RECOM User Manual

V1.1

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Contents

1 Introduction

The Relocatable Coastal Ocean Model (RECOM) is an automated relocatable model designed to be embedded within the eReefs GBR1 or GBR4 regional models to produce outputs of the physical state, wave climate, sediment transport, water column and benthic production and nutrient cycling in limited area domains within the Great Barrier Reef. It is particularly suited to produce high resolution simulations (at resolution of 10s to 100s of metres) over reefs, and within estuaries and embayments. The RECOM package is designed for non-specialist users, whereby the user simply and intuitively interacts with the models via a graphical workflow interface. Model configuration is automatic, based on a set of selectable configurations, so that the user need not be a modelling expert to produce model output. The mechanics of RECOM is described in detail in Herzfeld (2016, Section 4.8). This document provides instruction in the use of RECOM.

2 RECOM workflow

RECOM consists of a number of elements that have been assembled into a coherent workflow that allows the user to initiate high resolution simulations with minimal user input via a graphical interface.

The steps that a user must navigate in order to produce a downscaled hydrodynamic, sediment transport and biogeochemical simulation nested within the eReefs regional models are:

1. Log on to RECOM using a web browser.
2. Select RECOM from the model list,
3. Define the grid using the grid generation set of panels,
4. Select the time period to use and the forcing dataset to nest the RECOM model in,
5. Define the model configuration via tracer attribute, parameter and process sets,
6. Schedule the run.

These steps are considered in turn. Here we demonstrate a simulation at within Hervey Bay from 2 December 2014 for a 19 day simulation using a curvilinear grid.

3 Invoke RECOM

Interaction with RECOM is currently achieved via the web. RECOM is currently configured on CSIRO computing infrastructure, where servers perform the grid generation and actual running of the models. Similarly, all data bases required for model initialisation and forcing are hosted on CSIRO computers. At the time of writing this User Manual, RECOM is only deployable in a CSIRO development environment, however, future update of RECOM will likely require a deployment strategy beyond the CSIRO system. The nature of this deployment will likely be dependent of the demand of RECOM and stakeholder preferences for access. The information presented in this manual therefore is applicable to the current installation of RECOM on CSIRO computers.

To invoke RECOM, first launch your browser (we recommend Google Chrome) and type in the URL location:

http://recom.it.csiro.au/

This will launch the RECOM workflow, where first a login is required, which if successful brings the user to the model monitoring pane (Section 9). Selecting the blue ‘New’ button will allow a new RECOM run to be made; the user is first directed to the user to the model selection pane.

4 Model selection

The RECOM infrastructure has been constructed in a manner that allows expansion in the future, whereby possibly alternative instances could be invoked; e.g. an instance that allows modelling in another regional location around Australia. Currently RECOM is the only instance developed, so the user chooses this option (Fig. 1).

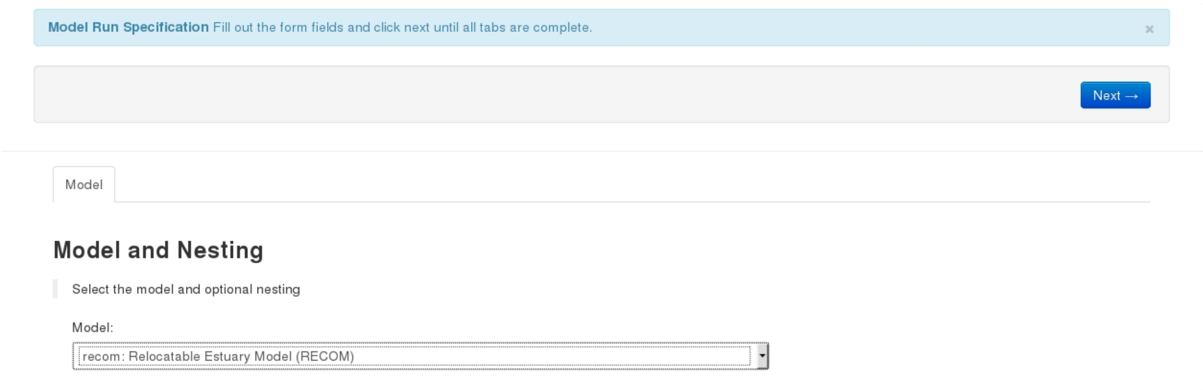

Figure 1. Screenshot showing model selection.

The user is able to move through the steps of RECOM as needed. Each step appears in its own tab within the web page and the user may either select the appropriate step directly by clicking on the tab for any modifications needed or use the blue ‘Previous’ and ‘Next’ buttons, at the top of the page to do so sequentially. Once the RECOM model has been selected, the user continues to defining the grid.

5 Grid generation

The grids that the user can build in RECOM are currently orthogonal curvilinear grids. Capability is likely to be included in future to simply generate rectangular or polar grids, but since these are sub-classes of curvilinear grids, the current functionality allows the generation of all possible grids.

Firstly, the user is presented with a list of all their saved existing grids under the ‘History’ tab

(Fig. 2). For new grids, click the green ‘New’ button to proceed. Clicking an existing grid will take the user to the last saved version of that grid where further modifications may be made.

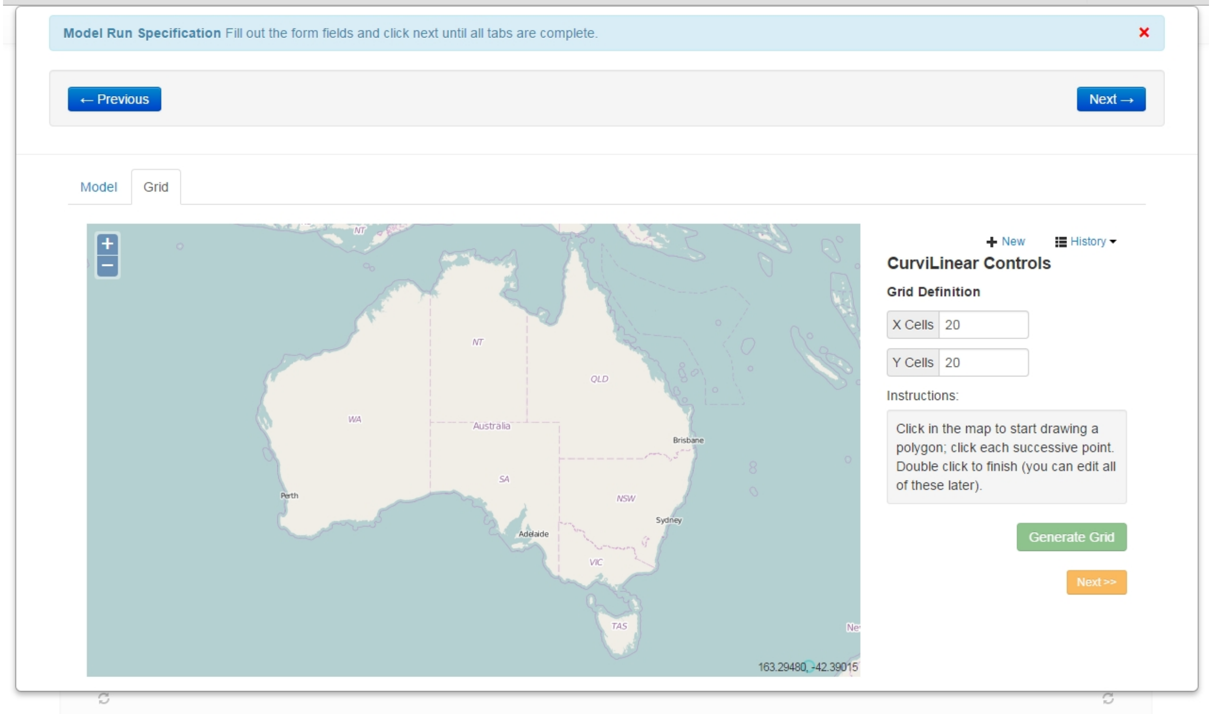

Figure 2. Screen shot of the grid generation entry page.

