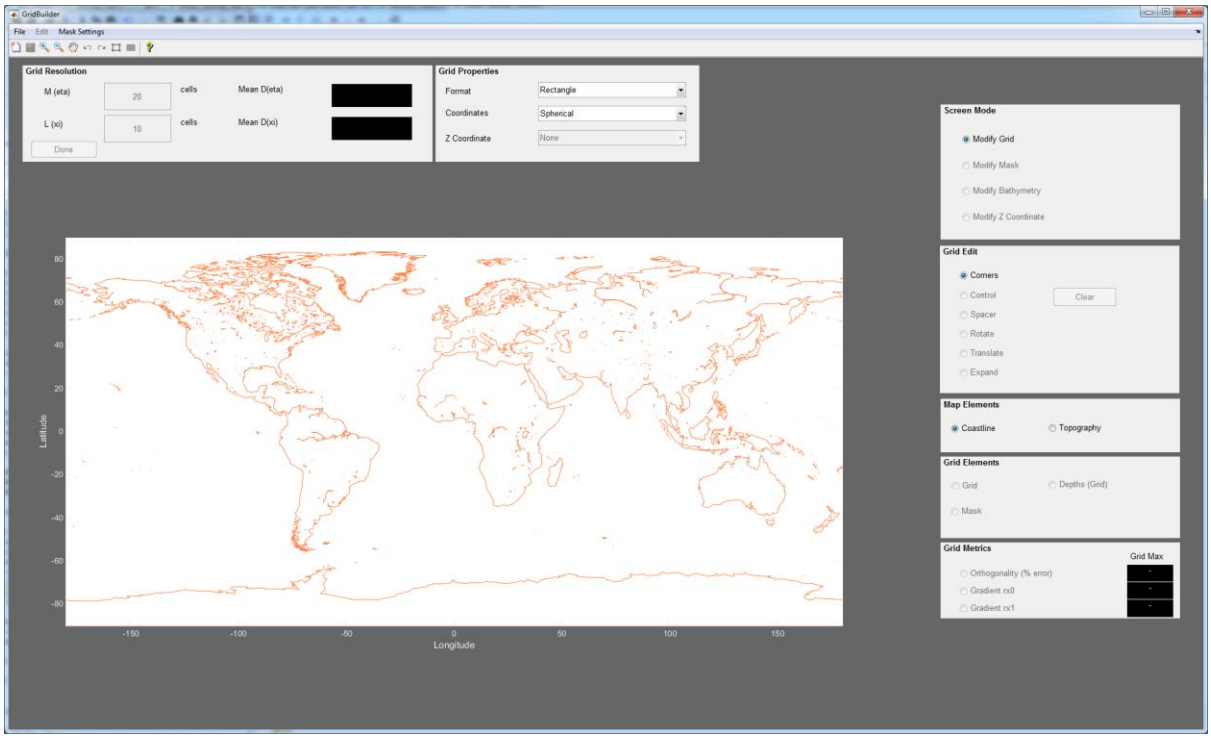
GridBuilder



Introduction:

GridBuilder is intended for rapid development of grids for numerical ocean models with a particular emphasis on elements commonly used in ROMS. The GridBuilder program combines features from the original SeaGrid program, with mask editing and grid smoothing. Grids are created by defining the four corners of a grid and manipulating the boundaries to satisfy individual requirements. The grid is created to be as orthogonal as possible using essentially the same fast Poisson solver routine as the original SeaGrid program. Other elements of the grid design will be familiar to users of SeaGrid including the application of control points to create curvature on the boundaries and spacer points to modify the local resolution of the grid.

GridBuilder designs grids in a global, spherical coordinate system of latitudes and longitudes by default and uses Etopo2 global bathymetry. However, GridBuilder can import higher resolution local bathymetry in a variety of formats. The full resolution GSHHG coastlines are also included, however users can import and use their own coastlines if required. GridBuilder can also build grids on a Cartesian coordinate system based on physical distances.

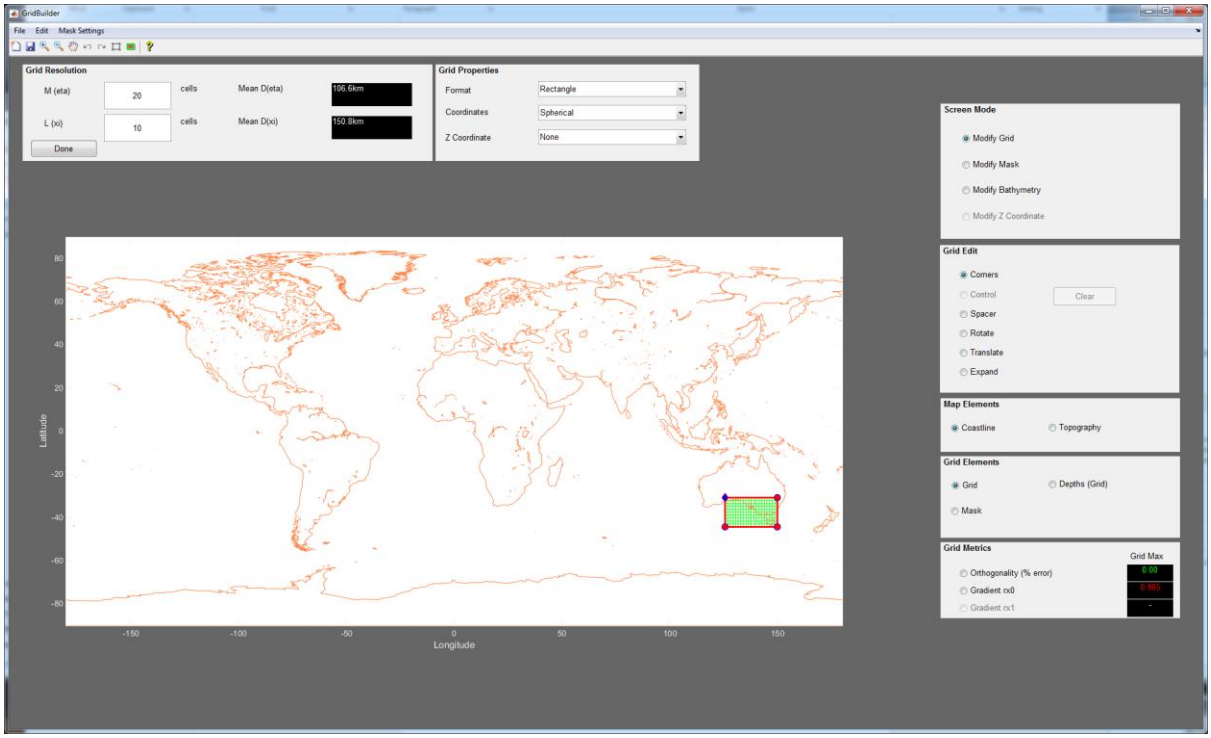
Several popular metrics are used to evaluate the grid during design. The grid orthogonality, the Beckman and Haidvogel grid stiffness, and (if the user defines a vertical coordinate) the Haney grid stiffness parameter.

ROMS Grids can be imported that have been developed with other software and manipulated within GridBuilder. Also, subgrids can be created from existing grids in order to create efficiently nested grids. GridBuilder will currently grids export to a ROMS compatible netcdf file and to SWAN compatible grid topography and coordinate files.

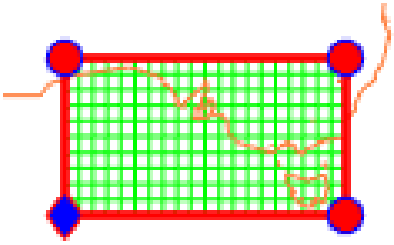
Getting Started (a short tutorial):

Creating a grid in the display area:

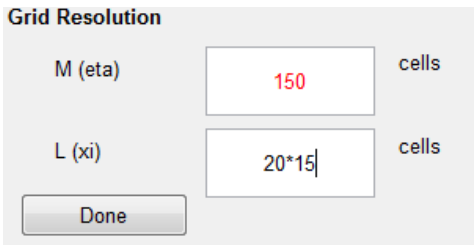
The first step is to select the type of grid and the coordinate system. The default grid type is rectangular with spherical coordinates. Clicking on the map and dragging a box will automatically create an approximately rectangular grid with North and South Boundaries parallel along constant latitudes and East and West Boundaries lying along lines of constant longitude. The default resolution is 20x10 cells, the grid origin is the first point selected and indicated by a blue diamond.



In this example the first point selected was the North-West corner but this will make the xi coordinate (on a ROMS grid) along the Western Boundary. If we want to make the origin at the South-West corner (so that the Southern Boundary defines the xi coordinate) we can right-click on the South-Western point and it will become the new origin (similar to "rolling" the corners in SeaGrid).



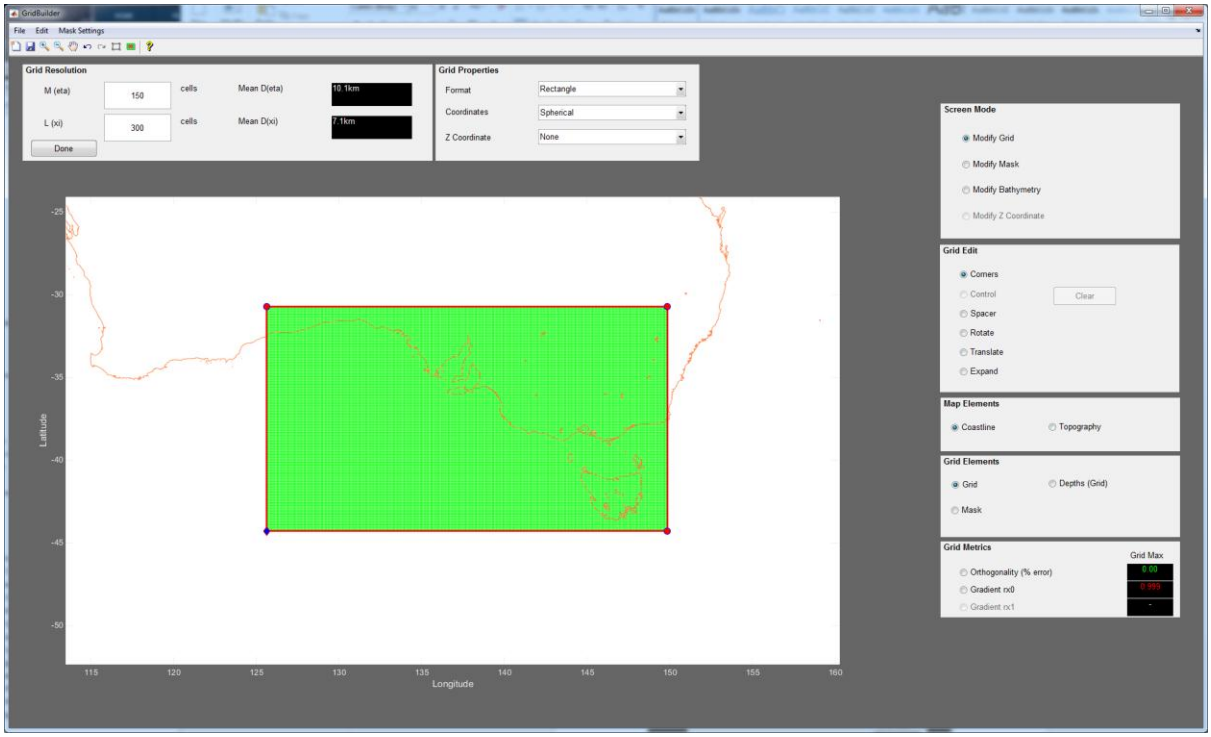
Increasing the grid resolution:



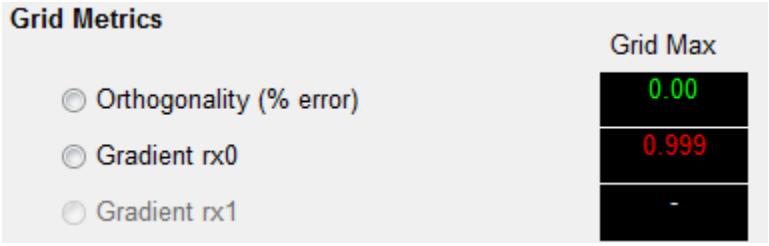
Hint: The default grid size of 10x20 cells is too few to run anything but the most basic model but is useful to provide a schematic of the final grid. It can be manipulated quite quickly and the difference in M and L values makes it easy to identify which axis is which. To increase the resolution of the grid we enter the number of cells in the boxes at the top left of the screen. (Note that after changing the origin, the resolutions of the eta and xi axis have now switched.) In this case let's increase the resolution by a factor of 15, we can do this by typing in *15 after each number and the program will

evaluate this as 150 and 300 respectively. The numbers turn red after being modified but the grid itself will only change after the “Done” button is pressed.

Zoom in on the area containing the grid by selecting the zoom tool from the toolbar and dragging around the area of interest, the coastline and bathymetry resolution will automatically update to the appropriate resolution for the view.



Whenever a grid is created or modified, the depths and mask are automatically updated for the new grid. Notice the Grid Metrics panel at the bottom right hand side. Two metrics have been computed – Orthogonality and rx0 (Beckman and Haidvogel grid stiffness). We haven’t defined a vertical coordinate so rx1 (The Haney grid stiffness) can’t be computed yet. Hint: Metrics highlighted in red indicate that they are outside the usually accepted range of values for a stable grid.

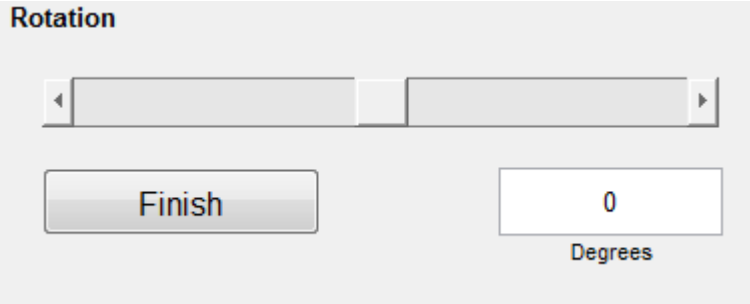


At the moment rx0 is “poor” (this will be defined below) because we have not restricted the depths to be greater than 0 or smoothed the bathymetry yet. Currently the orthogonality is “perfect” as we have defined a rectangular grid with all cells aligned with lines of latitude and longitude.

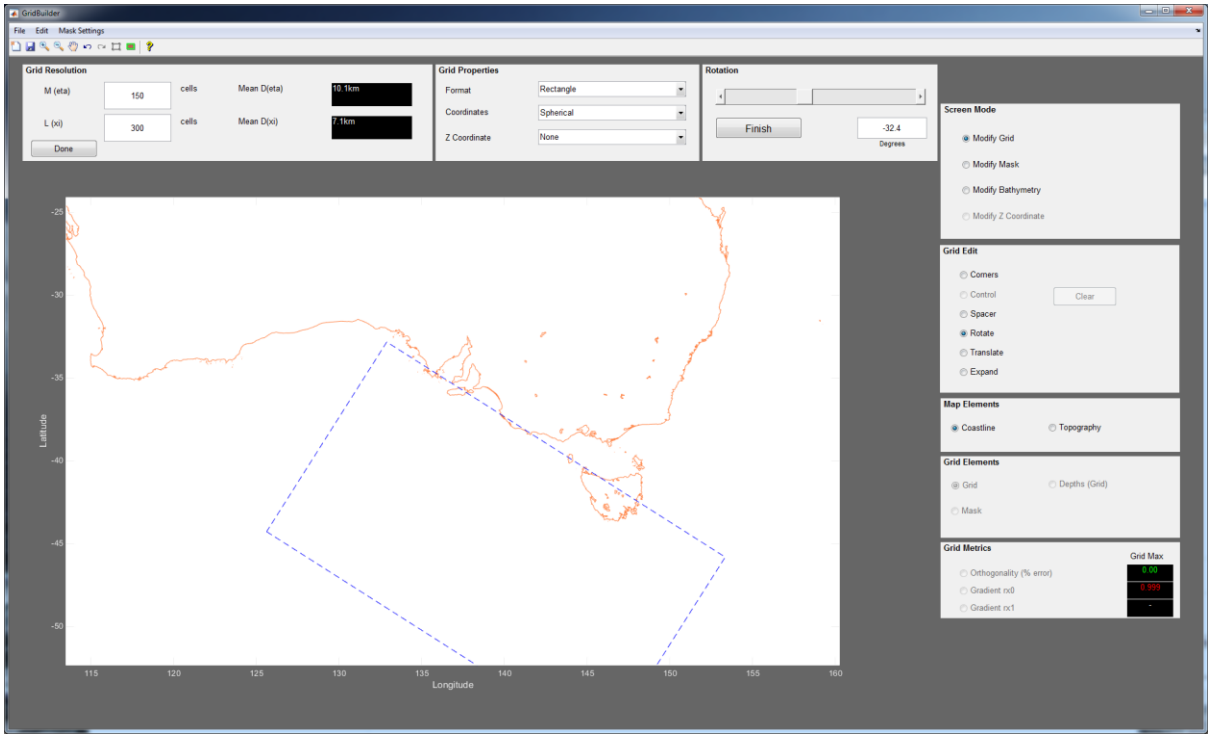
This grid covers a large area of land which can be inefficient for some models – we can use the Rotate and Translate features of GridBuilder to try and align the model boundaries with the coast. So that more of the grid cells are “wet”.

Rotating the grid:

Select Rotate from the Grid Edit panel and a new Rotation panel will appear

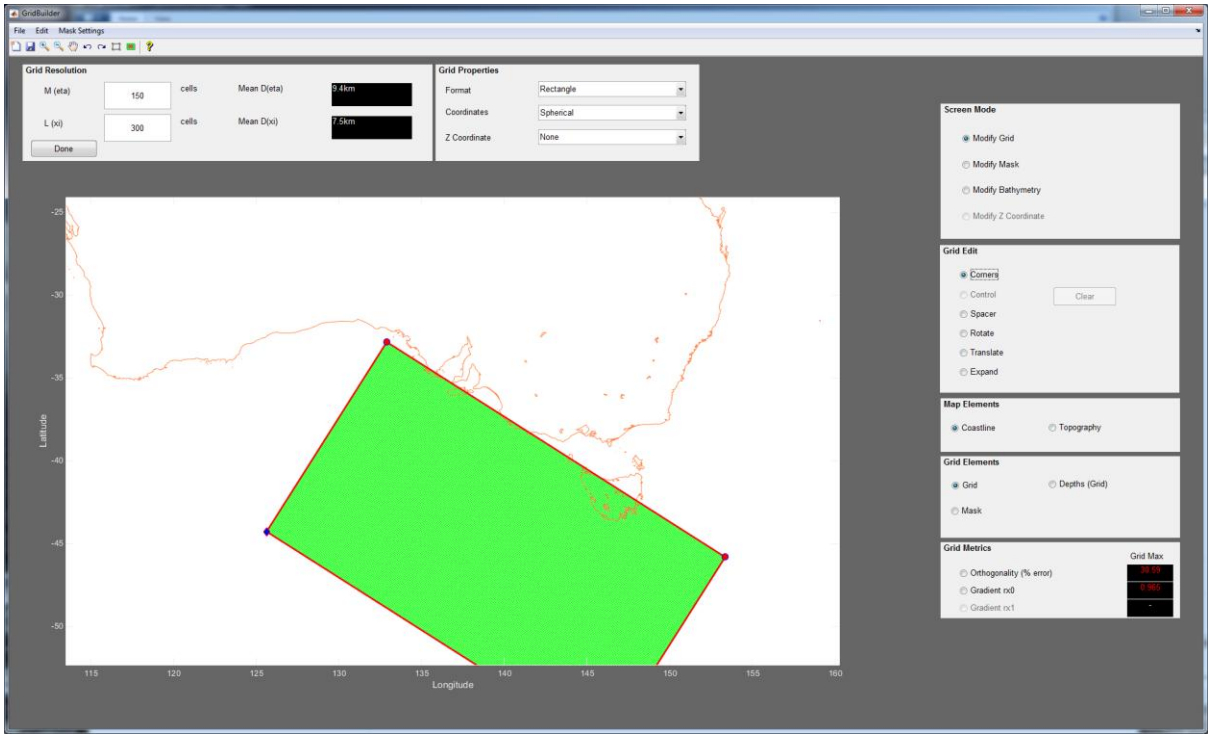


The boundary of the grid is displayed and moving the slide bar or typing a new value into the degrees field will rotate the grid around the origin point we selected. Rotate the grid to about -32 degrees.

