut) will invoke “hindcast mode” whereby the model will act as though a real-time event is in progress but instead of downloading data from the internet, will expect to find the necessary download files on the <user_path>. This feature is designed to assist in post-event analysis to test the impact of changing parameter selections. When this mode is active the following status is shown, together with codes indicating the types of data that are available on the <user_path>:




The user must still invoke a CYC file that is consistent with the previously saved data files on the <user_path> to enable the real-time displays.

The installation provides a sub-folder “SEAtide_User\Hindcast” that has an example of this feature for TC Debbie and advice on how to set up a shortcut to enable it.

**(j) Summary of EXE Runtime Arguments**

| | |
|---|---|
| *hindcast=<user_path>* | the path to saved real-time data files |
| *model=<ini_file>* | overrides default model RDF and INI file |
| *ini=<ini_file>* | overrides default model INI file |
| *nosplash* | suppresses the splash screen graphic and load progress on start-up |
| *temp=<temp_path>* | override the use of the default Windows %temp% path |
| *unlock=<code>* | will unlock the licence |
| *upgrade=<code>* | will replace an existing unlock code |

# Appendix B The *SEAtide* Wind Model and Pop-Up Profile

The *SEAtide* wind model is based on the Harper and Holland (1999) approach, augmented by the use of the "double Holland" concept (Thompson and Cardone 1996). This provides a continuous axisymmetric wind and pressure field with an applied "wavenumber-1" forward speed adjustment. The exact parameter settings can vary between the parametrically-modelled surge and wave regions and are detailed in each RDF file.

As noted in Section 3.3, *SEAtide* models the wind and pressure field according to:

- Storm MSL central pressure, $p_c$ (hPa);
- Ambient or environmental pressure, $p_n$ (hPa) (e.g. $p_{OCI}$ + 2 hPa);
- Radius to maximum winds, *RMW* (NM);
- Windfield peakedness *B*, which adjusts the wind profile shape;
- Track or forward motion vector, $V_{fm}$ (kn) and $\theta_{fm}$ (deg bearing).

Because the most common source for forecast track parameters of tropical cyclone intensity is obtained from the Dvorak method (Dvorak 1984) the initial intensity will likely be represented by a *Vmax*, from which an estimate of the central pressure *pc* is then obtained (e.g. Courtney and Knaff, 2009). It is important that this "intensity pairing" best matches the available *SEAtide* wind model assumptions so that the most appropriate storm tide response can be replicated.

The following are the important relationships to bear in mind when adjusting the Scenario parameters so that the best "Holland" wind field match is obtained:

- The *Vmax* estimate must be the 10-min average metric[40], aka *V600*;
- The "Holland B" value directly relates *Vmax* and *pc*, i.e. *Vmax* = f { *Δp* , *B* } ;
- The *B* value is independent of the *RMW*;
- The shape of the radial wind profile is dependent on *B*, such that e.g. *Rgales* = f { *B* }

Hence modifying *B* will both affect *Vmax* and also the outer wind profile shape and it may often not be possible to simultaneously match the desired Vmax, *Δp* and *Rgales*. This needs to be considered because the storm tide is an integrated inertial response that is driven by the total kinetic energy of the storm system as it interacts with the coastal features and is less sensitive to the central *Vmax* of the inner core. Accordingly, matching the radial wind profile over the range (say) 1.5 to 5 *RMW* may prove more effective in estimating the correct storm tide response than pursuing *Vmax* alone, especially because increasing *B* acts to decrease the outer wind profile. With scatterometry data often now being available *Rgales* can be more reliably estimated than *Vmax* and the user can optionally use *Rgales* instead of a fixed *RMW* to adjust the shape of the wind profile together with *B*. Figure B-1 from Harper (2002) illustrates the variability in wind profile shape for a Holland profile of fixed *Vmax* and a selection of varying *pc* and *B* values that will match that *Vmax*. The variability in *Rgales* (17.5 m/s) can be seen to be quite significant. The "double-Holland" profile in *SEAtide* reduces this sensitivity of *Rgales* to *B* by providing an outer B=1 vortex that has 8 hPa of the total *Δp* assigned to an outer R2 spatial wind scale of 100 km.

When a Forecast Track file fix is imported, *SEAtide* calculates the *B* value based on any supplied *Vmax* and (*pn-pc*) values (i.e. a 2 parameter fit). It also checks for consistency between these values, noting that the expected typical range for *B* is about 0.8 to 2.5, and each modelled region has only a finite range of modelled *B* parameter space available to interpolate. As noted by pressing the "View Issues" button, simply forcing *SEAtide* beyond its available parameter values has no effect on the result.

[40] Refer Harper, Kepert. and Ginger J., WMO TD1555, 2010.