Once a new grid is requested, the user is presented with an interactive map (in the style of Google Maps) on which they can place and edit waypoints required to define the curvilinear grid. When satisfied they can submit this for execution, where-upon the server generates and displays the grid on the map in the user's browser. If required, the grid may be edited. Once the user is satisfied with the shape of the grid, a land-mask is chosen from available datasets and applied to delineate which model cells are land and which are water. The land-mask may then be further edited manually. Once satisfied, the user chooses a bathymetry that is interpolated onto the grid from a database, after which manual editing is again possible. There are standard bathymetries in the database (Beaman, 2010), but the user may upload a custom bathymetry if desired. Lastly, if rivers are to be input into the model domain, the user can select these from a drop down menu, and the river mouths will be inserted at the closest location in the model grid to gauging station locations in the RECOM database. The user is able to iterate over the steps of grid generation as needed, using orange ‘Previous’ and ‘Next’ buttons. We consider these steps in more detail in turn.

5.1 Defining a Curvilinear Grid

On the map, the user defines a set of points used to create the boundary of the grid through the use of a Google Maps style point-and-click interface. Once located on the map, the waypoints can be moved using click-and-drag. Additional points can be inserted between existing ones using point-and-click. At any time the map can be dragged or zoomed using

Google Maps protocols. The actions for inserting, deleting or changing waypoints are listed to the right of the map on the browser, along with a list of the geographic locations of the points. The waypoints have attributes allocated to them defining the type of point they represent. These attributes are described in Table 1.

Table 1. Waypoint attributes for grid generation.

Type	Value	Colour	Description
Normal	0	Blue	Regular point to define grid boundary
Exterior	1	Red	Indicates an external corner of the grid
Interior	-1	Green	Indicates an internal corner of the grid
Origin	0	star	Denotes the grid origin

The external corners are associated with normal corners of the grid (i.e. in a 200 x 200 grid, cells (1,1), (1,200), (200,1) and (200,200)), whereas the internal corners are required if the user wishes to include a branch in the grid. Branches are useful when trying to join a long river into a bay in the grid; in this case internal corners are placed where the river meets the bay, to create a branch that resolves the river. The ends of the river branch use additional external corners to close the branch. It is important that the sum of all external minus the number of internal corner values add up to four before the user can continue to generating the grid. The size of the grid can be altered in the 'X Cells' and 'Y Cells' boxes; the larger these numbers the higher the grid resolution will be (and the slower the model will run).

Once satisfied the grid has the required shape and the sum of corner values equates to 4, then the grid may be generated by clicking on the green 'Generate Grid' button. The grid is generated using a set of mathematical rules based on the shape of the grid defined by the waypoints. The process is complex, and the final shape of the grid cannot easily be anticipated, so a degree of trial and error (moving or adding waypoints) is generally required before a satisfactory grid is generated. Practice is required to become skilled in grid generation and get the required grid resolution at the required location. Some useful hints are that the waypoints often have to extend beyond the region of interest in order to get the required resolution in the area of interest, a concave grid boundary results in high resolution adjacent to that boundary and a convex boundary results in low resolution near that boundary. If the grid dimensions are large, then it may take some time for the grid generation procedure to complete. Note that the higher the grid resolution is, the slower the model will run. Also, the ocean boundaries of the grid are nested into the regional models and there exist rules about ratios of nested to regional grid dimensions that can safely be accommodated. Generally a 5:1 ratio is reported to be satisfactory, meaning the resolution should not be less than 200 m at the ocean boundary if nesting into GBR1, or 1 km if nesting into GBR4. Note this is the boundary resolution and does not mean that resolution is maintained over the whole grid – curvilinear grids have variable resolution and it is possible to make polar type grids that have resolution of 10s of metres at their origin.

Once the grid is generated, it may be edited and re-generated; this process can be repeated until the user is satisfied with the grid's shape. The grids are saved for the user to recall and re-commence work at a later stage. A visual depiction of this step of the workflow is shown in Fig. 3. Once satisfied with the grid mesh, click the orange 'Next' button in the lower left corner.

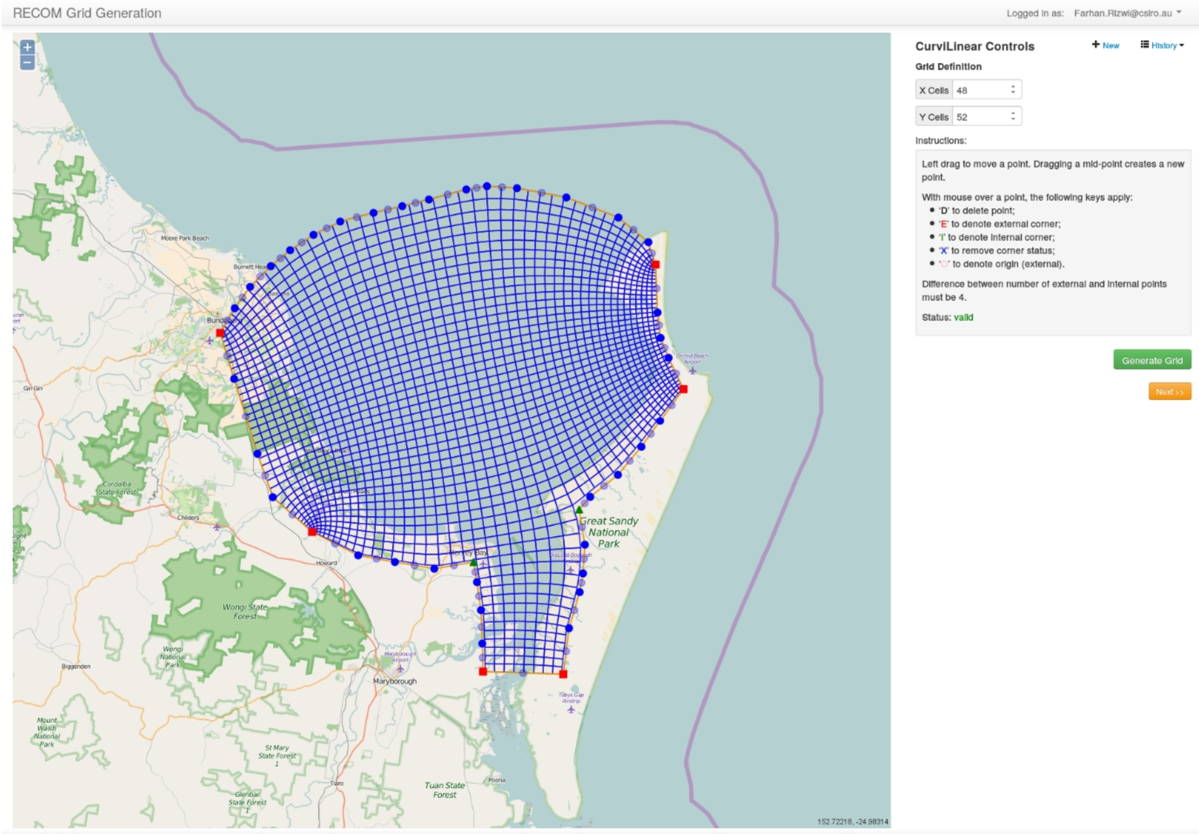

Figure 3. Illustration of a rendered grid in RECOM.