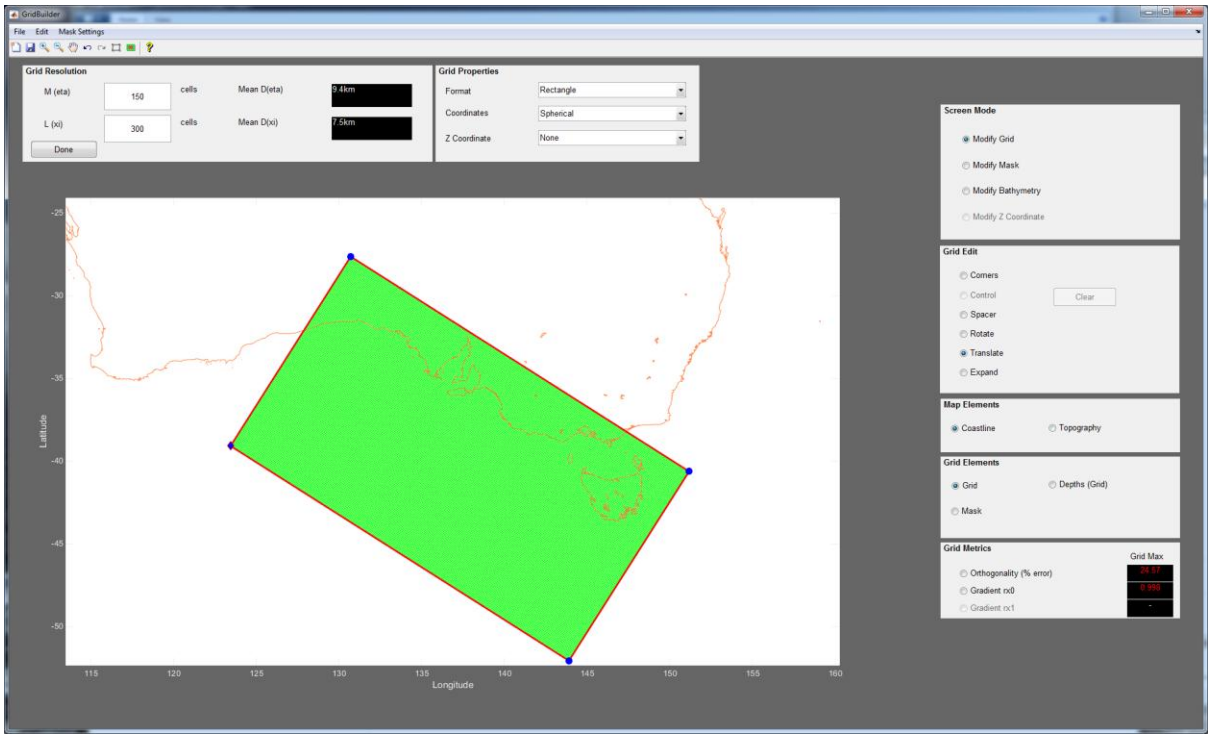


When you are happy with the rotation click Finish and continue. Hint: right clicking on a corner to define a new origin also changes the corner the grid rotates around, this can be used to help rotate the grid to exactly where you want it.

Translating the grid:



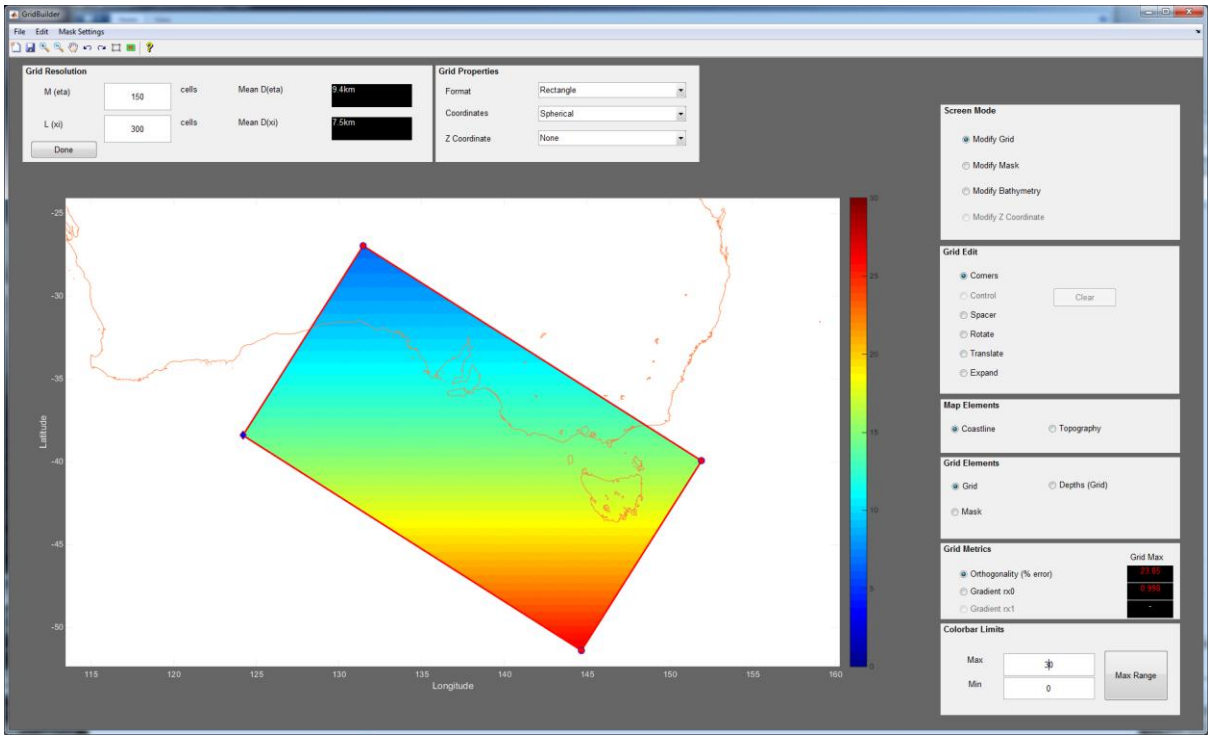
The new grid may now be partly off the display screen but this won't cause any serious problems, we could either zoom out and zoom back in or pan the screen with the hand tool. The main problem is that the grid is not where we want it. To shift the whole grid in one go select "Translate". The corners of the grid will turn blue to show they are active. You can click on any visible corner and drag it – a trace of the grid boundary will indicate where it is while you drag it. Drag the grid to a location that matches up with the coast.



Adjusting the grid orthogonality:

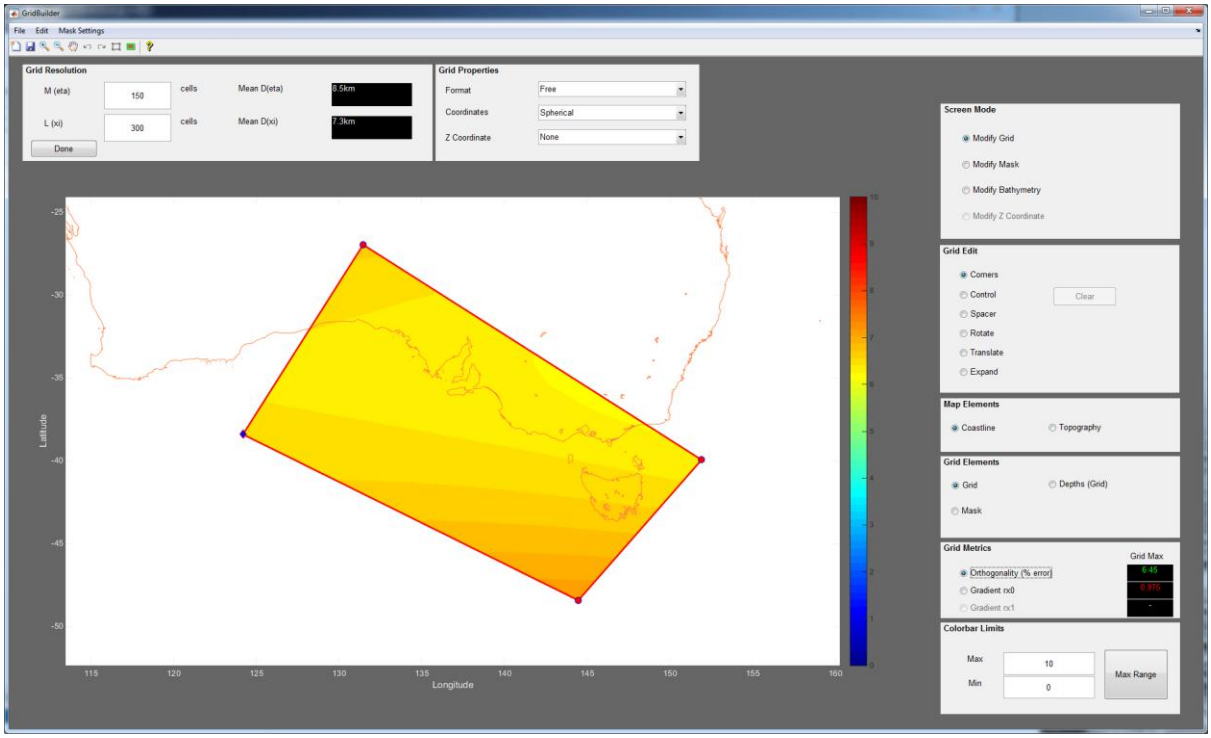
Now the grid is where we want it but in this example the orthogonality error is now too large, the grid still looks rectangular so what happened? The problem is that the map projection for GridBuilder necessarily distorts the surface of a spherical Earth; the grid was only orthogonal as long as the cells were aligned with latitudes and longitudes which meet at right angles.

To examine the variations in the orthogonality error select Orthogonality (% error) from the Grid Metrics panel. The orthogonality error in this example is quite large so adjust the colorbar limits by changing the value of Max in the Colorbar Limits panel to ~30.



The source of the error is now obvious – the convergence of the meridians at this latitude means the cells are becoming increasingly distorted towards the southern point. To fix this we need to modify the grid in “Free” mode. Select “Free” from the drop down menu Format under the Grid Properties panel. Once selected, the individual corners can be moved independently and control points can be added to create curving edges. This mode of grid editing will be familiar to anyone who has used the Seagrid program.

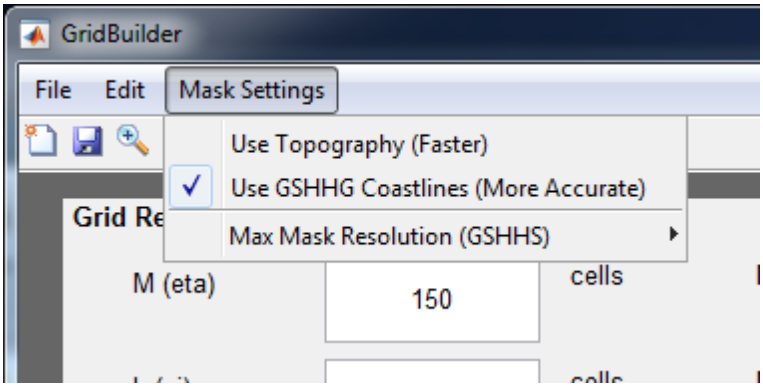
After some trial and error, you should be able to create a reasonably orthogonal grid by dragging the lowest corner in a northwest direction. To improve plot colour resolution reset the Max Colorbar limit to 10. Hint: The orthogonality plot will update as you move the corners and the orthogonality error will lighten when it dips below 15% and turn green when it goes below 10%. You can also add control points to create curvature on the sides to improve the orthogonality of the grid.