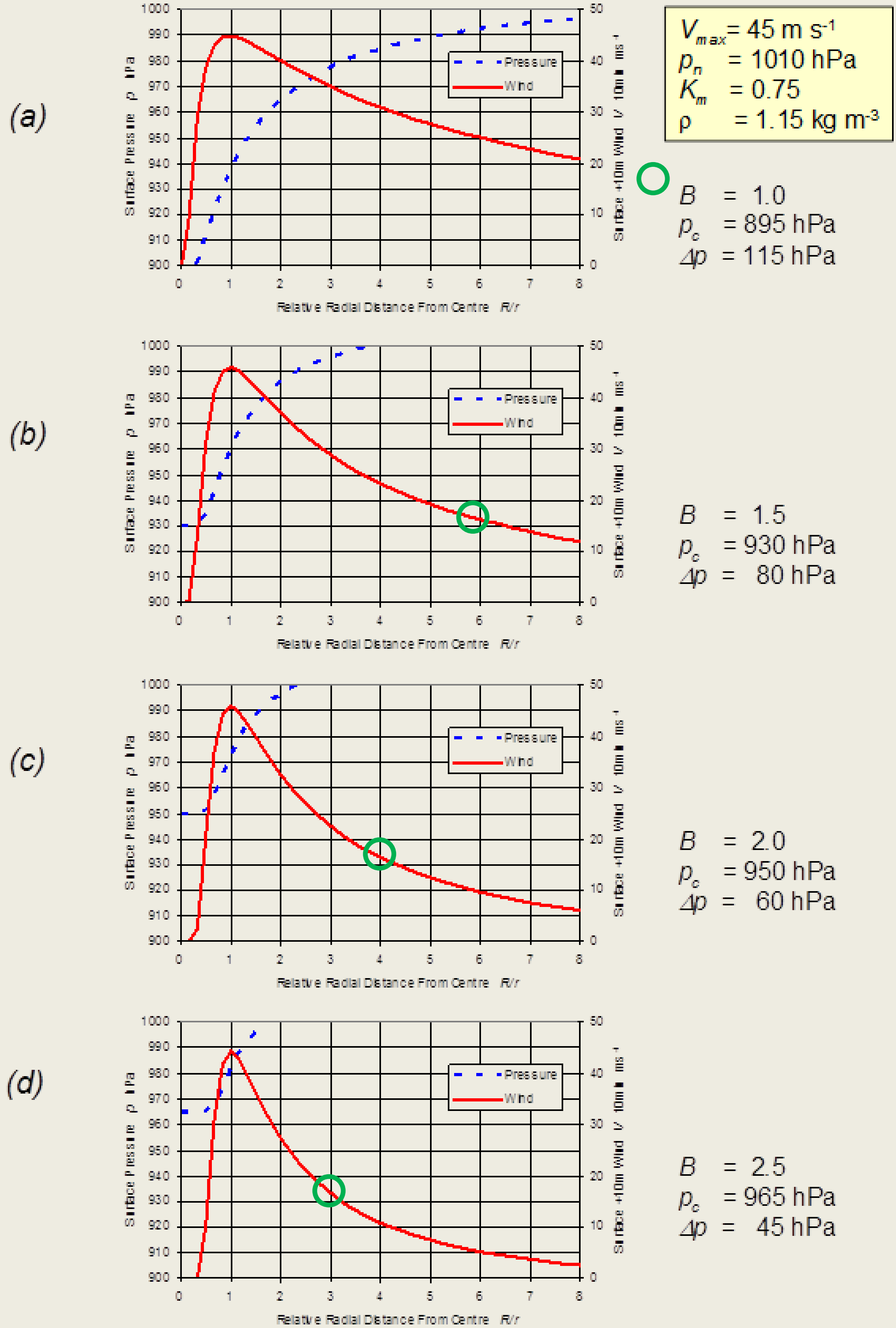


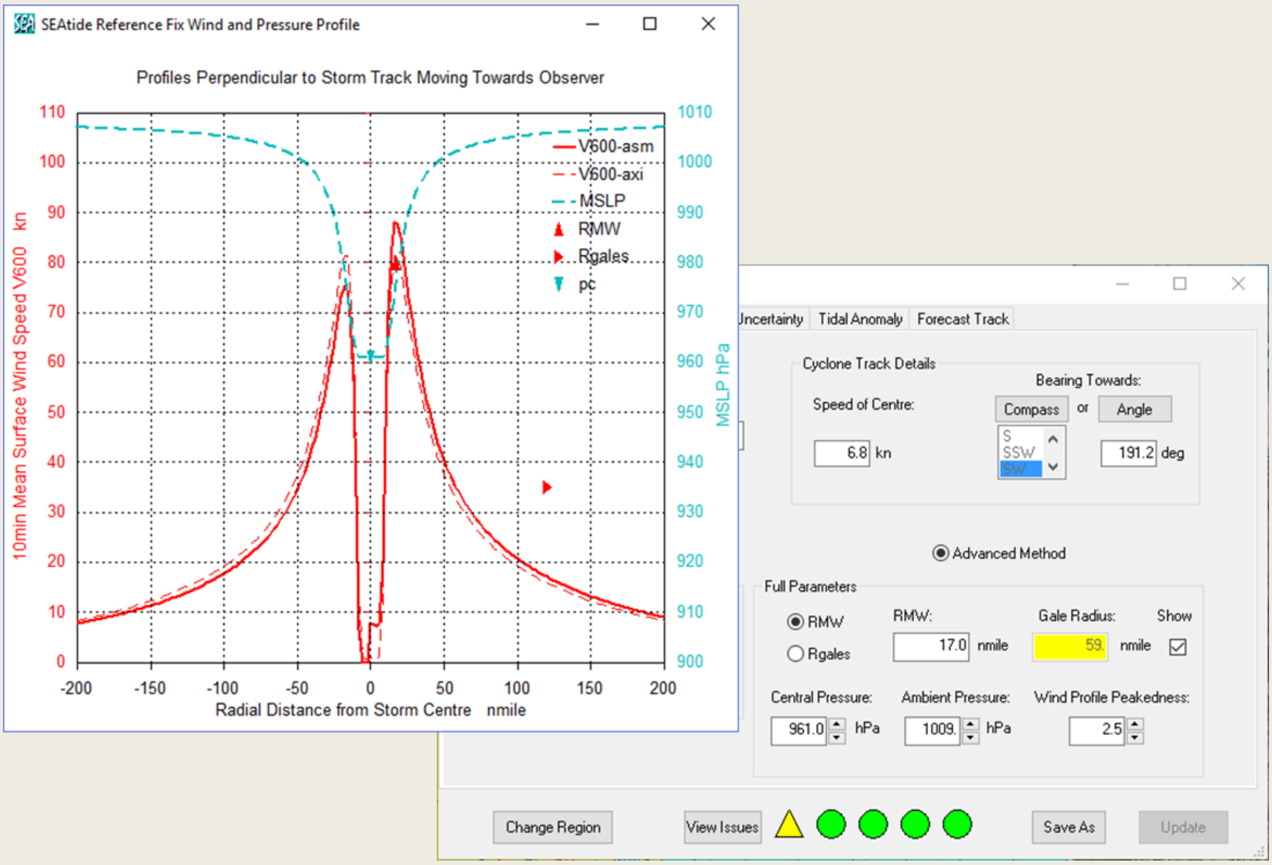

Figure B-1 Example wind-pressure profiles using a single Holland model (after Harper 2002)

***Reference Fix Wind and Pressure Profile Feature***

Selecting the *Show* tick box on the *Scenario Editor* | *Storm Parameters* tab will activate a wind and pressure profile pop-up graph to enable visualising differences between forecast *MLSP*, *Vmax*, *RMW* and *Rgales* vs the SEAtide "double Holland" model representation. Users can use this to assist in preferentially fitting the storm wind profile to *Rgales* rather than *RMW* and also to see the effects of changing *MSLP, RMW* and *B*. Any *RMW* vs *Rgales* changes are immediately displayed while other changes require an Update.

If no forecast values are available (i.e. from an imported track file) then they are not shown. Warning lights will now report if the difference between modelled and forecast *Rgales* is greater than 20% to suggest consideration be given to a better fitting between forecast and modelled.

The Scenario Editor example below shows a pop-up graph that is displayed if the *Show* tick box is activated. The yellow warning indicates that there is a mismatch between the forecast and modelled *Rgales* of more than 20%.




The graph presents the SEAtide model representation of the asymmetric surface mean wind speed (red solid line), axisymmetric mean wind (red dashed-line) and pressure (aqua dashed-line) for the crossection through the centre of the storm that is perpendicular to the storm motion at the supplied Reference Fix and in the context of moving towards the observer on that track.

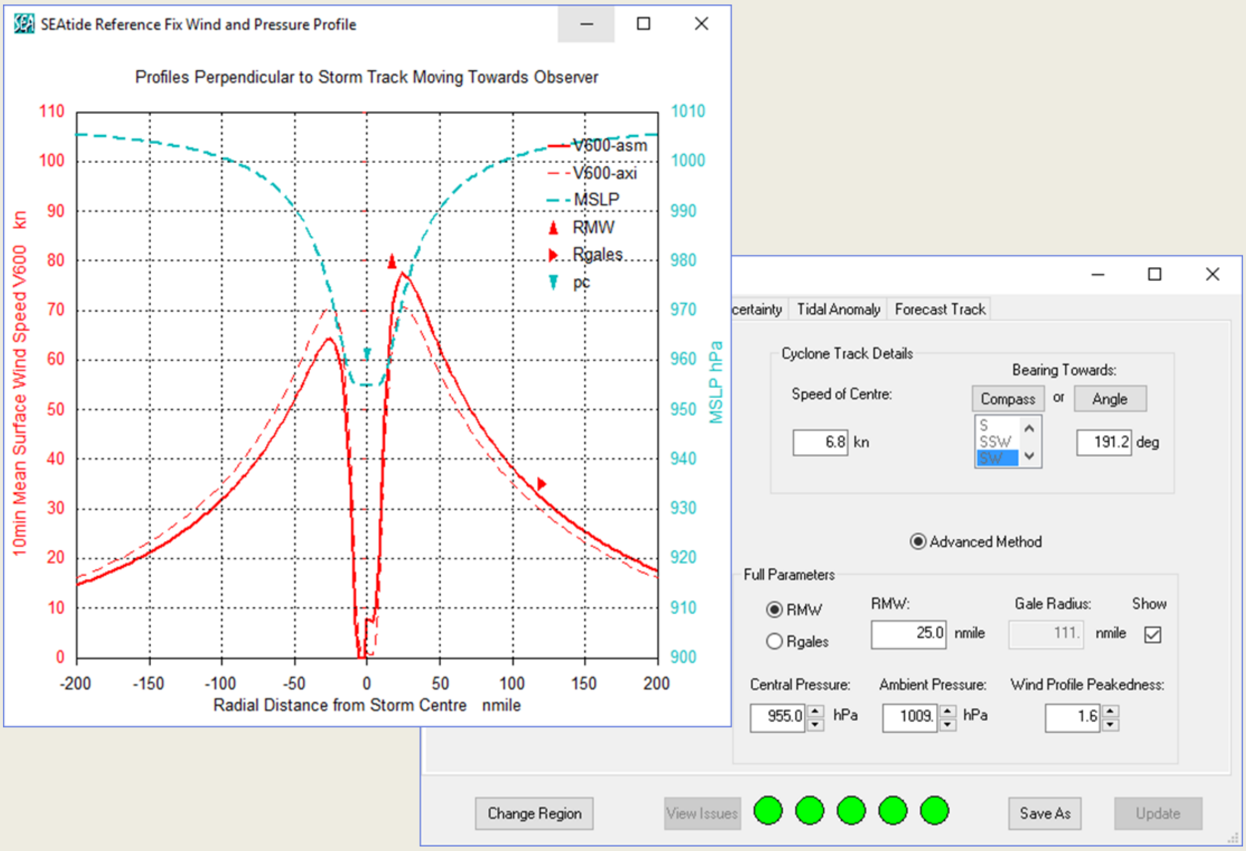
The symbols represent the supplied "forecast values" for *MSLP*, *RMW* (plotted at forecast axisymmetric *Vmax*) and the supplied *Rgales*. The forecast wind speed radii are only plotted on the critical "strong" side of the storm where the axisymmetric profile is assumed amplified by a contribution from the storm forward speed (6.8 kn in this example).

The forecast *Rgales* in this case was 120 NM (plotted as the red right-triangle) whereas the modelled *Rgales* is only 59 NM (as shown on the dialog) and therefore the modelled surface wind profile is much narrower than the forecast. This is not likely to provide the best matching of storm tide response to the forecast wind and pressure forcing. Note also that the forecast value of *Vmax* (assumed to be an axisymmetric estimate) was 80 kn, but the SEAtide profile extends to 89 kn with the full forward speed component being added.

This graphic visualisation will assist the suitably experienced user in adjusting any of the modelled parameters to obtain what could be regarded as the best reasonable fit, noting that the wind profile on the “strong” side over the region out to about 5 x *RMW* will likely be responsible for the principal surge response.

In this example, if there is much greater confidence in the *Rgales* estimate than the *Vmax* or *RMW*, then it might be appropriate to adjust either or all of those, or to reassess all the parameters in an objective manner and make changes accordingly (noting that $p_c$ and *B* will adjust *Vmax*)

A potential outcome in this situation is illustrated below, where several parameters have been adjusted to obtain a better overall fit.



# Appendix C Technical Details of the Model Assumptions

The *SEAtide* parametric storm tide model is based on the approach outlined in SEA (2002) and the following details may assist in understanding how to avoid particular situations that can produce error conditions.