5.2 Masking the grid

Once the grid shape is defined, the user can move onto the next stage of the process: to determine which cells represent land and which represent water. This is done via the Masking tab in the “Masking & Bathymetry tab”. The user has two choices at this stage; either mask against a predefined coastline stored in the RECOM database (recommended), or to manually click on cells and mark them as masked. Check the “GBR” coastline option and click on the green ‘Mask to Coast’ button to automatically select cells as water or land based on the stored coastline database. The result is that water cells will become shaded blue, while land cells will remain transparent; Fig. 4 shows the result of this process.

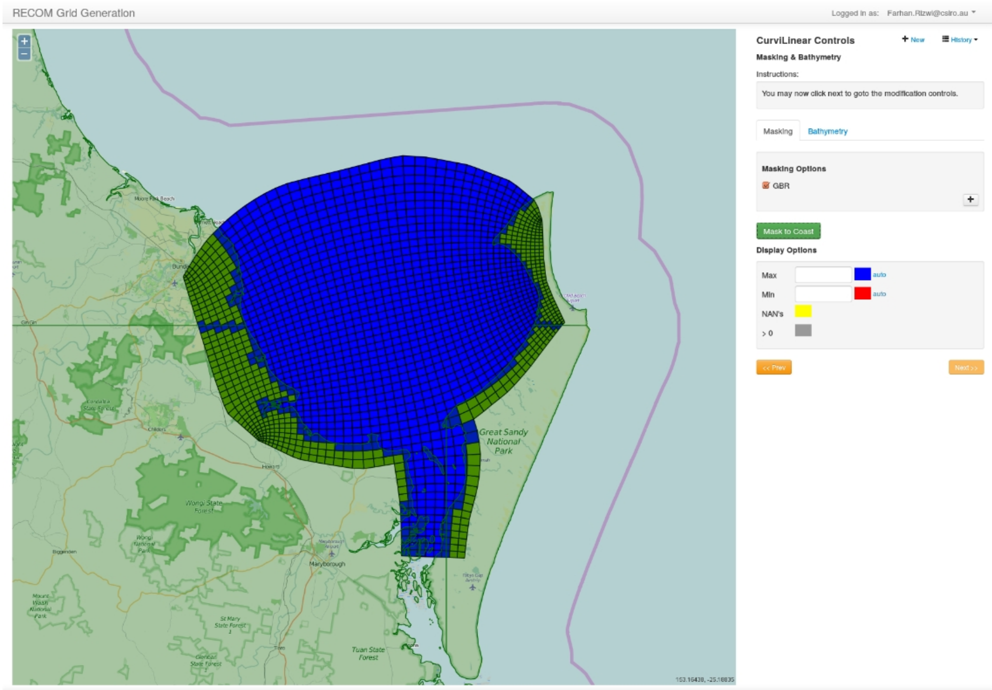

Figure 4. Illustration of masking a generated grid into land and water cells.

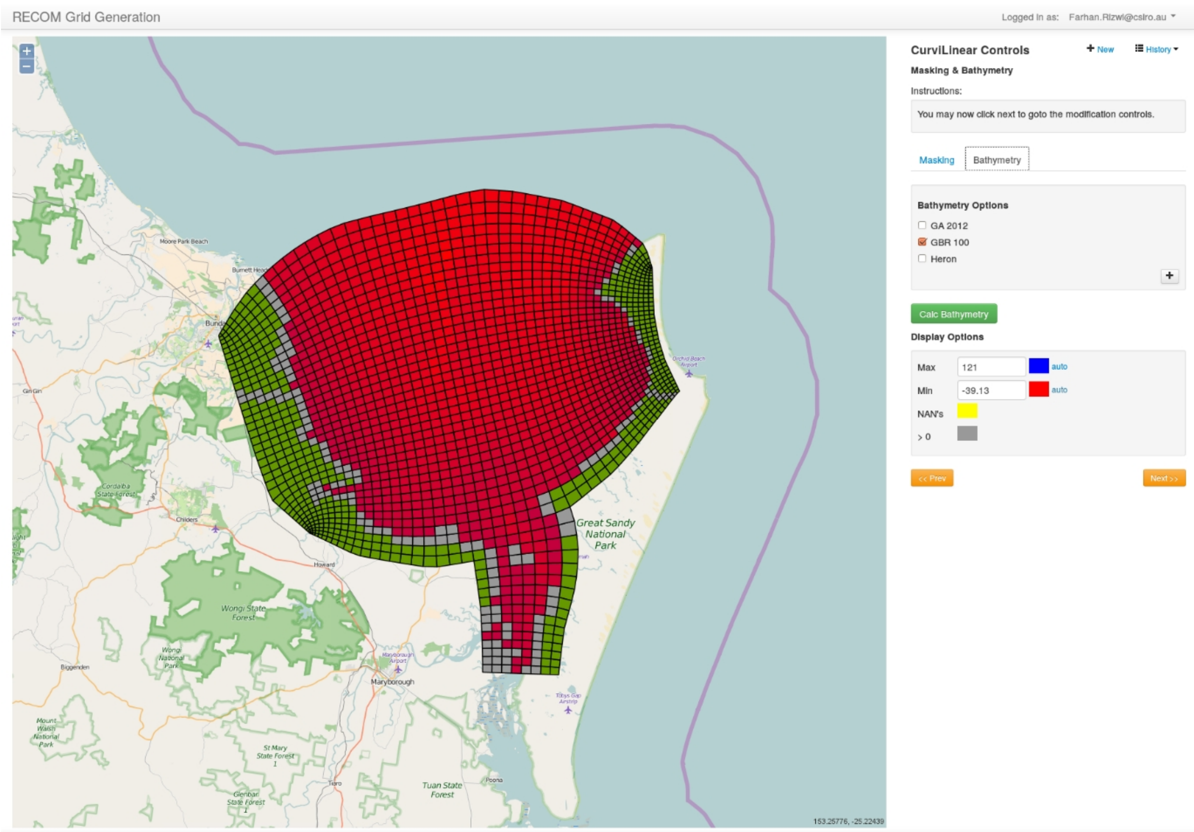

Figure 5. Example of bathymetry interpolated onto the grid.

5.3 Interpolating bathymetry

Clicking on the Bathymetry tab shows the available datasets in RECOM. Clicking the green 'Calc Bathymetry' button will interpolate the bathymetry using the selected dataset (e.g. GBR100 for Beaman (2010)) onto all water cells in the grid. The grid is then updated showing the bathymetry values in the water cells, with shallowest cells coloured red transitioning to the deepest cells coloured blue. Fig. 5 shows an example of the bathymetry rendered onto the grid.