Generating the land/sea mask

The next thing to examine is the grid mask. GridBuilder can generate masks in two ways – either through the bathymetry (which is fast) or by selecting points within the GSHHG coastline polygons (slower but more accurate).

For this example use the GSHHG polygons by selecting “Use GSHHG coastlines” from the Mask Settings menu; the program may take a few moments to define the new mask.



Hint: GridBuilder recomputes the mask whenever the location of any grid cells are modified so for improved performance select “Use Topography” until you have finished positioning and forming your grid, then select “Use GSHHG coastlines” to get best possible mask before editing.

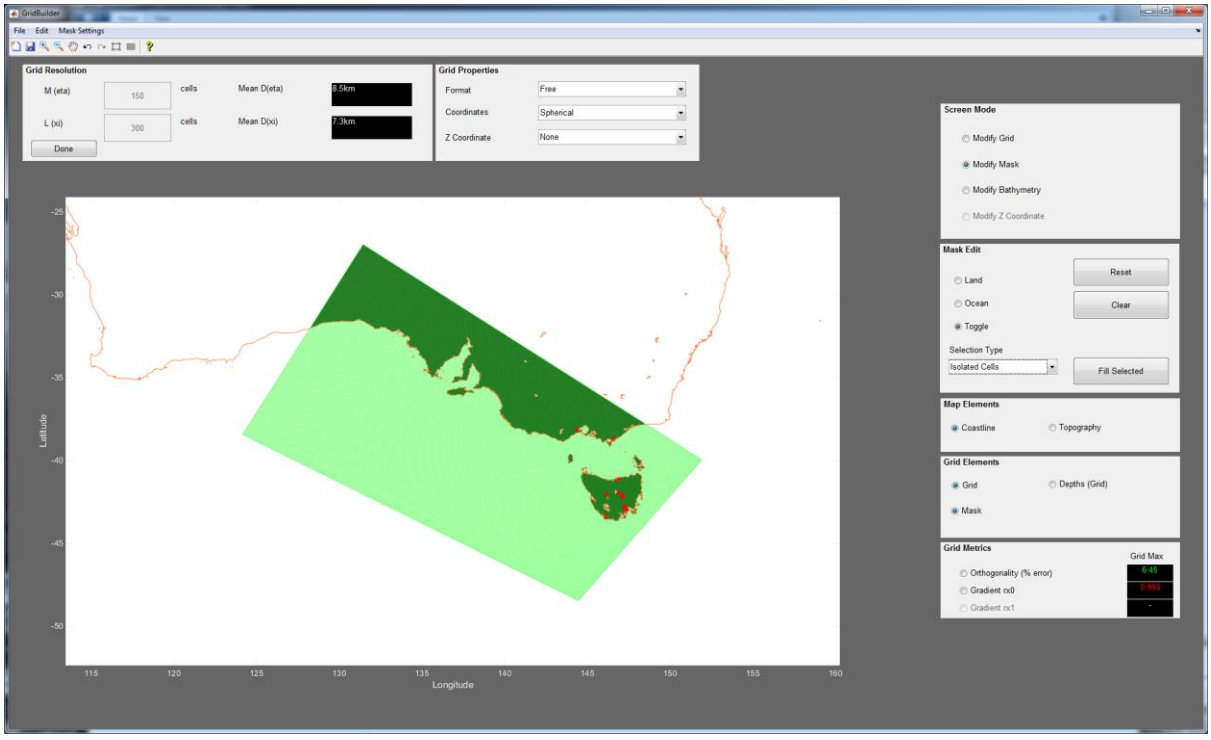
To display and edit the current mask, first, click on “Mask” within the Grid Elements panel. This will turn off the Orthogonality plot (you can turn off the grid too if that makes it easier to see) and you will see the new mask.

We can modify the mask to clear any anomalies that might lead to poor performance such as isolated cells or inlets. Select Modify Mask from the Screen Mode panel. Then select “Isolated

Cells" from the Selection Type drop-down menu in the Mask Edit panel. Red stars are plotted to highlight the questionable cells – these can either be edited manually by clicking on the cell – or filled automatically by pushing the "Fill Selected" button. Next select "Isolated Bays", these are cells with only one open boundary – you may not always want to fill these but they can sometimes cause problems – for now use the "Fill Selected" button. You may have to repeat several times as filling in some bays may create new ones – the menu will return to Isolated Bays as long as there are bays to fill. You can also search for narrow channels (one cell open at either end) which can be a problem when connecting to isolated bodies of water but we won't worry about them now.

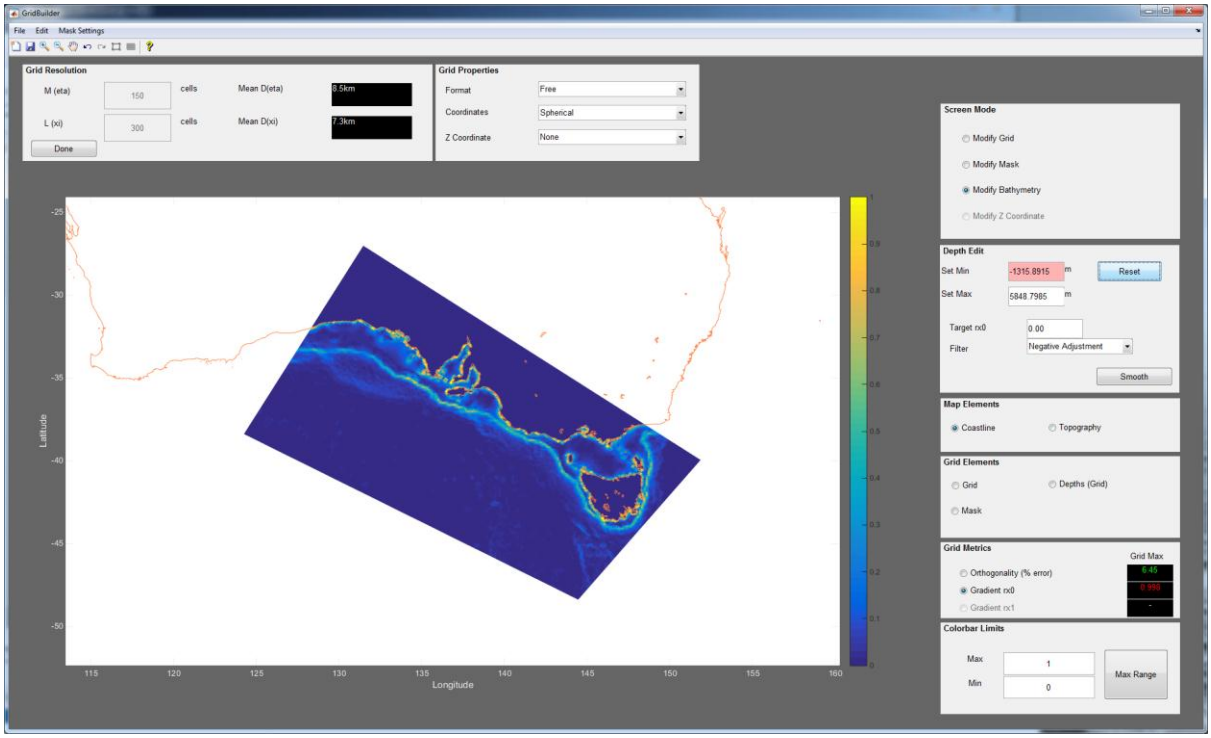
There may also be inland seas which will waste the models time if they are not masked. To manually mask regions, Zoom in to region and set the Land option, then drag the mouse over any wet cells that don't connect to the open ocean.

Hint: When you are done filling in bays and channels, always check for any new isolated cells that might have been created during the filling process.



Generating the grid bathymetry:

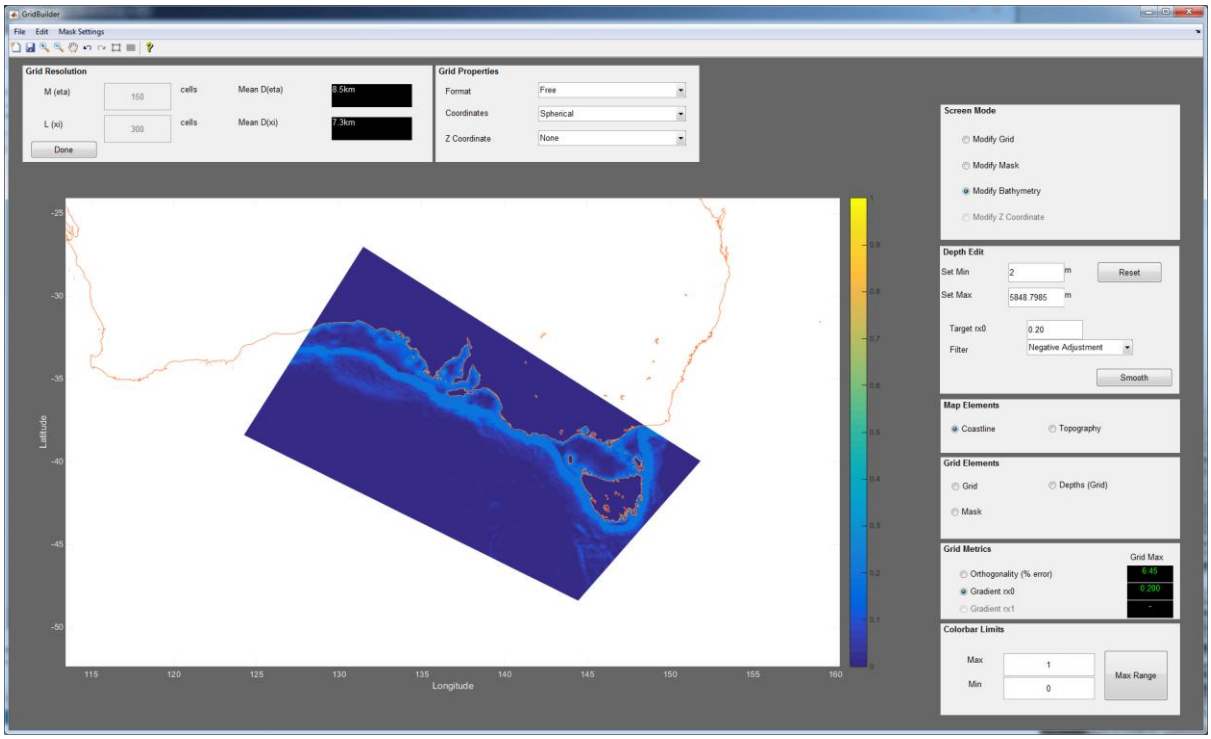
The Final step in preparing the grid is to smooth the bathymetry. To do this we select “Modify Bathymetry”. This changes to the Depth Edit view and displays one of the grid bathymetry metrics (rx0 by default). In this example there is no vertical coordinate so we only see the results of the rx0 calculation.