### *Model Tracks and the Reference Fix*

A *SEAtide* tropical cyclone track is straightline only with constant intensity parameters and hence implies an "equilibrium" condition. This is justified by the context of "near landfall", where only the final 12 h or less will normally significantly influence the resulting storm tide. Accordingly, the parameter set provided to the model must be considered as an "average" description over this nominal period but applicable at a specific site. While this might at first seem restrictive, it is more than compensated by the model's ability to undertake a simulation of as many variants as the user decides. Only a single **reference fix** is initially required to define the so-called **reference track** (lat, lon, UTC).

### *Model Landfall and Timing Windows*

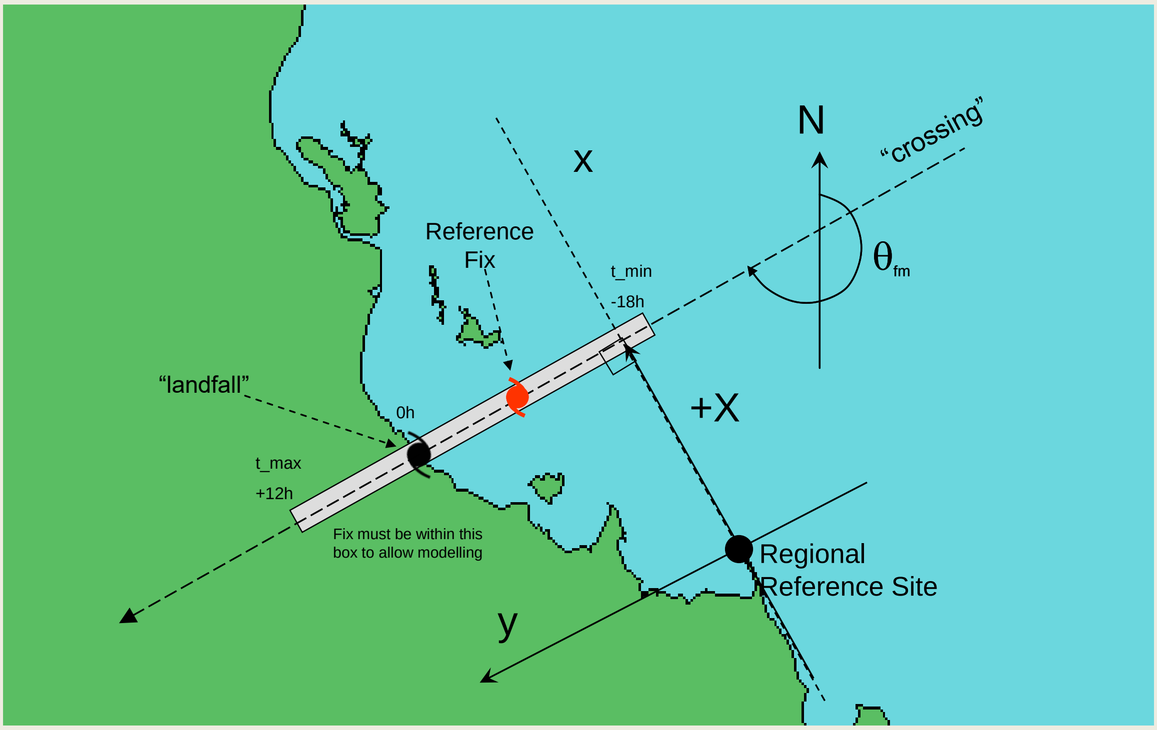
The underlying models are built assuming that a prediction is required at or near the likely time of "landfall". In the case of a true land-crossing event, this means a prediction window commencing (typically[41]) 18 h prior to landfall and extending up to (typically) 12 h after landfall (i.e. 30 h in total). In the case of a storm that is moving essentially parallel to a coastline, the same window exists but it is relative to an orthogonal drawn from a region-specific coastal reference point and normally extends further in time.

These concepts are presented in Figure C-1 below; (a) for the "crossing" case and in (b) for the "parallel" case. In each case the black storm symbol indicates the *SEAtide* "landfall" point for a storm on that specific heading, while the red storm symbol indicates a potentially valid "reference fix" entered by the user that lies within the modelled time window. When *SEAtide* is given a reference fix that lies outside the available timing window an error message is generated and the user is given the opportunity to have the fix shifted automatically, based on the track speed and bearing, so that it does lie within the timing window.

Fixes that are within the window but not close to the model's interpretation of landfall, are also able to be automatically shifted in space and time. This is to ensure that the model maintains an optimum prediction capability that will show the peak condition and focuses the user's attention on the critical case of a coast-crossing event. Importantly, the model graphed storm tide predictions are then restricted to a "viewport" of ± 12 h of the reference fix.

The "regional reference site" and its associated coordinate system are shown here only to illustrate the internal model concepts. The user does not need to be especially aware of these constructs when operating the model. However, if the need arises, an option exists to show the sequence of parametric model tracks that were used to develop any specific model region and this will assist in determining where the original regional reference point is located. Additionally, each model region has its own schematised definition of where the coast is located, which may not always exactly follow the true coast. This "coastline definition" can be displayed if required.

[41] The exact timing window can vary between model regions.




(a) the "crossing" case

(b) the "parallel" case

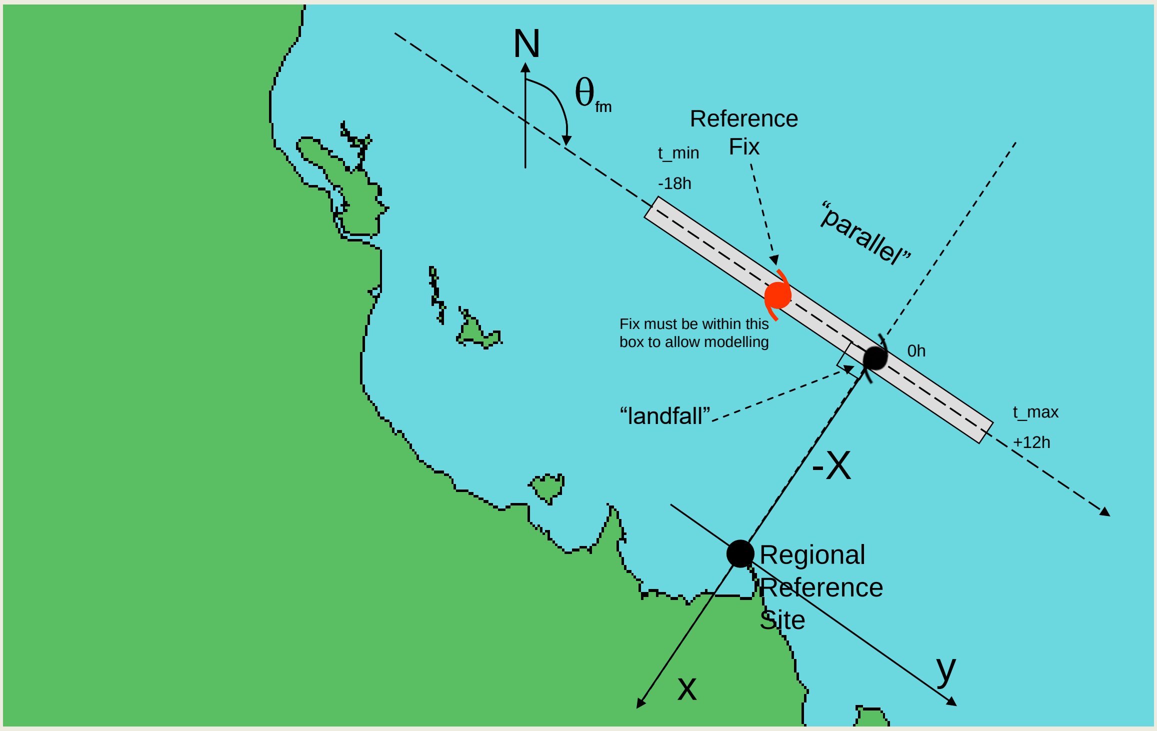



*Figure C-1 SEAtide* track and timing window concepts.

### *Model Parameter Limits*

Because of the nature of the simplifications in the underlying parametric models, *SEAtide* will typically have limitations on the parameter space available to the user. If the user chooses parameters outside of that space the interface will indicate which of the entered parameters is in error. This is done using a system of “warning lights” that vary in colour. The user can view the associated warning messages and the *View / Parameter Limits* menu item can be used to examine the full set of parameters that were used to formulate the model.

One of the principal limitations in any region will be the allowable track bearing range. To limit the effort in constructing the parametric models, typically the range of model track bearings is restricted by concentrating on the climatology records. This may result in some tracks not being able to be modelled in *SEAtide* because they are either very unlikely or if they do occur, are deemed not to present a high level of threat. Figure C-2 provides an example, whereby it is not possible to model tracks within the heading range of 300° to 30°.