5.4 Editing mask and bathymetry values

The next step allows users to modify the masking attributes of cells as well as to adjust the bathymetry values. Users can select cells using 4 different ways as per the radio buttons at the top of the right hand panel. 'Single' allows for cells to be selected (or deselected) whenever a cell is clicked on the grid. 'Column' and 'Row' will select the entire column or row, respectively, of the cell that is clicked. 'Polygon' allows to select an area with multiple clicks (of corner points), right-clicking to finish.

Once cells are selected, their depth values and mask status are shown in the right hand pane. Masked cells may then be edited, whereby the status of land, water or outside cells may be changed. This is useful if channels need to be widened or closed, or the general fit of the grid to the coastline is required to be optimized. To change the status of a mask cell, simply choose from the drop down list for each individual cell or choose once using the "bulk changes" and click on apply. Changes will not be saved to the grid until "Save" is clicked on. An example of this is illustrated in Fig. 6.

The bathymetry in cells may then be modified to values different to that computed by the bathymetry interpolation. This is useful if channels need to be deepened, or anomalous holes removed. Similar to masking, the individual cell depth values may directly be changed using each cell separately or via the "bulk changes". This allows for a single value or a relative modification of default depths. Again, changes are not updated until the save button is clicked. An example of this is illustrated in Fig. 7.

Custom bathymetry datasets may be upload by clicking the 'Upload' button. In this case a directory structure appears where the user may select the bathymetry dataset. This dataset must be in netCDF or ascii (longitude latitude value) format. Once uploaded, check the new dataset from the list and click on the green 'Calc Bathymetry' button to interpolate the new bathymetry onto all water cells in the grid.

Once the user is satisfied with the grid mask and bathymetry, click the orange 'Next' button to proceed to the river specification page.

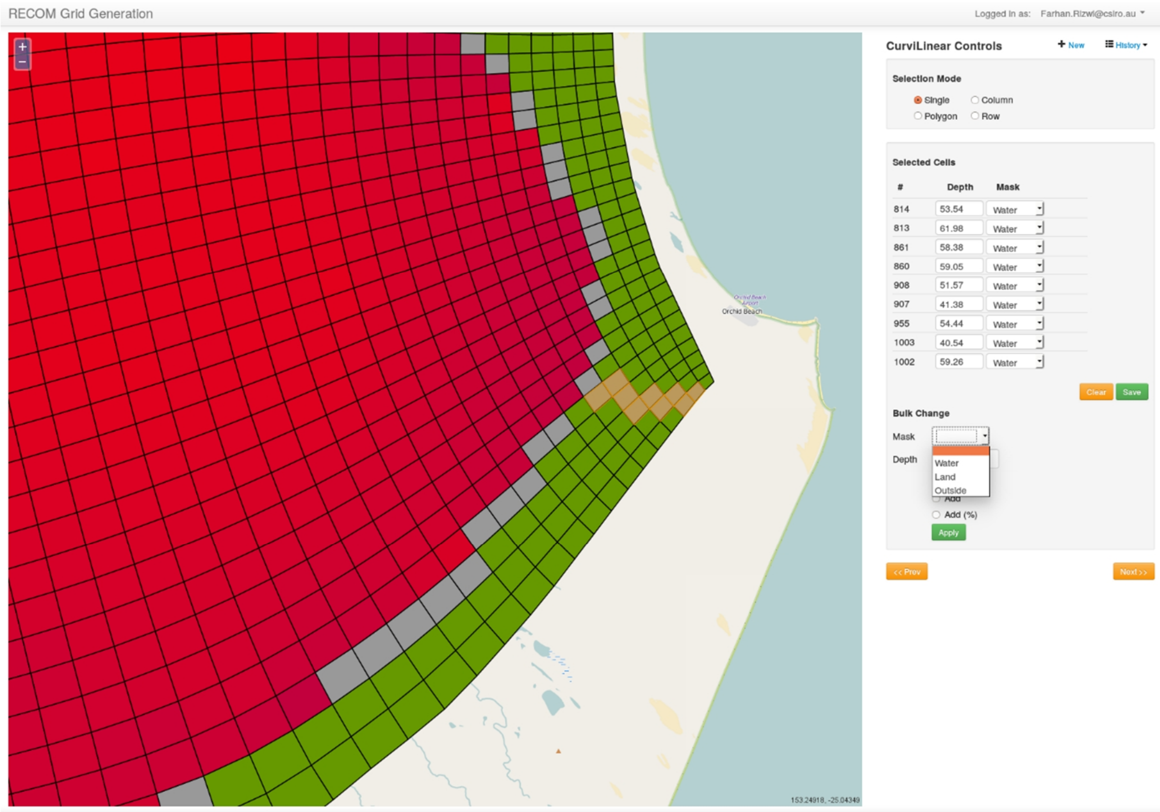

Figure 6. Illustration of mask editing, where selected cells status can be changed via the drop down menu.

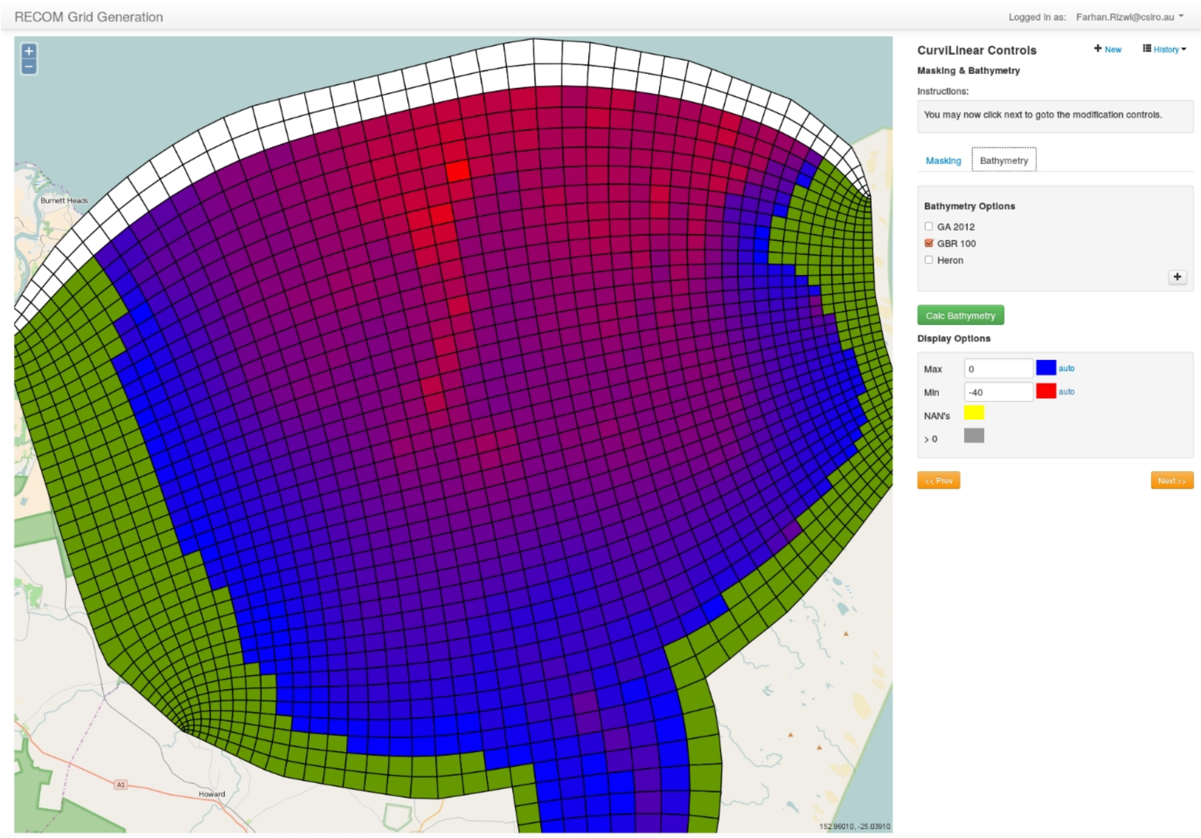

Figure 7. Example of edited bathymetry showing 2 rows of outside cells and colour range in the right hand panel.