The first problem is highlighted by the shaded minimum depth box. The topography includes land topography (negative depths for GridBuilder), we should set the minimum depth to be something greater than 0. Enter 2.0 into the “Set Min” box. The grid stiffness (rx0) is still too high, but we can use one or more of the smoothing algorithms to adjust this.

First apply a Shapiro filter to the deepest topography to soften any spurious sea mounts. Select the Shapiro (B.C. constant) filter from the drop down menu, enter 3000.00 into the “Apply below” field so that we only filter depths below 3000m. The default filter “Order” of 2 is fine here, select that if it is not already selected and push the “Smooth” button. This may not affect the maximum rx0 value shown as those values typically occur near the shelf break or coastline but it will have created a more uniform topography in the deep ocean.

Now, select the Negative Adjustment algorithm from the drop down menu if the default value of 0.2 is not already in the Target rx0 box enter it now and then select smooth.



Hints:

If the “Apply below” field is set to 0 for the Shaprio filter the filter is applied to every wet cell. This may produce too much smoothing while trying to reduce the maximum rx0 value sufficiently.

The negative and positive adjustment algorithms only affects cells surrounding those which violate the target rx0 limit so the result distorts the original topography less than the Shaprio filter.

Often a combination of Shapiro filter in the deep water followed by one of the adjustment algorithms will produce a well behaved grid. Filters can be applied as many times as required and in any order, but the adjustment routines won’t change a grid which already satisfies the target rx0 value.

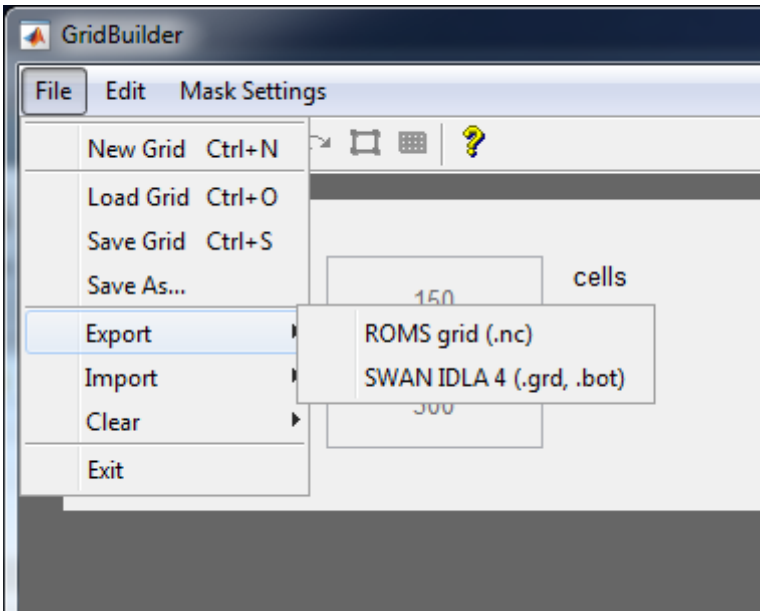
Sometimes applying a Shaprio filter after an adjustment algorithm will result in an increase in the rx0 value so use the adjustment algorithms last.

To reverse the effects of a filter, use the undo button, or use Reset to start over from the original topography.

Exporting the grid

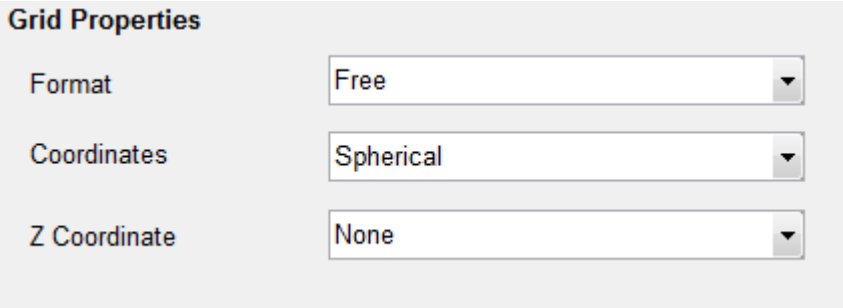
To Save a grid for future editing in GridBuilder select File>Save As… and save the Matlab file. This file can be also imported into Matlab and contains all the fields needed to recreate the grid (see Recognized Data Formats).

To export the grid for testing in ROMS or SWAN, from the menus select File>Export>ROMS grid (.nc) or SWAN IDLA 4 (.grd, .bot) and save the file. This file will contain the grid metrics and required variables for use in a ROMS numerical simulation but will not contain information about the control points used to generate the curvilinear boundaries.



GUI Controls:

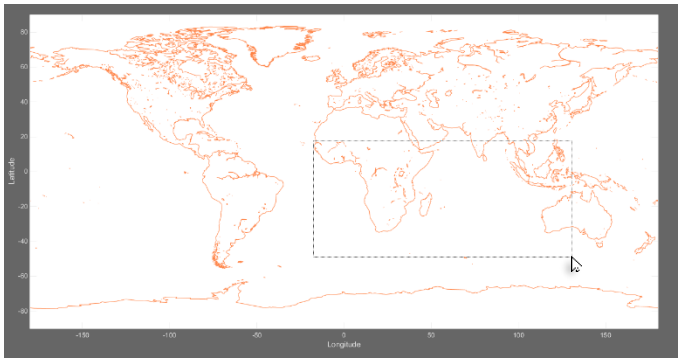
1. Grid Properties Panel



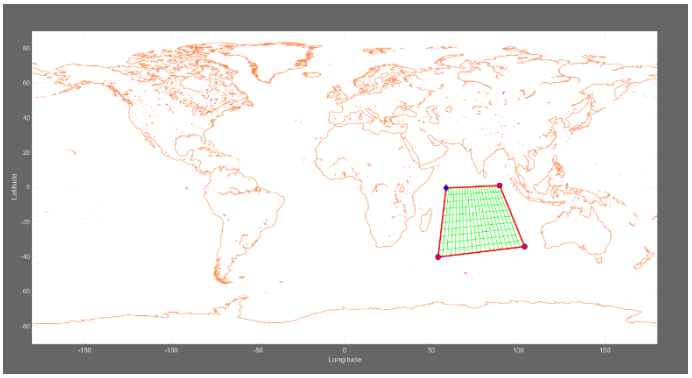
The Grid properties are properties that determine how the grid is created and edited.

Format

- Rectangular: The grid appears rectangular in all coordinate systems. Creation requires selecting a start point and dragging to the opposite corner to create the rectangular grid. A rectangular grid is only truly rectangular on Cartesian coordinates, it is not rectangular on spherical coordinates (no grid is) but it provides a fast and easy way to lay down the original grid over an area of interest. A rectangular grid can only have straight sides so there is no way to add *control points* to produce curvature (see Grid Edit). However the grid resolution can be telescoped by using *spacer points* (see Grid Edit). Editing corner positions will cause the grid to resize adjacent corners to a new rectangle.



- Free: The grid can take on any shape and is created by selecting the 4 corners in sequence. This form of grid is essentially the same as the grid in the original Seagrid program. Each of the four corners can be moved independently allowing more complex grid creation. In addition spline *control points* can be added to create curvature along sides and *spacer points* can be used to modify local resolution (see Grid Edit).



- Fixed: This is not a recommended format for creating and editing grids although the grid corners can be defined in the same manner as a Free Format Grid. This format is used to protect imported curvilinear grids from inadvertent modification by locking out corner and control point manipulation.

Grids can be converted between formats but be careful converting from Free or Fixed to Rectangular as the grid will be recalculated based on the origin and opposite points to create a new Rectangular grid.

Coordinates

- Spherical: The grid design area is laid out in terms of latitudes and longitudes and grid distances are always distorted to some extent by the curvature of the surface. The grid design workspace includes global topography and coastlines by default. Exported ROMS netCDF files will include the variable spherical='T' and grid points are defined with lon_* and lat_* variables.
- Cartesian: The grid design area is laid out in terms of distances in meters. Coastlines and bathymetry are not included by default, although they can be imported. Exported ROMS files will include spherical='F' and grid points are defined as x_*and y_*.

Z Coordinate

- None: The default mode is to create a 2-dimensional grid with no z-coordinate. The z-coordinate is only required for calculation of the Haney number, and then only if the vertical coordinate is a sigma style coordinate.
- ROMS: Currently the only type of s-coordinate supported. Selecting a ROMS z-coordinate enables the calculation of the Haney number (rx1) and *Modify Z Coordinate* under Screen Mode.

The Z-Coordinate has no effect on the grid created with GridBuilder but does allow calculation of the Haney number. The Haney number can be reduced by either smoothing the Bathymetry in *Modify Bathymetry* or by modifying the vertical structure in *Modify Z Coordinate*, typically the fewer vertical levels the lower the Haney number. Even an Exported ROMS grid does not contain any information about the vertical structure as this is defined at runtime within the ROMS initialization file, but the grid will satisfy the users rx1 requirements if the vertical structure defined in GridBuilder is used in the model run.

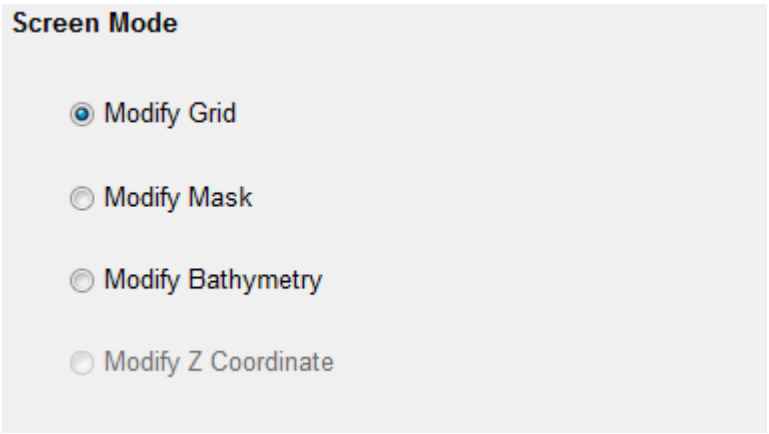
Hint: Creating a grid in "Free" or "Fixed" mode you can select the corners in any order although the first point will always be the origin. The corners are reordered if required to keep sides from crossing. However once a grid is created, GridBuilder will not allow you to drag a corner to a position that would cause sides to cross.