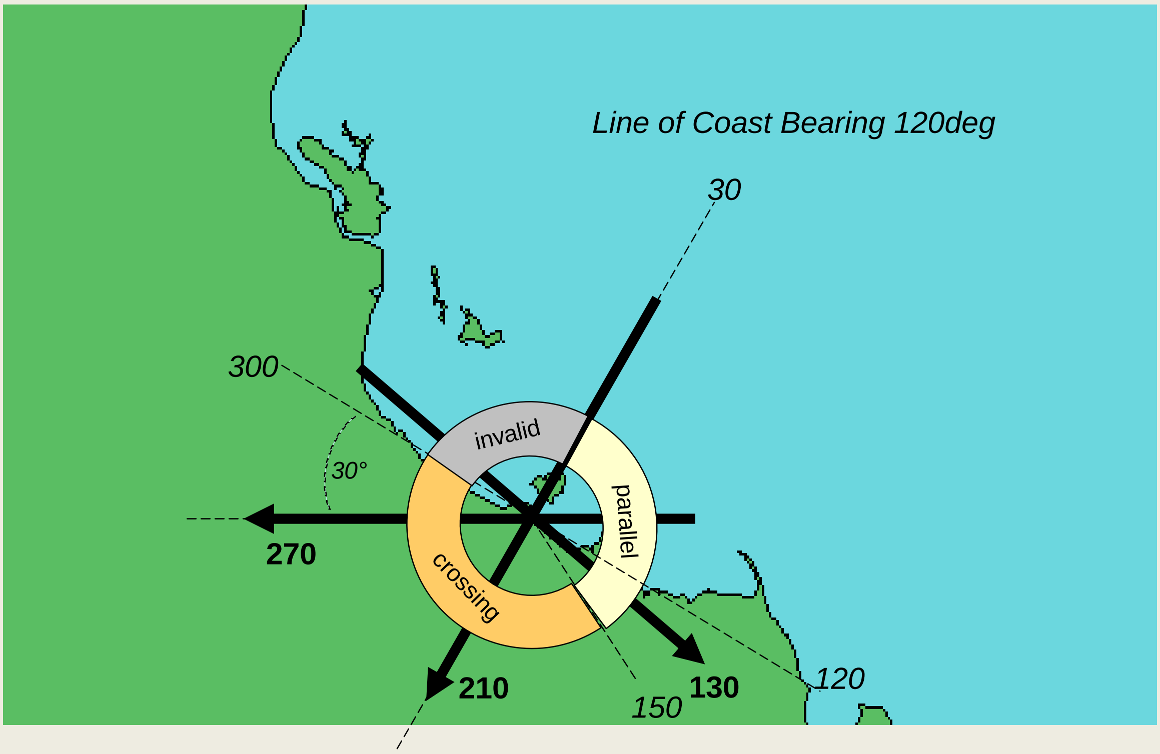



Figure C-2 Example of valid and invalid *SEAtide* track bearings for a region.

Based on the climatology of this area, the likelihood of a life-threatening scenario occurring within these restricted bearing ranges is deemed extremely low[42]. Also shown in this figure is the model crossover between classifying whether a specific track is “crossing” or “parallel”. This affects the calculation of the available modelling window, as explained earlier, but is otherwise not usually of interest to the user. The valid regional track bearings can be displayed for reference at any time.

[42] In the unusual case of a storm moving in an invalid direction, the user can always specify a stationary storm on a valid bearing to avoid this restriction but should then make allowance for any potential forward speed enhancement, perhaps by undertaking some similar valid sensitivity tests.

### *Probabilistic Track Generation*

The technical basis of the probabilistic prediction is depicted in Figure C-3, whereby the user must nominate a "pre-reference" time interval (*t_pre_ref* in the figure) that is used to project backwards in time from the reference fix to provide a fixed point in time and space. From this base position, the scenarios are then generated, such that after *t_pre_ref* elapsed time, the original fix will be modified on the basis of the varied track parameters.

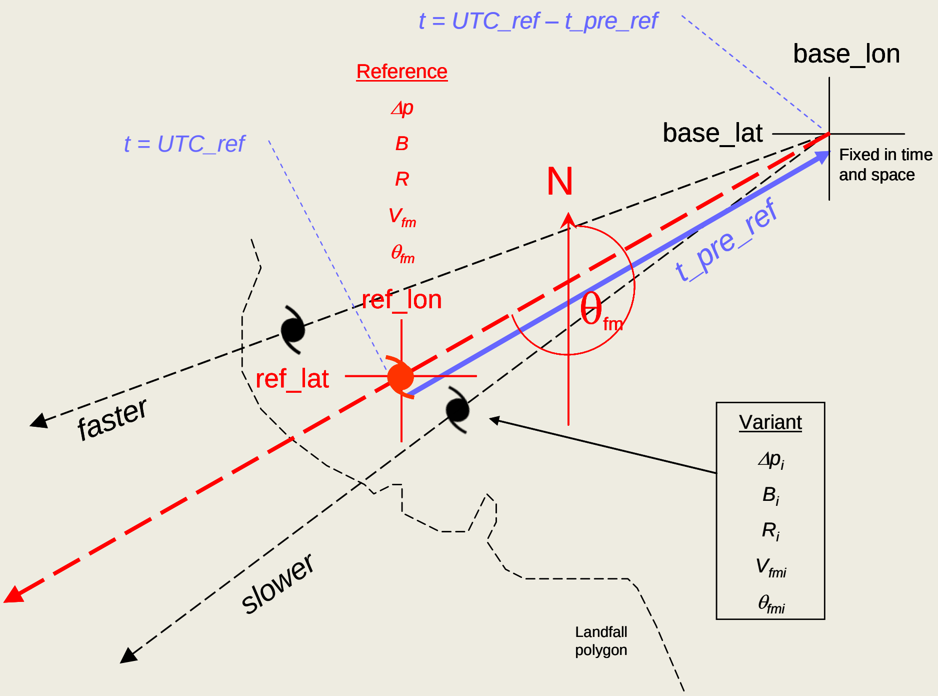



Figure C-3 Basis of the probabilistic track generator.

The default *t_pre_ref* value is 12 h but the user should select a value that produces the desired degree of spatial variability. This could also be regarded as the current "point of truth" from which point the variability is applied.

### *Re-Sampling of Tracks*

During probabilistic simulations, if the parametric model cannot model a particular set of sampled storm parameters then it automatically chooses another set. Storms can get re-sampled for a variety of reasons but mostly it will be cases where there is a sudden change in the distance to "landfall" for a small change in bearing (e.g. a landfall near a prominent cape such as exists in the Princess Charlotte Bay region, such that storms may have much further to travel to land on different sides of the cape). Re-sampling can be detected with a fixed *Count* by noting the "total storm count" that is displayed briefly at the end of each simulation period. If re-sampling has occurred then the displayed count will exceed the requested *Count.* The slower storms will likely be more affected in that case but they tend to produce a lower surge. Any significant re-sampling issues would likely be visible in the map view as being unrepresentative of the uncertainty bounds. Even a small change to the reference fix or the uncertainty spread may alter the behaviour so sensitivity testing is recommended if it is suspected that re-sampling is significant.

The case of oblique coast crossings is handled differently and re-sampling is less likely because at a certain bearing the model changes from its "landfalling" to its "parallel" mode of operation.

### *Breaking Wave Setup*

The model provides estimates of the possible effects of breaking wave setup on open coast locations based on the modelled nearshore wave parameters (*Hs, Tp*), the assigned local water depth, representative beach slope and dune crest height. Since wave setup can be a very localised effect, the model resolution is not sufficient to provide highly accurate estimates of this phenomenon. Even when experimentally measured, actual wave setup can be highly variable spatially and temporally. The model therefore only provides a guide as to this possible effect.

To assist understanding of the variability in wave setup estimates that might be evident, each site has a “morphology class” attribute that has been used to assist in assigning beach slopes and the formula to be applied.

Each model site is allocated a particular wave setup formula based on its assessed “exposure” compared with the basis of the commonly used empirical formula by Hanslow and Nielsen (1993) and Stockdon et al. (2006). The former is based on high energy beaches in SE Qld and northern NSW and generally open coast sites south of Sandy Cape will specify this formula, which is insensitive to beach slope. At most other locations the Stockdon et al. formula is assigned, which is sensitive to beach slope.

Generally, tide gauge (TG) or storm surge gauge (STG) sites will typically have wave setup estimates suppressed (formula shown as “none”). If wave data is not available for a specific site then the formula will show “n/a”. Open sea sites (e.g. WR waveriders) also show “none”.

The wave setup formula and associated parameters are able to be specified in the model SAS file for each region.

# Appendix D  Details of the Astronomical Tide Generation

Every modelled *SEAtide* point has its own set of tidal harmonic magnitudes and phases for the widely-used set of 37 constituents below. As well, each site has an assigned (or calculated) HAT, LAT and AHD offset (if available), which are all specified to the MSL datum with SLR adjustments.