5.5 River specification.

The final step of generating the bathymetry involves the specification of any river inflows. Freshwater inputs that may be included in RECOM are available from a drop down menu (Fig. 8); the user clicks on a cell to be designated as a river boundary and then selects the desired river from a drop down menu. RECOM will find the cell in the grid closest to the geographic location of the gauging station used to specify that river's flow. Additional rivers not in the list may be uploaded if required by clicking the '+' button in the 'Upload flow data' box and following the prompts. When the final grid has been generated with the appropriate masking and bathymetry applied, click on the blue next button in the top right to advance to the next step in RECOM's workflow. It is recommended that the river boundary box be a cell in which there is only one face adjoining other wet cells. By doing this the user creates both a location and a direction in which the river discharges.

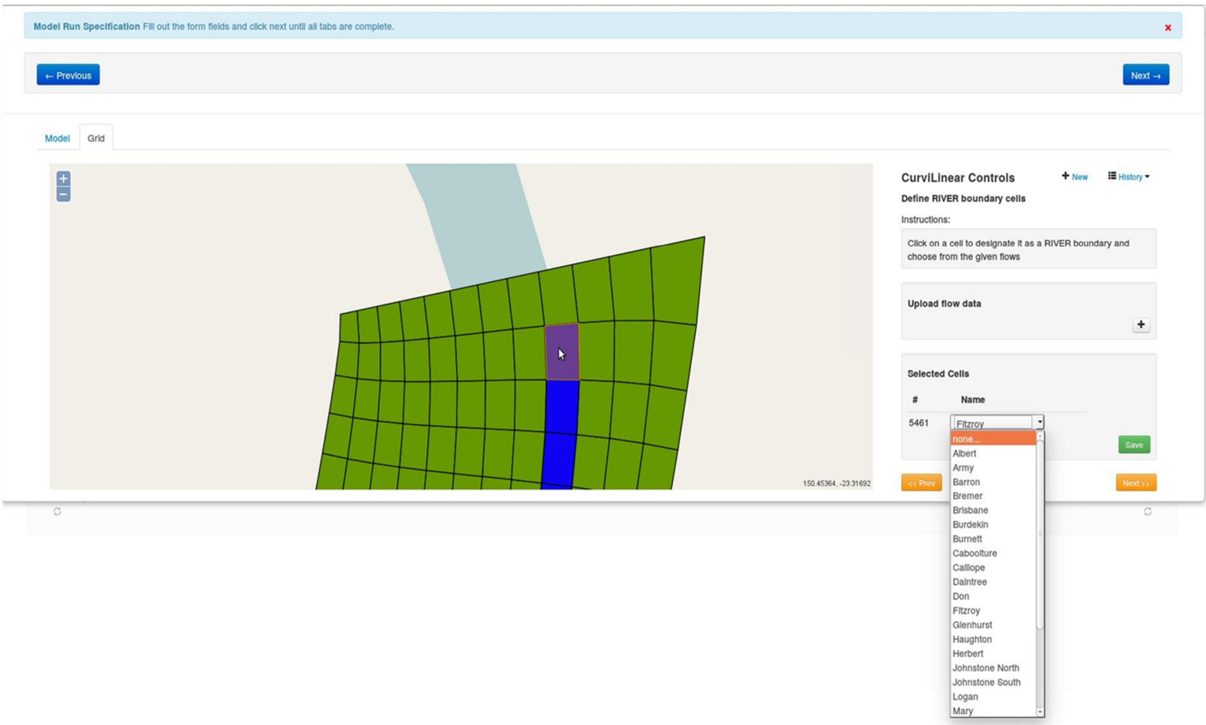

Figure 7. Screenshot of river specification.

5.6 Output

The user has the option to download various aspects of the grid information in a variety of formats. A screenshot of the outputs page is shown in Fig. 8. Datasets available for download are:

points	the original user grid points specification
Grid Definition (single)	single density grid points
ddgrid	double density grid points
mask	mask values of cell centres

The formats available for download are:

- ascii

An output format “shoc-bathy” is currently being developed that will generate the grid points and bathymetry data (including OUTSIDE/LAND masks) into a single file that can be directly inserted into a SHOC parameter file.

To save the selected dataset in the requested format, click the green ‘Download’ button. If no download is required, or after the download is complete, to proceed to the forcing page clock the blue ‘Next’ button in the top right hand corner.

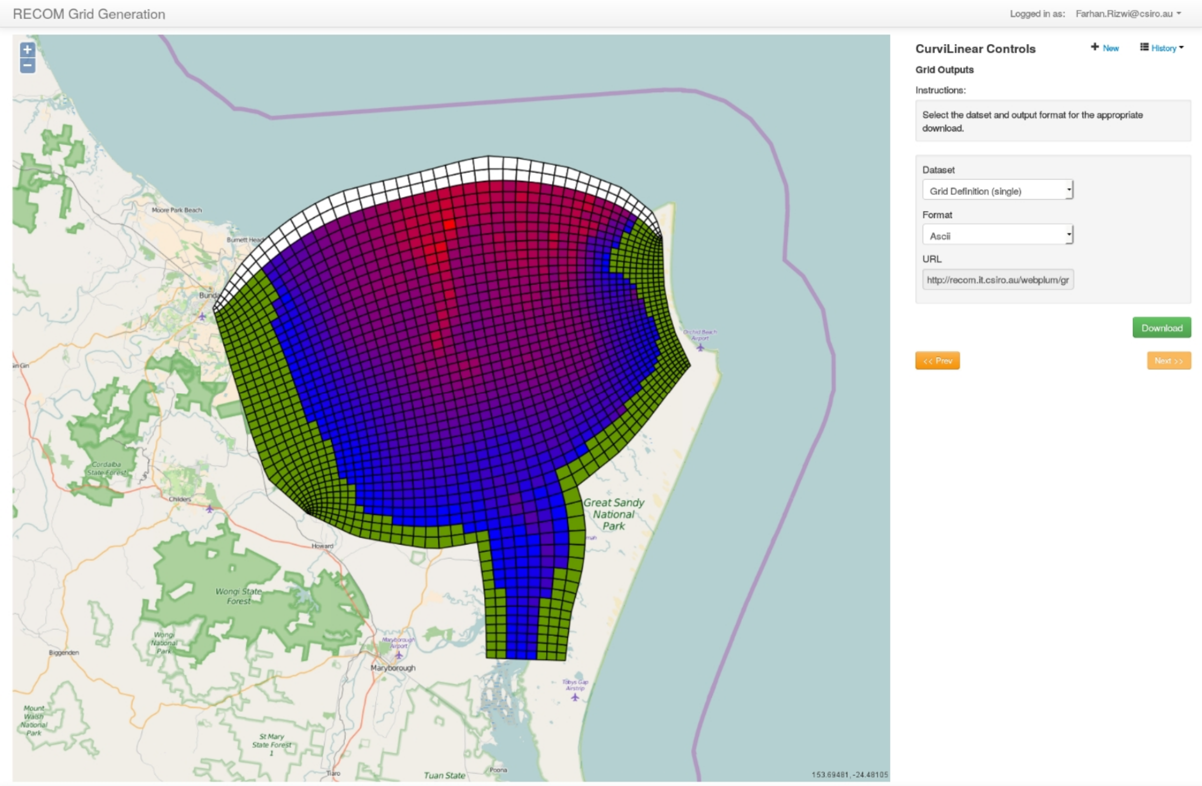

Figure 8. Screenshot of final grid and bathymetry.