2. Grid Resolution Panel

The Grid Resolution Panel is inactive until a grid is created or loaded. When it is loaded the grid resolution can be modified by entering the number of cells in each direction. In keeping with standard ROMS notation, the xi axis is defined as the axis counter clockwise to the *grid origin point* (see grid creation) and the eta axis is defined as the axis clockwise to the grid origin point. The number of cells in along the xi axis is indicated by L and the number of cells along the eta axis by M. The centre of the cells correspond to the rho points in the ROMS convention, but note that in ROMS the outer rows of cells are considered external to the computational grid and are used for boundary conditions. The internal intersections of the grid correspond to the ROMS psi grid.

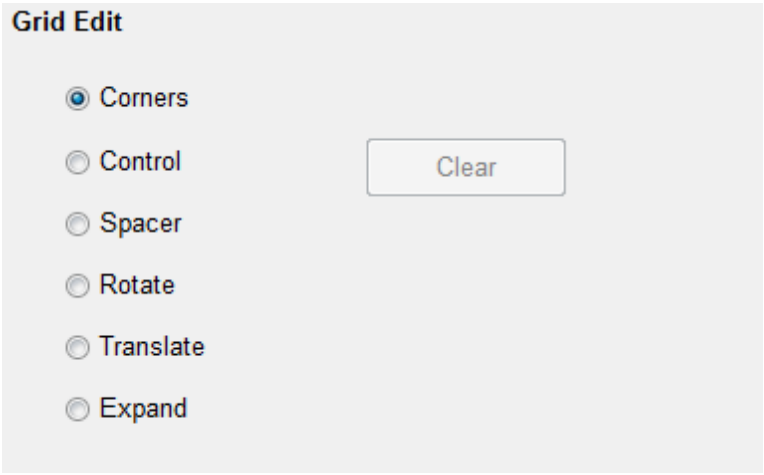
Hint: When changing grid resolution you can use natural Matlab expressions to compute the new resolution (i.e. 270*2 will evaluate to 540, 270*2-3 will evaluate to 537) although the result will always be rounded to the nearest integer greater than 2 (GridBuilder requires a minimum of 3x3 cells). This can be useful when trying to create a nested grid with a resolution that is an integer multiple of the parent grid.

3. Screen Mode



Screen mode determines which property of the grid is currently being modified. The properties are the grid itself, the grid mask, the grid bathymetry, and the grid Z-Coordinate

Modify Grid/Grid Edit

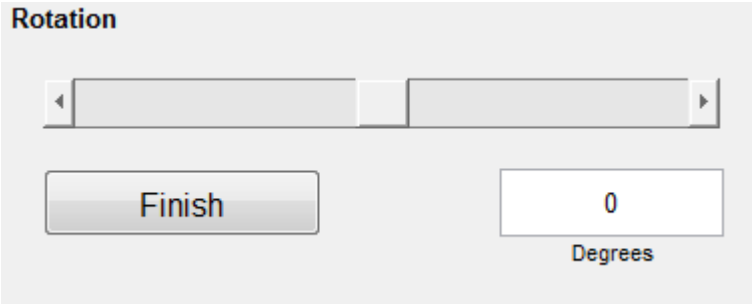


In the original Seagrid program, *corners*, *control* and *spacer* points could all be manipulated at the same time and the program would sometimes misinterpret the user's intention when points were close to each other. To avoid this we have separated the control of these points into separate functions so corners can only be manipulated when "Corners" is selected and so forth.

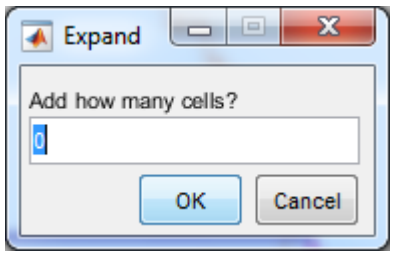
- Corners: Left mouse click on a corner allows user to drag corner to new location. In Rectangle mode the two adjacent corners are repositioned to form a new rectangle, in Free mode the corner is moved by itself. Right mouse click on a corner to make that corner the new grid origin (signified by a blue diamond shape), grid axis and rotations are defined relative to this point. In Fixed mode only the redefinition of the origin is available so corner points can't be dragged to a new position.
- Control: A left mouse click on one of the sides will create a new control point signified by a small blue circle. A left mouse click on an existing control point will allow the control point to be moved by dragging to a new point. The curvature of each side is defined by a cubic spline through the control points. A right click on an existing control point will delete it and cause the side to be recalculated. A "Clear" button is provided to rapidly clear all control points which will cause the sides to all be straight lines. For very coarse grids the control points may not lie exactly on the line but still define the equation of the spline onto which the line segments are matched. Hint: With control points it is possible to create an invalid

grid (i.e. grid points lie outside the boundary of the grids) this typically happens with low resolution and large curvature and is a limitation of the Poisson solver at core of the program. If the grid is invalid the colour of the grid will change from green to magenta. An invalid grid can be rectified by either moving the control points or sometimes by increasing the resolution of the grid. Control is not available in Rectangle or Fixed mode as it is used to generate curved sides.

- Spacer: By default all grids start with 5 equally spaced spacer point on each axis. Spacer points are plotted as small blue squares. A left mouse click on one of the sides will create a new spacer point. A left mouse click on an existing spacer point will allow the user to drag the spacer point along the line. A right click on a spacer point will delete the point and a middle mouse button click on the side will reset all spacer point to equidistant separations. Spacer points work by modifying the width of cells according to a spline interpolation through the spacer point's separation. Where spacer points are closer together the cell width is smaller allowing the user to "telescope" the grid into higher resolutions in some locations. The spacing algorithm is symmetric on opposing sides so modifying one side is the same as modifying the opposite side. The "active" sides for spacer manipulation are always the two sides adjacent to the origin point. Spacer points are available on any grid format.
- Rotate: A new feature of GridBuilder is the ability to rotate any existing grid. When selected a schematic of the border is shown as a dashed blue line and the Rotation panel is available for doing rotations and fine tuning. The rotation can be modified quickly with the slide bar, or a more precise rotation can be given by editing the value in the text box. Once the grid is rotated into the position desired the user clicks on the "Finish" button to recalculate the grid at the new orientation. Rotation is available for any grid format.

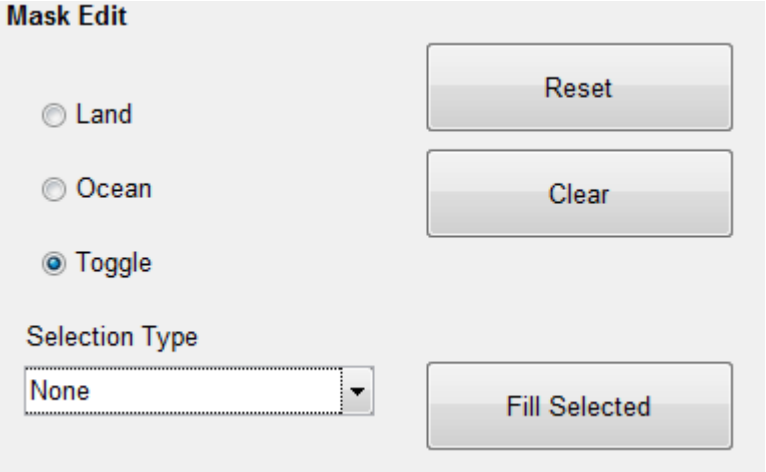


- Translate: A new feature of GridBuilder. When selected the four corners turn blue and clicking on one of the corners allows the entire grid to be dragged to a new location without altering its orientation. When the mouse button is released the new grid is calculated. Translation is available for all grid formats.
- Expand: A new feature of GridBuilder. When selected the four sides turn blue and clicking on one of the sides prompts the user to add additional cells to that side (you must click on OK after entering the number). The new cells are added without modifying the existing grid (although any control points will be removed from all sides). The grid resolution panel will be updated to reflect the additional cells. The depths and mask are only added for the new cells, but this still may change some of the metrics so the user may want to resmooth the depths and recheck the mask. Hint: expand becomes contract if you enter a negative number, this is useful for trimming unnecessary dry rows or columns from an existing grid without having to recalculate the mask and depths as those rows or columns are deleted as well. This feature will work on curvilinear grids as well with new points calculated by linear extrapolation, for

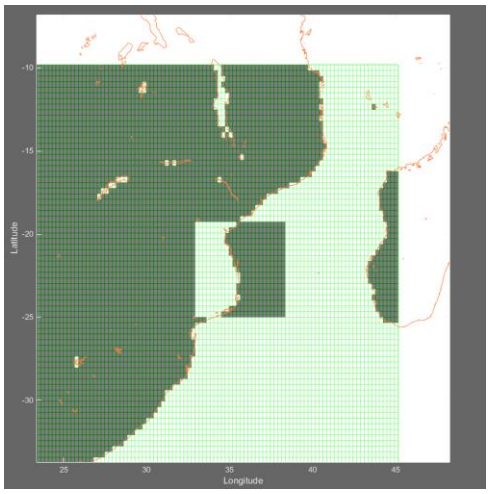


strong curvature this may produce unacceptable orthogonality errors. Curvilinear grids will also lose their control points so subsequent modification of corners or addition of control points will cause the grid to lose its original structure. Hint: it is possible to create an invalid grid by excessive expansion (the linear extrapolation can cause sides to cross if opposite sides converge), the program will detect if the expansion will create an invalid grid and will give the user a message and return to expansion mode without executing the expansion. Because the locations of the original grid elements do not change, Expand is available for all grid formats including Fixed.

Modify Mask/Mask Edit

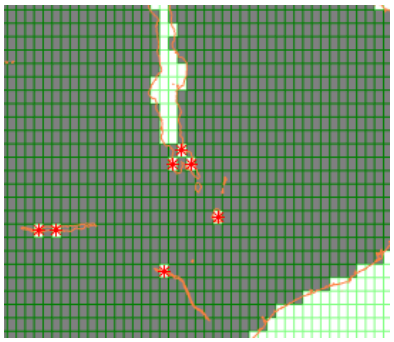


Selecting Modify Mask brings up the Mask Edit Panel and displays the current mask in the grid display area. The default mask edit mode is "Toggle" in this mode when the user clicks on a cell within the grid the mask changes status so a dry point will become a wet point and vice versa. Clicking and dragging will select a rectangular region of the grid and all cells centred within that region will have their status modified according to the edit mode.