These are the 37 harmonic constituents that are used:

| | | | | | |
|---|---|---|---|---|---|
| 1 | Sa | 14 | 2N2 | 27 | MN4 |
| 2 | Ssa | 15 | mu2 | 28 | M4 |
| 3 | Mm | 16 | N2 | 29 | SN4 |
| 4 | Msf | 17 | nu2 | 30 | MS4 |
| 5 | Mf | 18 | M2 | 31 | MK4 |
| 6 | Q1 | 19 | L2 | 32 | S4 |
| 7 | O1 | 20 | T2 | 33 | 2MN6 |
| 8 | M1 | 21 | S2 | 34 | M6 |
| 9 | P1 | 22 | K2 | 35 | 2MS6 |
| 10 | S1 | 23 | 2SM2 | 36 | 2MK6 |
| 11 | K1 | 24 | MO3 | 37 | MSK6 |
| 12 | J1 | 25 | M3 | | |
| 13 | OQ2 | 26 | MK3 | | |

The Qld east coast models use a spatial interpolation of phase and magnitude by distance between Primary and Secondary ports for which there are available constituents (supplied by MSQ in 2012 for the 1992-2011 epoch). Where necessary, pseudo-ports are nominated to facilitate interpolation. In complex areas this is only an approximation and an additional Range Ratio and Time Difference may be used to force an expected behaviour where there is no other information, such as amplification and delay in a narrowing estuary. Published HAT levels at all Primary and Secondary ports are preserved and at intermediate points HAT is interpolated. LAT at intermediate points is estimated over the epoch with a 5 min timestep. *SEAtide* may generate a tide slightly higher than the indicated HAT because of sea level rise adjustments over time.

In the Torres Strait, away from the recently installed tide gauges at some sites, the sometimes very complex tides are reliant on numerical modelling undertaken by SEA for TSRA in 2010. For example, at Moa Island, where even the 114-constituent std dev of residuals for Kubin is 0.57m, tide is not reliably reproduced by the 37-constituent subset. Likewise, in the Gulf of Carpentaria the paucity of ports requires that modelled constituents from a calibrated tide model are used to fill the gaps. The published constituents and HATs are still preserved wherever they are available.

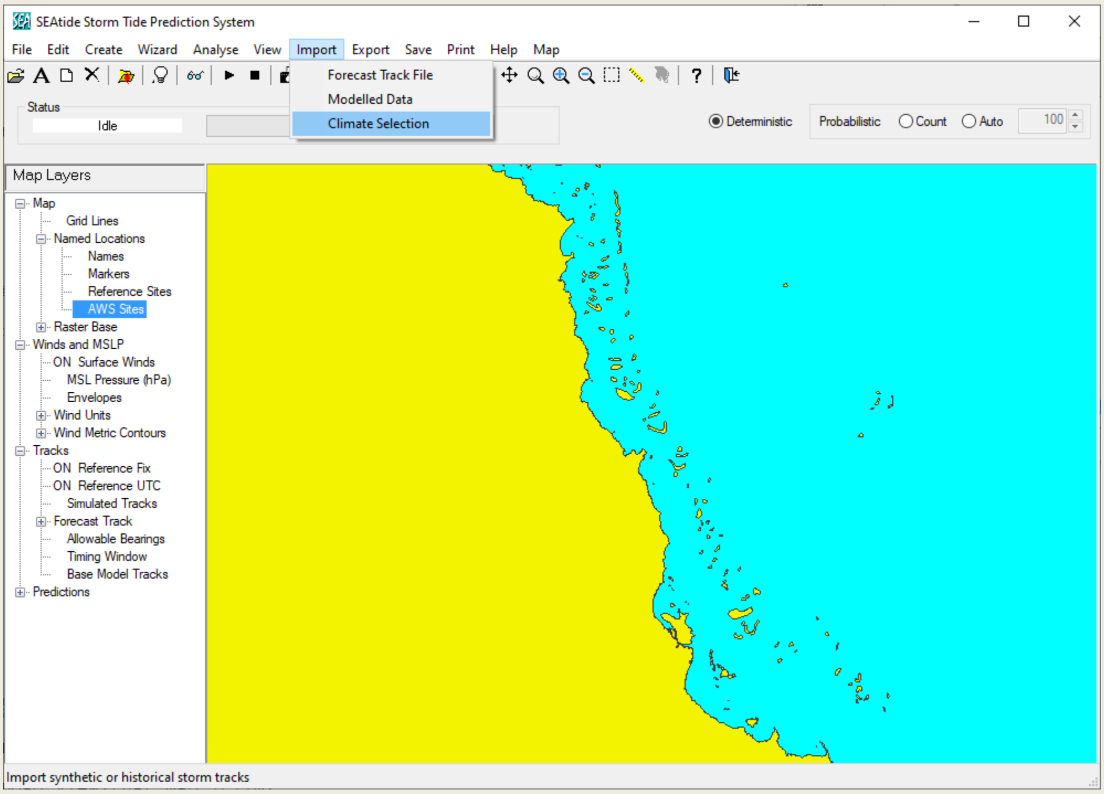
The NT version of *SEAtide* relies on an 8 constituent BoM NTU model that was provided to SEA in 2005 to provide consistency across the sparsely sampled northern coastline regions. The model then allows cross-checks against the scattered AUSTIDES locations for additional confidence (although some of the AUSTIDES sites may be unreliable if not located on the open coast).

*SEAtide* high and low tide predictions (and timing) are based on a 10 min timestep and may differ slightly from published values. Notwithstanding, the user is cautioned that published tide times and levels are not necessarily highly accurate as the peak of the tide typically extends over a period of 10 minutes or more.

# Appendix E  Importing TC Climatologies

## (a) SEAtide capability to extract and model selected synthetic climate events (target radius plus storm parameter filters, climate change adj)

This is implemented via the Import | Climate Selection menu:

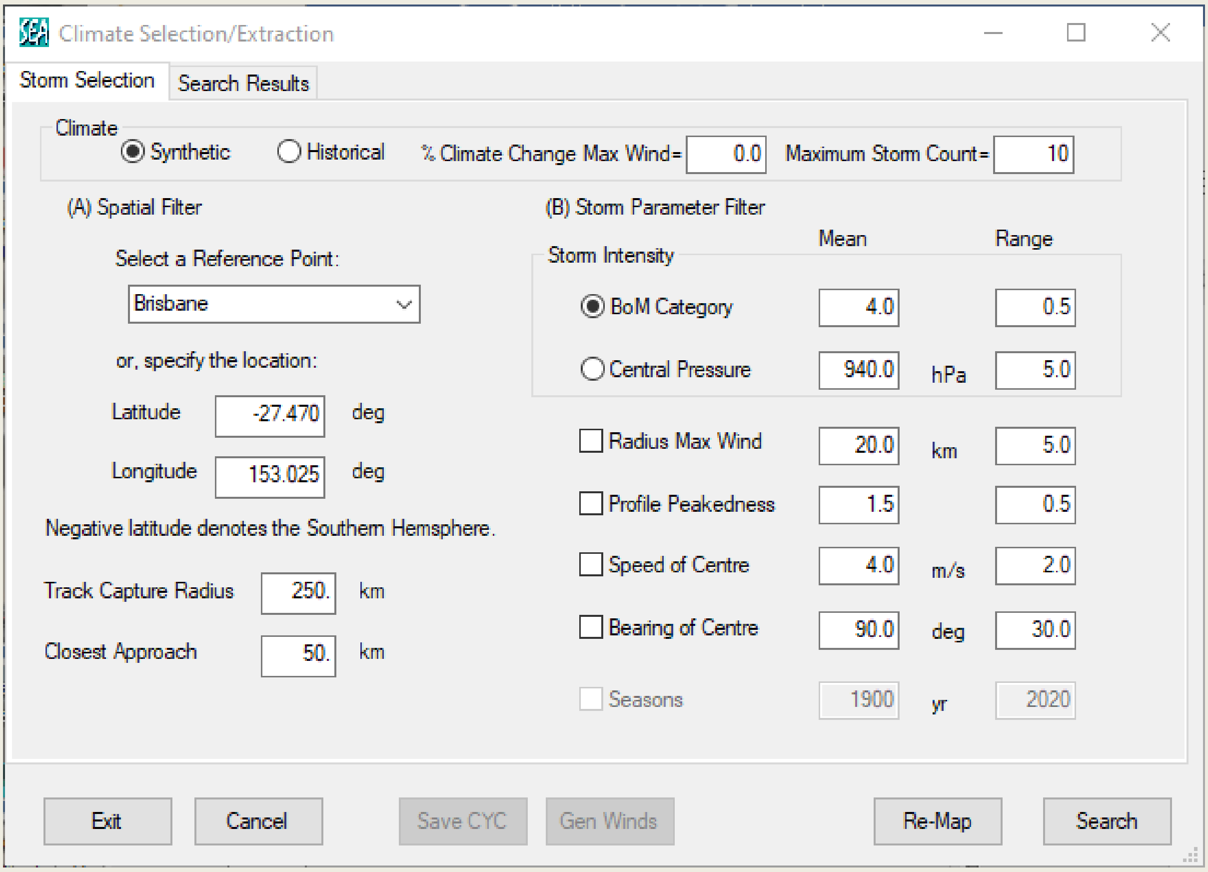



In the above view, the starting Wizard has been cancelled (i.e. no starting scenario), but a scenario can be used as the “target” for the climate import at any time. In real-time this would likely be based on an imported or downloaded agency forecast track.

**Concept**

The process assumes that in a real-time situation the user may want to be quite selective about which events are of interest and, although the extraction parameters are quite powerful, getting a truly representative storm set is expected to involve some operator discretion. Accordingly, the process of extraction of events of interest proceeds in a series of steps, where the results of the search are presented in a set of tabulations of storm parameters and their tracks are mapped. At each step the user can choose to remove storms of lesser interest. This is facilitated by the ability to “uncheck” some and to “remap” the tracks accordingly. This viewing and testing activity can continue until the user is satisfied with the selection. Another set of events can be obtained by continuing with another “search” and these checked events will continue to build the complete set of storms. Once one set of events is added the user cannot return to an earlier set. When satisfied with the selection, either all events can be exported as CYC files and/or the windfields can be generated and exported in a variety of forms.