6 Forcing

The regional model used for ocean boundary conditions and the atmospheric forcing is now defined. In this case we are nesting the model within the GBR4 regional model for ocean variables, ACCESS-R for winds and WaveWatch3 for waves (Fig. 9). The temporal extents of the forcing data are shown next to each dataset as a time bar. The user manipulates the time slider in the first row labelled ‘Temporal Extent’ to select the period of interest for the RECOM simulation. Clicking the ‘Zoom button’ will expand the time period chosen, and ‘Reset’ will revert to the original view. The date range is written in orange above the selected period. For any forcing data that falls within this period, a radio button appears next to it to indicate that it is valid and may be selected. In this case for the ‘RECOM Initialisation data’ data available are ‘gbr4-recom-init’ and gbr1_recom-init’. The latter is enabled via the radio button. Black information ‘i’ buttons are available next to each dataset to provide a brief description of those data. Similarly there are two choices each for Hydro and BGC boundary forcing. Currently there is only one choice for atmospheric and wave dat. Once forcing datasets have been selected, click the ‘Next’ button.

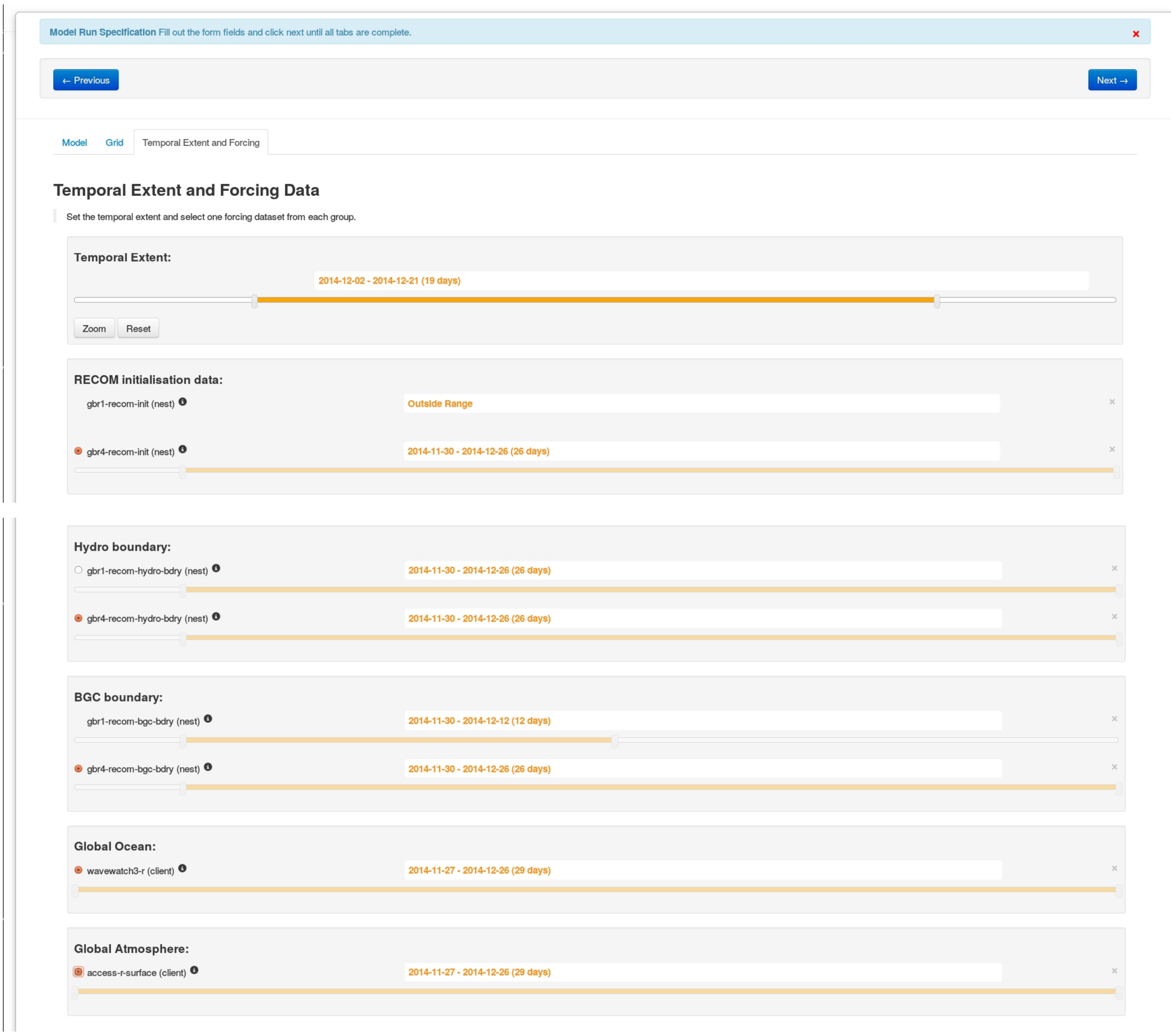

Figure 9. Screenshot of Temporal Extent and Forcing data selection.

7 Parameter specification

Predefined sets of hardwired parameter sets are available to configure hydrodynamics, sediments and biogeochemistry (Fig. 10). This includes the BGC processes to invoke and the sediment classes one wishes to use. The BGC tracers used in the model are automatically inferred from the specified BGC processes, and this specification is therefore invisible to the user. However, these BGC tracers have associated attributes (e.g. dissolved or particulate, present in water column or sediments or both, particle size, sinking rates and density for particulates), and predefined attribute 'sets' must be selected by the user for both sediments and BGC tracers.

RECOM biogeochemistry currently supports three options for the process definition (***gbr4***, ***optics_only*** and ***gas_only***), but only one choice is available for tracer attributes and parameterisations (***standard***). The ***gbr4*** and ***standard*** parameter and tracer attribute specification are the same as those used in the GBR4 regional model. Further choices are likely to be added as the need arises.