For example, selecting a box region including wet and dry points near the coast with "Toggle" on will switch all point status within the box. With edit mode "Land" all selected points are converted to dry points and with edit mode "Ocean" all selected points are converted to wet points. The "Reset" button will recalculate the mask from scratch using the current mask settings (see "Mask Settings" in menu items) and the "Clear" button will set all points to wet.

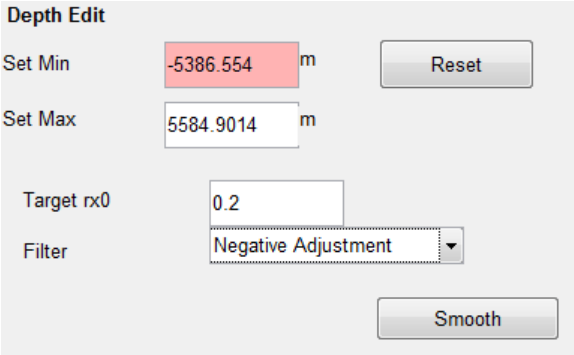
It is also possible to select multiple cells that satisfy one of several criteria for masking. There are currently 3 group selection types available (excluding the default "none").

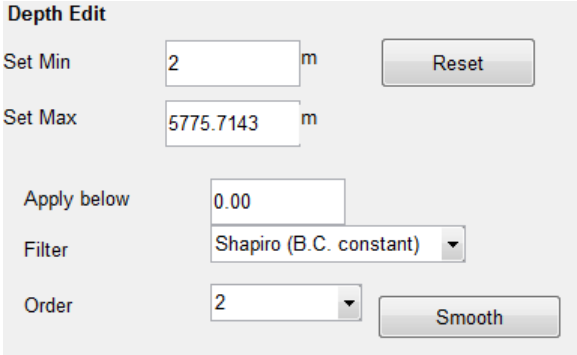


- Isolated Cells: Cells with no external contacts. Filling these cells simply reduces the number of cells for which calculations are done without affecting the model performance. Note that this will not pick up isolated lakes or ponds if they contain more than one adjacent cell.
- Isolated Bays: Cells with only a single external contact. These cells can sometimes lead to artefacts in model solutions and the user may want to consider filling them.
- Narrow Channels: Cells with two external contacts on opposite sides. These cells may or may not need to be filled but may cause issues, especially with flushing of small or isolated bays.

Changes made to the mask in Modify Mask mode take effect immediately but can be undone with the undo options (see Undo).

Modify Bathymetry/Depth Edit





Selecting Modify Bathymetry brings up the Depth Edit panel. Changes here effect the depths on the current grid. The main display will display either rx0, rx1 or Depths depending on the users previous selection.

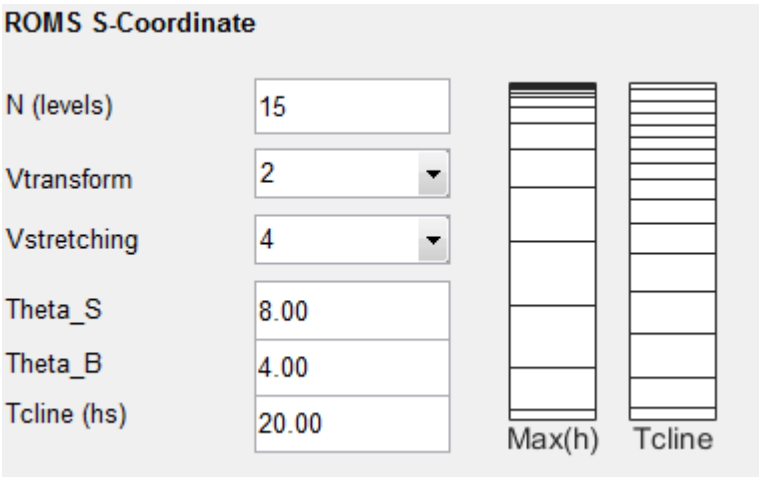
- Set Min: The value entered here will be the minimum depth over the entire grid. Values less than this value will be reset to this value. Numerical models using sigma coordinates cannot have depths <=0 so the minimum depth field is highlighted in red when values above this threshold are entered. Changes to the minimum depth field are applied immediately.
- Set Max: The value entered here will be the maximum depth over the entire grid. Values greater than this value will be reset to this value. There are no numerical limitations to the size of the maximum depth. Changes to the maximum depth field are applied immediately.
- Reset: This resets the depths by recalculating the depths on the predefined grid. It will use the original default bathymetry (etopo2) merged with any imported bathymetry to reproduce the original raw topography with no limits or smoothing.
- Target rx0: For the Adjustment filters that are guaranteed to converge, the user can set a Target rx0 value. The filter will automatically iterate until the target rx0 value is achieved. Hint: If the rx1 value is too high even for a good rx0 value and you don't want to alter the vertical coordinates, reduce the target rx0 value by the same factor that you want to reduce the rx1 value by (for a particular vertical structure the two numbers are proportional).
- Apply Below: For the Shaprio filters the user can select a depth below which to apply the filter. The Shapiro filters are often most effective on deep ocean peaks and can over-smooth

in shallow water. Selecting a depth of 0 will smooth everywhere, selecting a depth of 4000 will only smooth the topography below 4000m.

- Filter: A number of filter options are available to smooth the grid.
    - Negative Adjustment (default): Modifies cells adjacent to cells where the rx0 value exceeds the target by adjusting the topography downwards. This filter will converge to a target value. Changes are only applied when the Smooth button is selected.
    - Positive Adjustment: Modifies cells adjacent to cells where the rx0 value exceeds the target by adjusting the topography upwards. This filter will converge to a target value. Changes are only applied when the Smooth button is selected.
    - Shapiro (B.C. constant): Applies a Shapiro filter to the entire domain with constant boundary conditions. This filter can be run at a number of different orders but is not guaranteed to converge. It can be run repeatedly by the user to achieve better rx0 values. Changes are only applied when the Smooth button is selected.
    - Shapiro (B.C. smooth): Applies a Shapiro filter to the entire domain with smooth boundary conditions. This filter can be run at a number of different orders but is not guaranteed to converge. It can be run repeatedly by the user to achieve better rx0 values. Changes are only applied when the Smooth button is selected.
- Order: Determines the order of the Shaprio filter.
- Smooth: Will execute the currently selected filters.

Filtering can be applied in any order and subsequent filtering is applied to the current depth so the effect is cumulative. To go back to the original depths use the “Reset Button”.

Modify Z Coordinate/ROMS S-Coordinate



This panel is selected by choosing “Modify Z Coordinate” in the Screen Mode panel. This option is only enabled if the Z-Coordinate is set to ROMS in the Grid Properties panel. It displays the settings used in the ROMS initialization file to define the vertical structure of the s-coordinate. There are 6 parameters that need to be set to determine the vertical structure and they can be modified by either typing in a new value or pulling down a setting from a drop down menu.

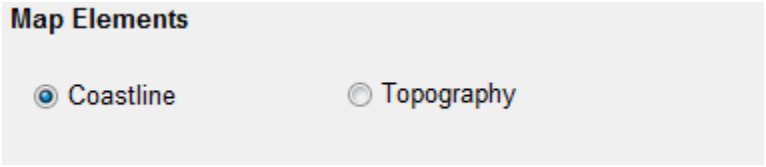
- N: The total number of vertical levels
- Vtransform: A ROMS s-coordinate uses one of two vertical transform algorithms that can be specified here.
- Vstretching: A ROMS s-coordinate uses one of 4 vertical stretching algorithms that can be specified here.

- Theta_S: Specifies the degree of stretching at the surface. The effect of Theta_S depends on the transform and stretching algorithms selected.
- Theta_B: Specifies the degree of stretching at the bottom. The effect of Theta_B depends on the transform and stretching algorithms selected.
- Tcline (hs): Specifies the so-called critical depth, the effect of Tcline depends on the transform and stretching algorithms.

To the right of the parameters are two schematic representations of the s-coordinates. The one labelled Max(h) shows the distribution of levels from the surface to the deepest point in the current grid. The one labelled Tcline shows the distribution of levels for a cell which has a depth equal to Tcline. The user can examine the distribution of the vertical levels as the parameters are modified. The calculation of rx1 is also updated after each modification. If rx1 is still too high even when rx0 is adequate, it may be necessary to resmooth the bathymetry with a smaller target for rx0.

Hint: for a particular vertical structure rx1 (the Haney number) will be proportional to rx0 so the only way to reduce rx1 without additional smoothing is to modify the vertical structure. Reducing the number of levels often helps but the other parameters also influence the Haney number. ROMS users can also use this panel to explore the effect of the vertical structure on the Haney number of any existing ROMS grid by importing it and playing with the parameters.

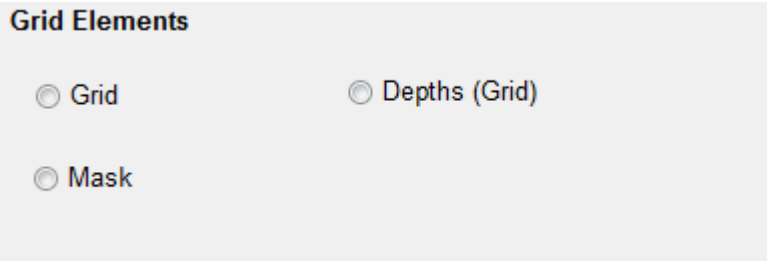
4. Map Elements



For a workspace in spherical coordinates there are two elements that can be plotted even if no grid has been defined.

- Coastline: Selected by default. The coastline is presented by an orange line and is based on the GSHHG coastlines. The actual resolution used depends on the axis limits of the workspace and will use the full resolution polygons for small enough regions. If the user has loaded their own coastline (see import Coast Data) this will be plotted in blue and overlaid on the GSHHG coastline.
- Topography: When selected this will show the basic etopo2 topography included with GridBuilder. If the user has loaded their own topography (see import Bathymetry Data) the users bathymetry is bounded by a black and white border and merged with the existing topography. A new grid will use the user's topography where it exists and etopo2 elsewhere.