If a purely statistical climate extraction is preferred, the user can quickly move through the searching steps without manual intervention. If the selection criteria is quite narrow, then there may only be a few events in a 50,000-y climate that will satisfy all specified conditions. Present testing settings limit the selection to a total of 100 events.




"Climate" allows selection of either Synthetic or Historical (BoM not yet available); %climate change will make the indicated adjustment when importing; Max storm count to be imported sets the number of storms that will be selected each time the SEARCH button is selected.
(A) Spatial Filter allows selection from a set of sites, geographically listed from Brisbane to Perth, or any name can be entered, and the Lat Lon added manually also. Track capture radius from the lat/lon defines the length of any imported track; Closest Approach sets the selection criteria.
(B) Storm Parameter Filter allows specification of a mean value and a range in each case. Intensity can be either category (i.e. wind) or MSLP. The other parameters are optional. Seasons will be available for historical storms later.
EXIT leaves this window.

CANCEL clears the window settings and can be used to ABORT a search that is underway.

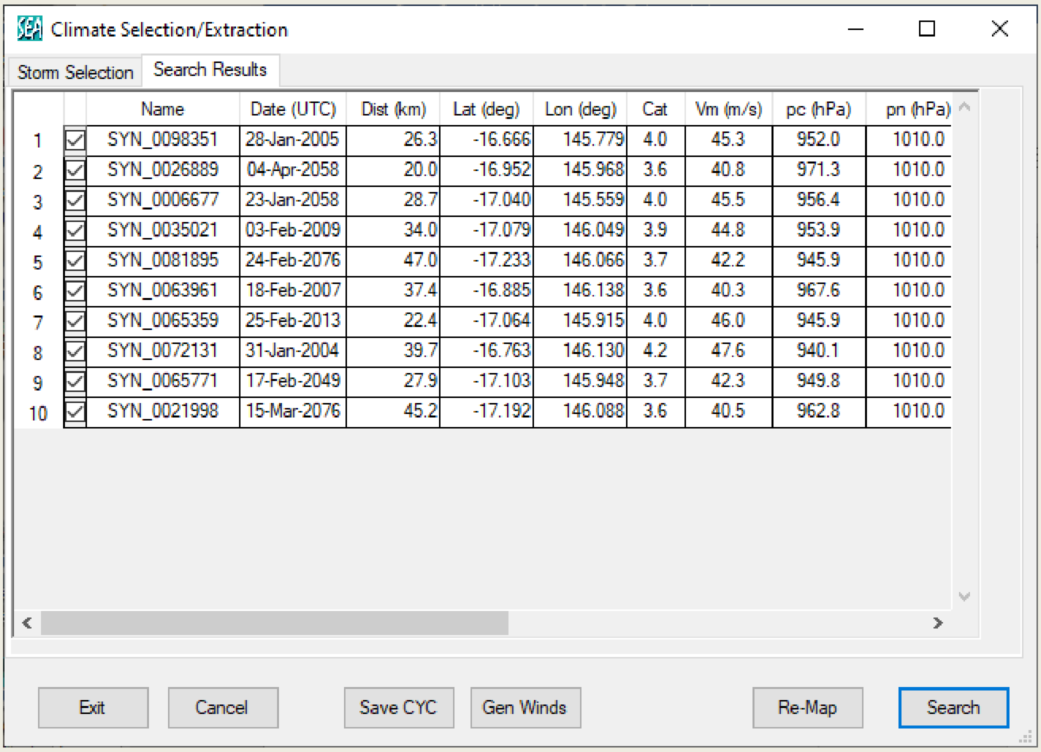
SEARCH commences the importation based on the parameters; displays the results in the Search Results tab and also on the map window.

RE-MAP will re-plot tracks based on user selection (refer next)

SAVE CYC will create CYC files for each selected event that can be later read by SEAtide.

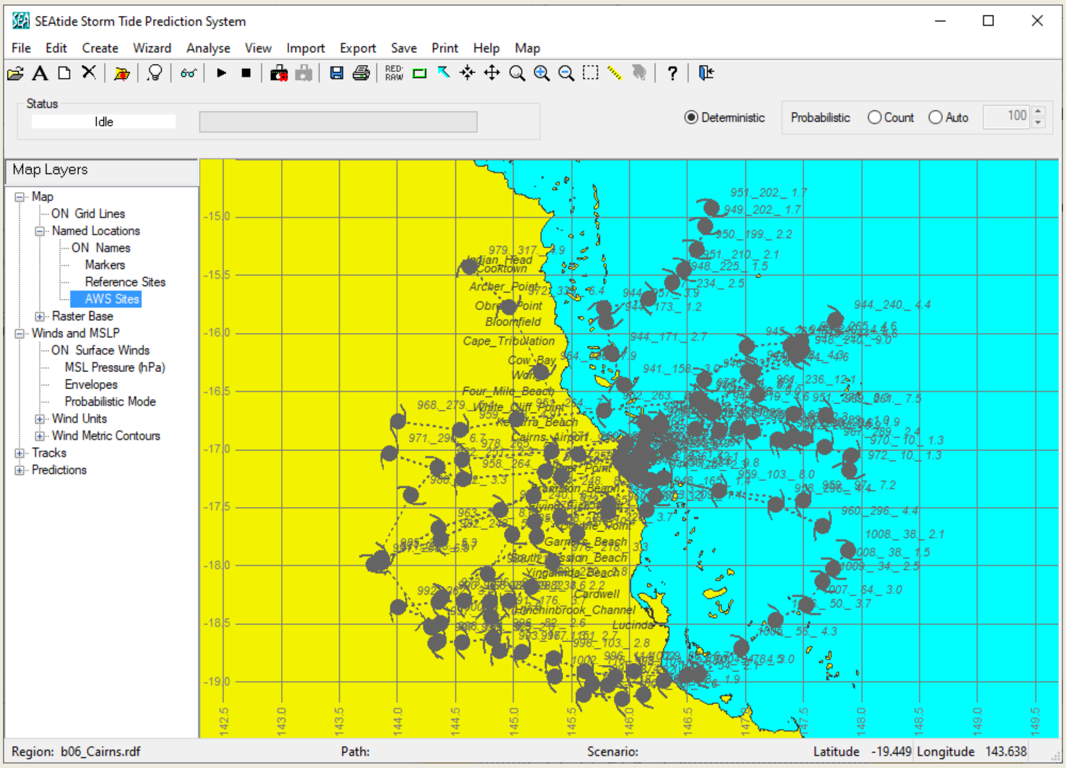
GEN WINDS will generate wind fields for each selected track (refer later)

This is the Search Results tab after “Cairns” is selected as the site and SEARCH initiated:



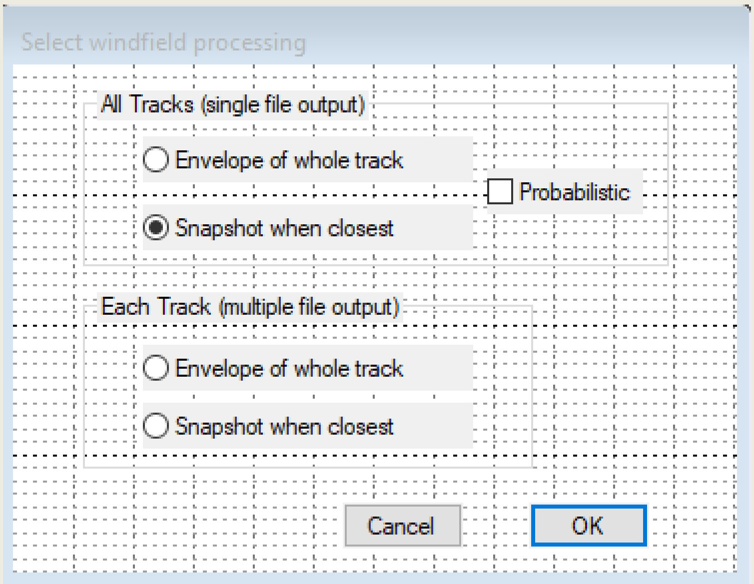

| | | Name | Date (UTC) | Dist (km) | Lat (deg) | Lon (deg) | Cat | Vm (m/s) | pc (hPa) | pn (hPa) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ☑ | SYN_0098351 | 28-Jan-2005 | 26.3 | -16.666 | 145.779 | 4.0 | 45.3 | 952.0 | 1010.0 |
| 2 | ☑ | SYN_0026889 | 04-Apr-2058 | 20.0 | -16.952 | 145.968 | 3.6 | 40.8 | 971.3 | 1010.0 |
| 3 | ☑ | SYN_0006677 | 23-Jan-2058 | 28.7 | -17.040 | 145.559 | 4.0 | 45.5 | 956.4 | 1010.0 |
| 4 | ☑ | SYN_0035021 | 03-Feb-2009 | 34.0 | -17.079 | 146.049 | 3.9 | 44.8 | 953.9 | 1010.0 |
| 5 | ☑ | SYN_0081895 | 24-Feb-2076 | 47.0 | -17.233 | 146.066 | 3.7 | 42.2 | 945.9 | 1010.0 |
| 6 | ☑ | SYN_0063961 | 18-Feb-2007 | 37.4 | -16.885 | 146.138 | 3.6 | 40.3 | 967.6 | 1010.0 |
| 7 | ☑ | SYN_0065359 | 25-Feb-2013 | 22.4 | -17.064 | 145.915 | 4.0 | 46.0 | 945.9 | 1010.0 |
| 8 | ☑ | SYN_0072131 | 31-Jan-2004 | 39.7 | -16.763 | 146.130 | 4.2 | 47.6 | 940.1 | 1010.0 |
| 9 | ☑ | SYN_0065771 | 17-Feb-2049 | 27.9 | -17.103 | 145.948 | 3.7 | 42.3 | 949.8 | 1010.0 |
| 10 | ☑ | SYN_0021998 | 15-Mar-2076 | 45.2 | -17.192 | 146.088 | 3.6 | 40.5 | 962.8 | 1010.0 |