Differences between the process definitions are:

gbr4: The biogeochemical model considers four groups of microalgae (small and large phytoplankton, microphytobenthos and *Trichodesmium*), three macrophytes types (seagrass types corresponding to *Zoste*ra and *Halophila*, and macroalgae) and coral communities. Photosynthetic growth is determined by concentrations of dissolved nutrients (nitrogen and phosphate) and photosynthetically active radiation. Autotrophs take up dissolved ammonium, nitrate, phosphate and inorganic carbon. Microalgae incorporate carbon (C), nitrogen (N) and phosphorus (P) at the Redfield ratio (106C:16N:1P) while macrophytes do so at the Atkinson ratio (550C:30N:1P). Microalgae contain two pigments (chlorophyll *a* and an accessory pigment), and have variable carbon:pigment ratios determined using a photoadaptation model.

Micro- and meso-zooplankton graze on small and large phytoplankton respectively, at rates determined by particle encounter rates and maximum ingestion rates. Additionally large zooplankton consume small zooplankton. Of the grazed material that is not incorporated into zooplankton biomass, half is released as dissolved and particulate carbon, nitrogen and phosphate, with the remainder forming detritus. Additional detritus accumulates by mortality. Detritus and dissolved organic substances are remineralised into inorganic carbon, nitrogen and phosphate with labile detritus transformed most rapidly (days), refractory detritus slower (months) and dissolved organic material transformed over the longest timescales (years). The production (by photosynthesis) and consumption (by respiration and remineralisation) of dissolved oxygen is also included in the model and depending on prevailing concentrations, facilitates or inhibits the oxidation of ammonia to nitrate and its subsequent denitrification to di-nitrogen gas which is then lost from the system.

Additional water column chemistry calculations are undertaken to solve for the equilibrium carbon chemistry ion concentrations necessary to undertake ocean acidification (OA) studies, and to consider sea-air fluxes of oxygen and carbon dioxide. The adsorption and desorption of phosphorus onto inorganic particles as a function of the oxic state of the water is also considered.

In the sediment porewaters, similar remineralisation processes occur as found in the water column. Additionally, nitrogen is denitrified and lost as N_2 gas while phosphorus can become adsorbed onto inorganic particles, and become permanently immobilised in sediments.

optics_only: This option calculates the inherent optical properties (IOPs) and apparent (AOPs) considering only suspended sediment and clear water scattering and absorption, and absorption due to CDOM. No ecological transformations occur. This option is to be used when a sediment - optics model is required.

gas_only: This option includes carbon chemistry and oxygen dynamic calculations as forced by the hydrodynamic. This it includes the effect of wind on sea-air fluxes, temperature and salinity on saturation states, as well as circulation and ocean boundary forcing. The effect of biogeochemical processes (photosynthesis / respiration) is excluded.

The ecological processes are defined using the ‘PROCESSFNAME’ drop down menu, ‘ECO_VARS_ATTS’ defines the attributes applied to the biogeochemistry tracers and ‘BIOFNAME’ defines the global parameter set applied to the ecological processes.

The DO_ECOLOGY and DO_SEDIMENTS drop down menus define whether ecology and sediment transport respectively is invoked in the model or not via a 'YES' or 'NO' selection. Note that DO_ECOLOGY must be 'YES' for 'optics_only' and 'gas_only' options.

The sediment layer thicknesses are defined in the 'SED_LAYERS' box, with the first thickness corresponding to the layer closest to the water column and the last corresponding to the deepest layer. This box is populated with default thicknesses, but the user may change them if desired.

The names of the sediment classes to be used are listed in the 'SED_VARS' box; again this is populated with defaults, but may be changed to any the classes listed in Table 2.

Table 2. Sediment class attributes used in RECOM

Name	Particle size (m)	Settling (ms^{-1})	Deposit	Resuspend	Cohesive	Flocculate
Gravel	0.0005	-0.7	Yes	No	No	No
Sand	0.00025	-0.002	Yes	No	No	No
Mud	0.00025	-0.0002	Yes	Yes	Yes	Yes
FineSed	0.00025	-0.0002	Yes	Yes	Yes	Yes
Dust	0.00025	-0.00001	Yes	Yes	Yes	No

The RECOM sediment parameterisation provides the choice of four different configurations, viz. ***estuary***, ***standard***, ***shelf***, or ***basic***. Each of these configurations is characterised by a particular sediment model parameterisation. The user selects one of these configurations from the 'SED_VAR_ATTS' drop-down menu.

The ***standard*** configuration is based on the same settings as the GBR4 model except that bottom roughness in RECOM is uniform across the region while in the whole GBR model the roughness varies across the shelf.

The ***estuary*** configuration of parameters has a roughness twice the roughness of the *standard* configuration, implying higher rates of the resuspension and, subsequently, more turbid environment.

The configuration ***shelf*** has roughness smaller than the roughness of the *standard* model. Simulations based on these setting tend to produces less turbid environment compared to the standard run.

Finally, the configuration ***basic*** provides simplified description of the sediment processes on the shelf. The corresponding configuration assumes no bioturbation in sediments, no flocculation, and no diffusion across water-sediments interface. Sediment exchange between pelagic and benthic layers in this configuration is driven only by resuspension and deposition of particles. These simulations tend to produce less turbid environment compared to the *standard* model.

Hydrodynamic models are subject to stability constraints that if violated will cause the model to become unstable and fatally terminate. To render models more stable, generally frictional processes are increased, but this has the effect of reducing accuracy. RECOM includes a 'ROBUST' setting that ranges from 1 to 10, whereby a lower setting corresponds to a more realistic but potentially less stable hydrodynamic configuration, and a higher setting corresponds to a more stable but potentially less accurate solution. The configuration corresponding to the ROBUST settings are:

ROBUST=1:

- The model starts from rest,
- The k-ε mixing scheme is used,
- Smagorinsky horizontal diffusion is used with a constant of 0.1,
- The ULTIMATE QUICKEST tracer advection is used,
- No active instability mitigation is used,
- Flux adjusted open boundaries using the default timescale,
- 1 bathymetry smoothing pass.

ROBUST=2: Same as ROBUST 1 above, constant viscosity, maximum bathymetric gradient = 0.05.
ROBUST=3: Same as ROBUST 1 with active instability mitigation, sponge zones on the boundary 8 cells wide ramping to 5 times the interior value, Van Leer tracer advection.
ROBUST=4: Same as ROBUST 3, constant viscosity.
ROBUST=5: Same as ROBUST 3, Mellor-Yamada 2.0 vertical mixing.
ROBUST=6: Same as ROBUST 5, starts using global model velocity fields.
ROBUST=7: Same as ROBUST 5 with hard T/S ramp relaxation.
ROBUST=8: Same as ROBUST 7 with constant viscosity.
ROBUST=9: Same as ROBUST 6 with constant horizontal viscosity.
ROBUST=10 ????: Same as ROBUST 5 with constant horizontal viscosity.

Once these sets have been specified, then select the 'Next' button to proceed.