5. Grid Elements

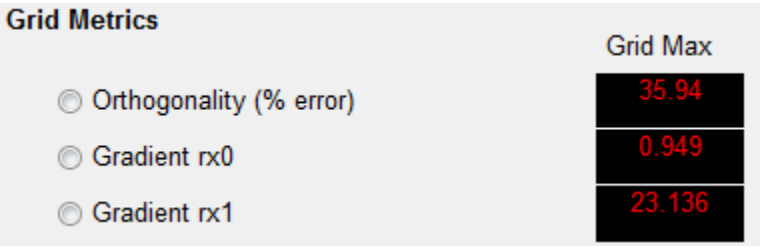


Once a grid has been defined it automatically generates the depths on the grid and the mask. These properties can be plotted up in the workspace by toggling these buttons on and off.

- Grid: The grid here refers to the green mesh grid which defines the individual cells. For very high resolution grids the mesh itself may interfere with details the user may want to see so it can be unselected here. There are also some editing options which will turn off the grid and to see the grid the user will need to turn it back on. In most cases the corners and sides of the grid remain when the mesh is hidden.
- Depths (Grid): The depths here refer to the depths interpolated to the cells of the grid rather than any user or default topography. If the depths have been modified or edited the results of that will be reflected here.
- Mask: The mask defines wet and dry points on the grid. If the mask has been modified with the Mask Edit controls, the changes will be reflected here until the grid is moved or edited.

These grid elements will be saved or exported with the grid.

6. Grid Metrics



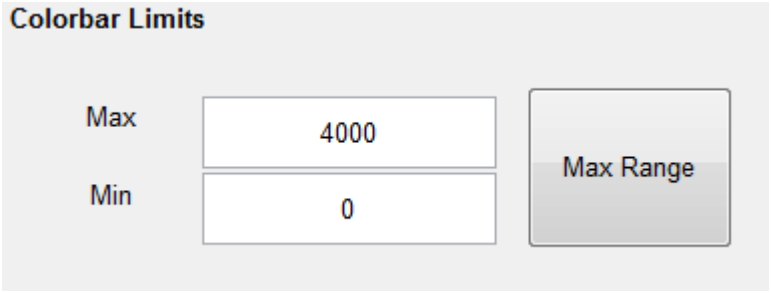
There are three grid metrics that can evaluate the potential stability of the grid when used in a numerical model. Only one of the metrics can be plotted at a time as they overlay each other.

- Orthogonality (% error): The error in the orthogonality of the grid is determined by looking at each intersection of the cell boundaries and measuring the maximum departure from 90^{O} in the 4 adjoining cells. The angle of intersection is calculated in spherical coordinates when they are selected so a rectangular grid will not, in general, be rectangular on a sphere, however a rectangular grid will be perfectly orthogonal (0% error) on a Cartesian coordinate system. In general grid orthogonality errors should be 10% or less. If the maximum orthogonality error is less than or equal to 10% the value is coloured green, between 10 and 15% the value is coloured orange, and above 15% the value is coloured red to indicate a relatively high error.
- Gradient rx0: The Beckmann and Haidvogel number is a measure of the relative change in depth in adjacent cells normalized by depth. Generally a maximum value of 0.2 for rx0 is considered acceptable for grid stability so rx0 values less than or equal to this are coloured green. The value of rx0 is calculated without considering negative depths (above water

topography) so the maximum value it can attain is 1.00. The value of rx0 will change from orange to red if it is larger than 0.4 to indicate a relatively large rx0.

- Gradient rx1: The Haney number looks at the gradient and the spacing between sigma levels in order to help quantify the potential for errors in the pressure gradient terms (gradients along constant depths as opposed to constant sigma surface). The larger the Haney number the worse the grid performance. Comments on the ROMS forum suggest that Haney numbers up to 7 are usually stable and are coloured green. Even Haney numbers larger than that can be used if the vertical stratification of the model is relatively weak. The colour of the rx1 number changes from orange to red for values of maximum rx1 > 10 to indicate a relatively large rx1.

7. Colorbar Limits



When Topography, Depth, Orthogonality, rx0, or rx1 are plotted a panel appears that lets the user modify the current colorbar limits. This is most useful for helping identify topographic features where there is often a large gradient between the deep ocean and coastal areas, but it can also be useful for highlighting critical values in the grid metrics.

- Max: Sets the maximum value to be plotted in the display. If this value is less than the Minimum value it becomes the minimum value.
- Min: Sets the minimum value to be plotted in the display. If this value is more than the Maximum value it becomes the new maximum
- Max Range: Automatically sets the limits to the maximum range of the current parameter being plotted.

8. Menu Items

File

- New Grid: Clears current workspace and reinitializes GridBuilder to create a new grid
- Load Grid: Loads a new grid from a Matlab file created by GridBuilder
- Save Grid: Saves Current Grid to a Matlab file that can be read back in or loaded into Matlab. If the current grid has been saved this will keep the same name and over-write the last file.
- Save As…: If the current grid has been saved but the user wants to save under a new name.
- Export:
    - ROMS grid (.nc): This will create a netCDF file which is compatible with most current versions of ROMS
    - SWAN IDLA 4 (.grd,.bot): This will create two separate files that can be used as the basis for a SWAN wave model. The grids will be consistent with ROMS grids and can be used for two-way coupling.
- Import:
    - ROMS: This will import an existing ROMS netCDF grid file. The imported file will be assigned to a fixed format. If the ROMS file has curved sides GridBuilder will not be able to assign control points to match the grid shape.
    - Coast Data: This will import custom coast line data in a range of binary and text formats (see recognized data formats).
    - Bathymetry Data: This will import custom topographic data in a range of binary and text formats (see recognized data formats).
    - Reference Points: This will import x,y points from a variety of binary and text formats (see recognized data formats). These points can then be plotted to aid in new grid design (see toolbar items).
- Clear:
    - User Coast Data: Clears any imported coast data and reverts to all coasts to default coasts (GSHHG)
    - User Bathymetry: Clears any imported bathymetry data and reverts all bathymetry to default (etopo2)
- Exit: Exits GridBuilder (same as clicking on close button)

Edit

- Undo: Will undo all steps back to grid creation or new grid
- Redo: Will redo steps previously undone.

Mask Settings

- Use Topography (Faster): Base mask on topography where land is wherever depth is <0. This is the fastest way to generate a mask but does miss some high resolution features.
- Use GSHHG Coastlines (More Accurate): Create mask by comparing locations to GSHHG polygons. The method is slower as all polygons within the grid must be checked but it is much more accurate for high resolution coastlines. This method will also set lakes and ponds to wet points so some mask editing may be required once the mask is generated.
- Use Imported Coastline: Will use the current imported coast line to generate the mask. Note that *only* the imported coastline is used to create the mask so if the grid extends beyond the range of the imported coastline any land cells must be manually masked using the Mask Edit panel or they will be treated as wet cells. This option is only available if the user has imported a custom coastline.

- Max Mask Resolution (GSHHS): The GSHHS comes in 5 levels of resolution, Coarse, Low, Intermediate, High, and Full. When using the GSHHG polygons to generate a mask GridBuilder selects the appropriate resolution based on the minimum grid spacing, but this can be overridden here and a lower resolution can be selected to speed up processing. The default setting is automatic and lets GridBuilder decide which resolution to use.

9. Toolbar Items

-  Clear current grid and reinitialize Grid Builder for new grid.
-  Quick save current grid.
-  Zoom and Pan current domain.
-  Undo and Redo steps.
-  Toggle reference points (if imported). Reference points are plotted as black crosses.
-  Select a subgrid. When selected the mouse can be used to select a region within the current grid by clicking and dragging on the current grid. The selected region is highlighted in red and when the mouse button is lifted the user is prompted to clear the unselected grid. The user is also prompted to save the previous grid. The creation of a subgrid does not reinitialize the grid so the step can be undone.
-  Gives information on the version number and author contact.

Recognized Data Formats

Input Files

- Model Grids: GridBuilder can read in grids from Matlab files created with GridBuilder and Seagrid (.mat) and netCDF grids created for use with ROMS (.nc).
- Reference Points: GridBuilder will read in the boundary rho points from a ROMS file (lon_rho and lat_rho) and apply them as reference points. GridBuilder can also read data from a two column ASCII file with longitudes (x data) in the first column and latitudes (y data) in the second column.
- Bathymetry: GridBuilder can read in data from a variety of bathymetry files including three column ASCII files (Seagrid, Geosciences Australia, etc.). GridBuilder will also try and extract bathymetry from a wide array of netCDF files including ROMS grid files or Matlab files. The x, y and z coordinates will be read from any variable with one of the following names:
    - 'X', 'x', 'xbathy', 'lon', 'Lon', 'longitude', 'Longitude', 'LON', 'x_rho', or 'lon_rho'
    - 'Y', 'y', 'ybathy', 'lat', 'Lat', 'latitude', 'Latitude', 'LAT', 'y_rho', or 'lat_rho'
    - 'Z', 'h', 'z', 'zbathy', 'depth', 'Depth', 'DEPTH', 'Elevation', 'Band1', or 'depths'
- Coastlines: Grid builder can read in coastlines from two column ASCII files with polygons separated by NaNs or from Matlab files with any of the following x, y variable names
    - ‘x’, ’lon’, ’Lon’, ’longitude’, ’Longitude’, or ’LON’
    - ‘y’, ‘lat’, ‘Lat’, ‘latitude’, ‘Latitude’, or ‘LAT’

Output Files

- GridBuilder: Saves to a GridBuilder Matlab file with the following fields:
    - grid: location of grid nodes (psi points + sides) and various grid metrics.
    - side: location of boundary points, control points and spacers.
    - corner: location of corners starting with origin.
    - mask: current land/sea mask (0=land,1=sea) on rho points of grid.
    - depths: current depths on rho points of grid.
    - coast: truncated GSHHS polygons visible during last display update.
    - bathymetry: eTopo2 bathymetry visible during last display update
    - limits: x,y limits of last display update
    - Translation: x, y displacement from original grid origin if a translation has been done
    - Rotation: rotation relative to original grid, in degrees;
    - Dtheta: incremental change in rotation since last rotation, in degrees.
    - projection: Spherical or Cartesian
    - GridType: Rectangular, Free, or Fixed
    - bathyInterpolant: Matlab interpolant (gridded or scattered) generated from eTopo2
    - userbath: true or false if user has imported bathymetry
    - user_BathyInterpolant: if userbath=true contains Matlab interpolant of user bathymetry.
    - usercoast: true or false if user has imported coastline data
    - user_coast: if usercoast=true, structure with user imported polygons.
    - Z: field exists if user has defined a Z coordinate – currently only ROMS coefficients supported.
- ROMS: GridBuilder will export to a ROMS compatible netCDF grid file
- SWAN: GridBuilder will export to SWAN compatible depth and coordinate files.