This lists the maximum of 10 tracks specified and summarises their parameters at the time of closest approach to Cairns, plus the map shows:



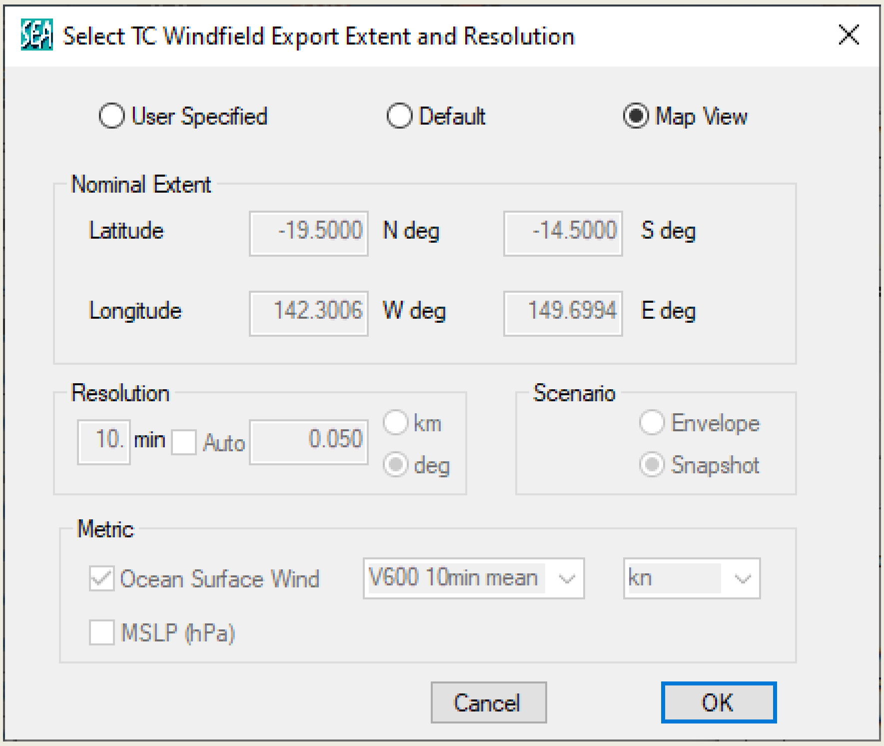

The SEARCH button can be used to find another 10 events and they will also be over-plotted, or the mapped tracks can be filtered by adjusting the LHS tick boxes and using RE-MAP etc.
When satisfied with the selection, SAVE CYC or GEN WINDS can be chosen.

GEN WINDS will then display:




Which allows either a combined selection whereby all tracks will be combined into a single wind file of the maxima (envelope) or each wind field will be produced. Either the whole track (swath) or the snapshot when closest is also selectable. (NB whole track envelopes may take a while…) The ALL TRACKS option additionally can be made PROBABILISTIC (refer part C).

Choosing the ALL SNAPSHOT (default) then allows selection of the windfield parameters:



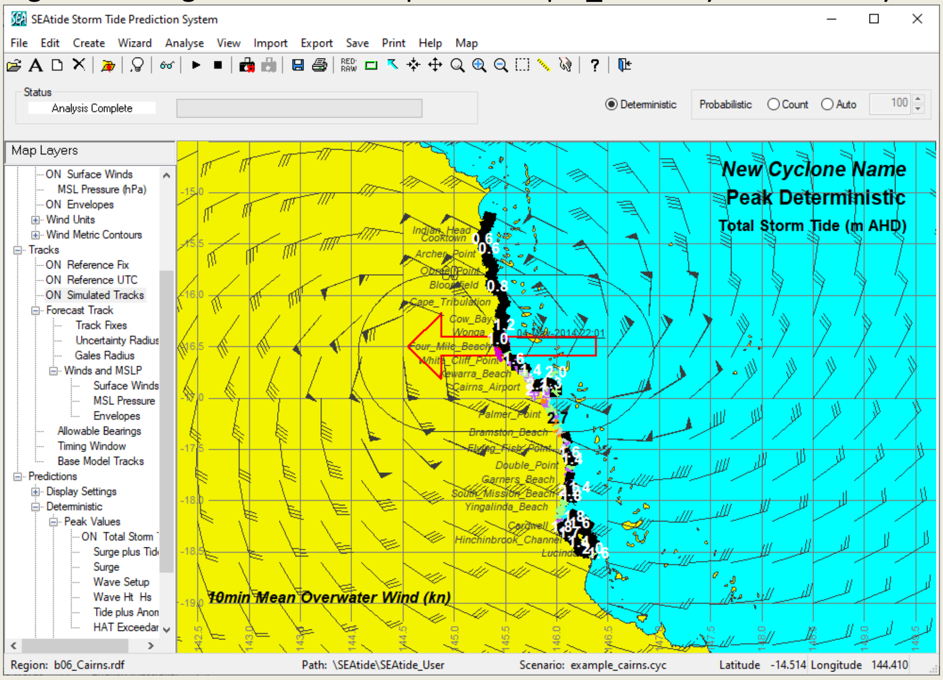

The default set of parameters specifies the current "Map View", where no changes are possible. Selecting "Default" will provide the default spatial settings and allow some other changes. Selecting "User Specified" will inherit whatever spatial parameters are already showing and allow changes (except for "Scenario" which was set by the previous window).

After OK, output folders will be confirmed and the winds will be generated in CSV formats.

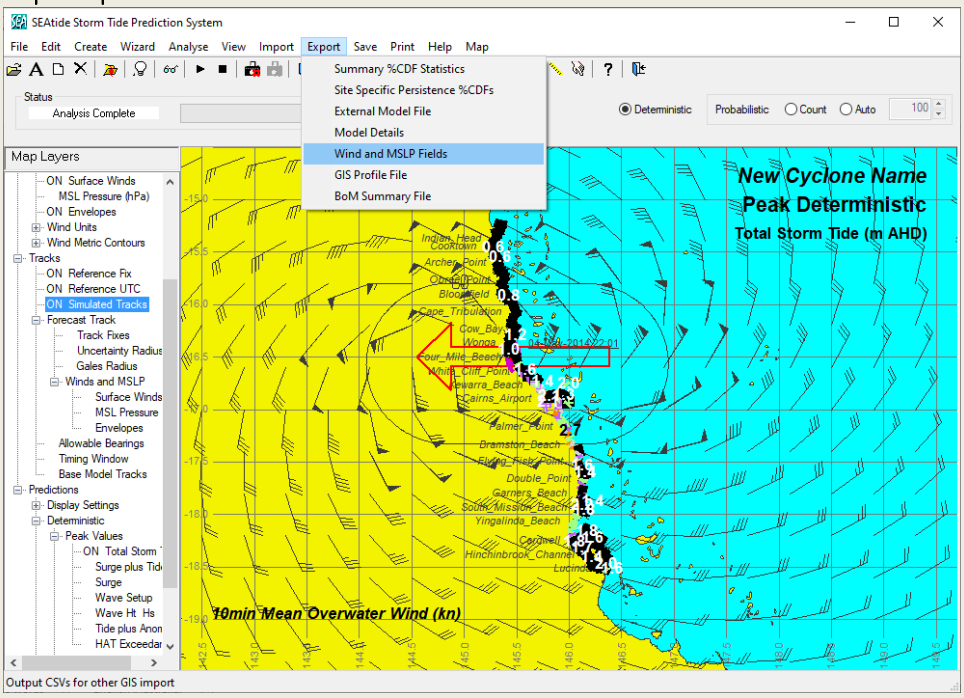
## (B) SEAtide capability to control export of wind swath extent and resolution (other than as displayed).

This has been developed to support (A) and enhance the default operation of Export | Wind and MSLP Fields:

e.g. after using the Wizard to open "example_Cairns.cyc" and "Analyse":




After the chosen set of wind or MSLP metrics, units etc, are made then: Export | Wind and MSLP Fields can be selected:

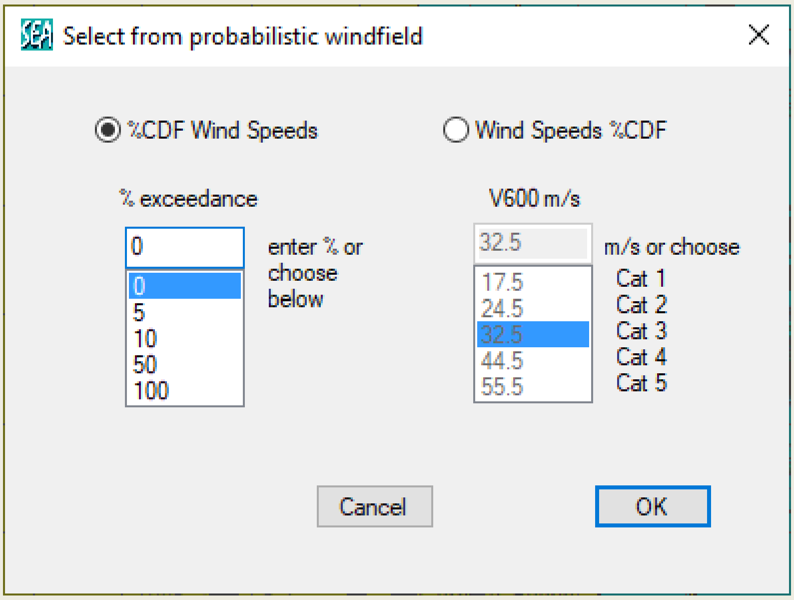



This will bring up the previous "Export TC Windfield Extent and Resolution" window with parameters pre-populated to either choose the View or the other options etc.

### (C) SEAtide capability to provide probabilistic winds.

This feature is implemented mainly behind-the-scenes and then integrated into the (A) and (B) features as an additional option.

For (A), after GEN WINDS is selected with the PROBABILISTIC setting checked, an additional dialogue is presented that allows the user to select the specific % etc:




The default option is to provide the %CDF (% cumulative distribution function value) and obtain the windspeeds according to that. For example, choosing 0% will generate the peak windspeed from all the tracks at each point and is functionally equivalent to the ENVELOPE option[43]. Of more interest statistically is to choose a lesser %CDF such as the 10%, which will create the windfield only exceeded by 10% of the events in the set.

The other option is to produce the %CDF probability field for a given windspeed, with a list of 10-min mean windspeeds (V600) offered that correspond to BoM Category scales. Hence, choosing 44.5 m/s will produce a field of % exceedance values indicating the likelihood that the point will experience winds greater than or equal to Cat 4.

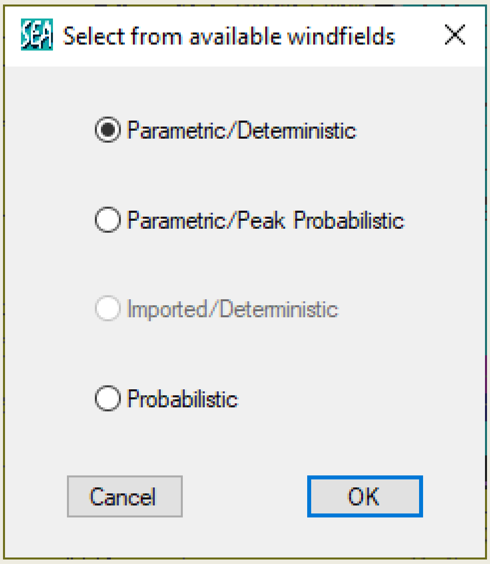
To note that SEAtide will issue a warning if the selected number of storms is less than a minimum of 10 for a PROBABILISTIC simulation. Then the “10%” exceedance means only one storm in the 10 produced the indicated wind speed.

When the wind files are generated, they are named according to whether they contain winds “CDF_V600” or probabilities of exceedance “V600_CDF” of a chosen windspeed.
To note that the probabilistic wind speed analysis is omni-directional.

[43] Due to the discrete exceedance methodology there will be some small differences between the 0% and the ENVELOPE results. The current exceedance resolution is 1 m/s steps (approx. 2 kn) but will be increased after testing.

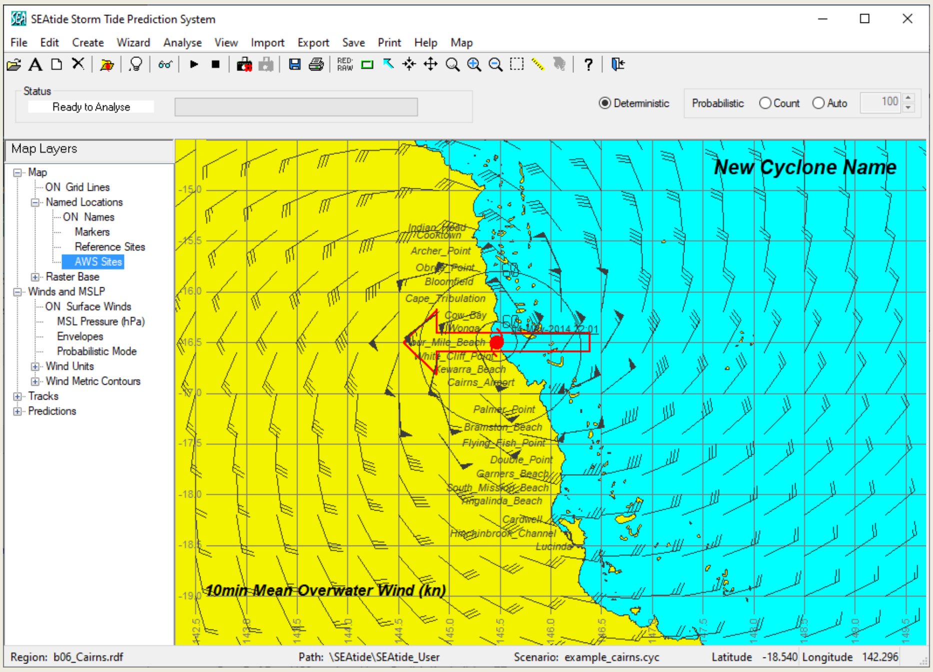
For (B), the PROBABILISTIC option is available via the Export | Wind and MSLP feature and also as a “map layer” analogous to the “Envelopes” layer in the “Winds and MSLP” branch.

From the Export | Wind and MSLP feature, an extra choice is available:



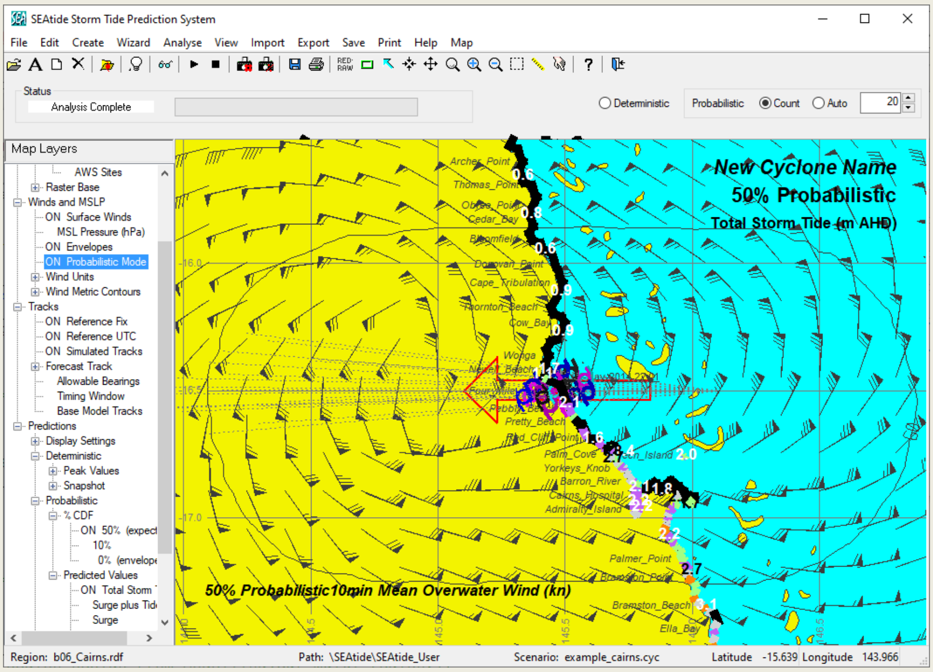

If Probabilistic is chosen, then the same “Select from Probabilistic windfield” dialogue will then appear to specify the type of output.

In the storm tide simulation context, and following the previous (B) example, there is now a “Probabilistic Mode” layer:




This is described as a “mode” because it is more than just a layer control. If set ON then any Probabilistic run, in addition to providing an envelope windfield and a Peak Probabilistic windfield, will generate Probabilistic wind fields that match the available %CDF storm tide map layers. It must be ON prior to the probabilistic run commencing and because of the additional computations required it provides an opportunity to adjust the "Export TC Windfield Extent and Resolution" parameters, akin to the Climate Import and Export | Wind and MSLP Fields features.

In the following screenshot the map has been zoomed, "ON Probabilistic" is indicated and a 20 storm run has just completed showing the default layer of the 50% wind speed exceedance in the metric and units as selected by the other layer controls.




To note that the probabilistic wind speed analysis is omni-directional, so the enveloped wind directions are used as a proxy to provide a vector representation.
If the probabilistic layer is turned off then the Peak Probabilistic Winds would be displayed instead, regardless of the %CDF storm tide layer being displayed.