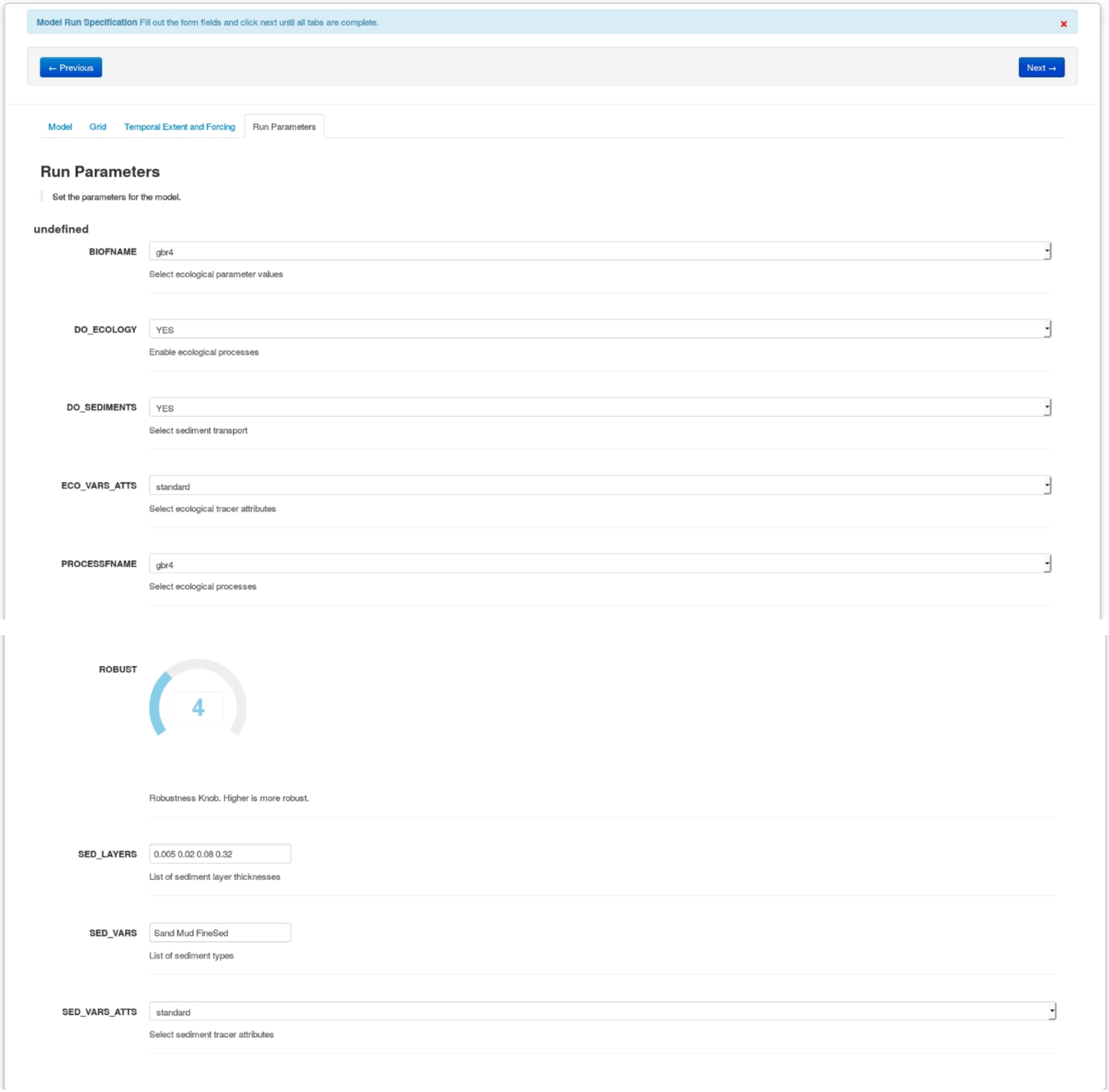

Figure 10. Screenshot of RECOM parameters.

8 Submit

Finally, the model is ready to be submitted to run (Fig. 11). A summary of configurable parameters is provided (grid, temporal extent, forcing) for appraisal. If the user wishes to change an option, then the blue ‘Previous’ button in the top left corner can be used to navigate back to the desired page. Click the blue ‘Submit Run’ button to start the RECOM simulation.

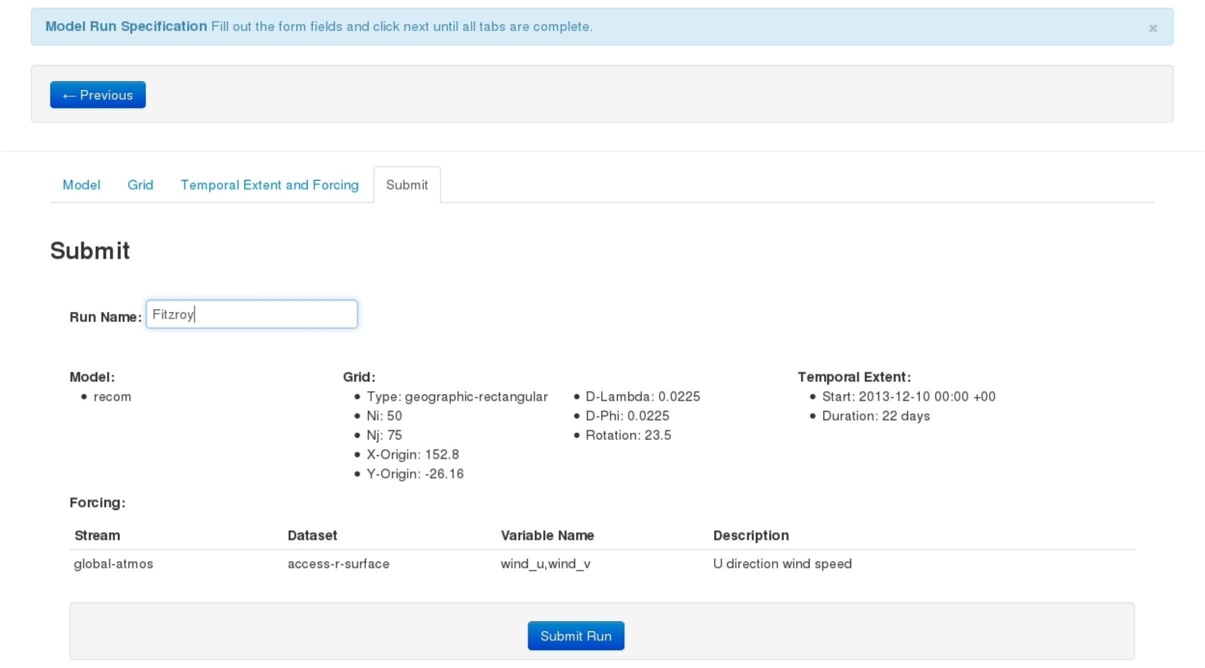

Figure 11. Screenshot of model submission.

9 Monitoring

Once the run is submitted, the simulation can be comprehensively monitored using the RECOM interface (Fig. 12). This includes an overview of runs submitted (name, time submitted etc.), run status (in-progress, finished, aborted etc.), time to completion, error and status messages, an overview of run configuration ('i' button next to 'Model'). From this view the simulation may be stopped ('Abort' button), finished or aborted runs may be deleted ('Delete button), existing runs may be cloned, saved but not running runs may be edited or a new run may be spawned. If a running model fails, a red 'Error' button is associated with the run and an error message is supplied indicating the nature of the problem. When the simulation is complete (runtime depends on the size of the grid) the workspace is available from downloaded by clicking the green 'Finished' button. This workspace can be saved locally to disk, and contains all the elements required to replicate the simulation offline if desired (for more advanced users). These elements include model executable, parameter files, and forcing & initialisation data. Most importantly this workspace contains the outputs of the simulation under the 'outputs' directory for hydrodynamics and 'tran_outputs' for BGC and sediments. These outputs are in CF1.0 compliant netCDF format, which can be viewed using a multitude of tools.

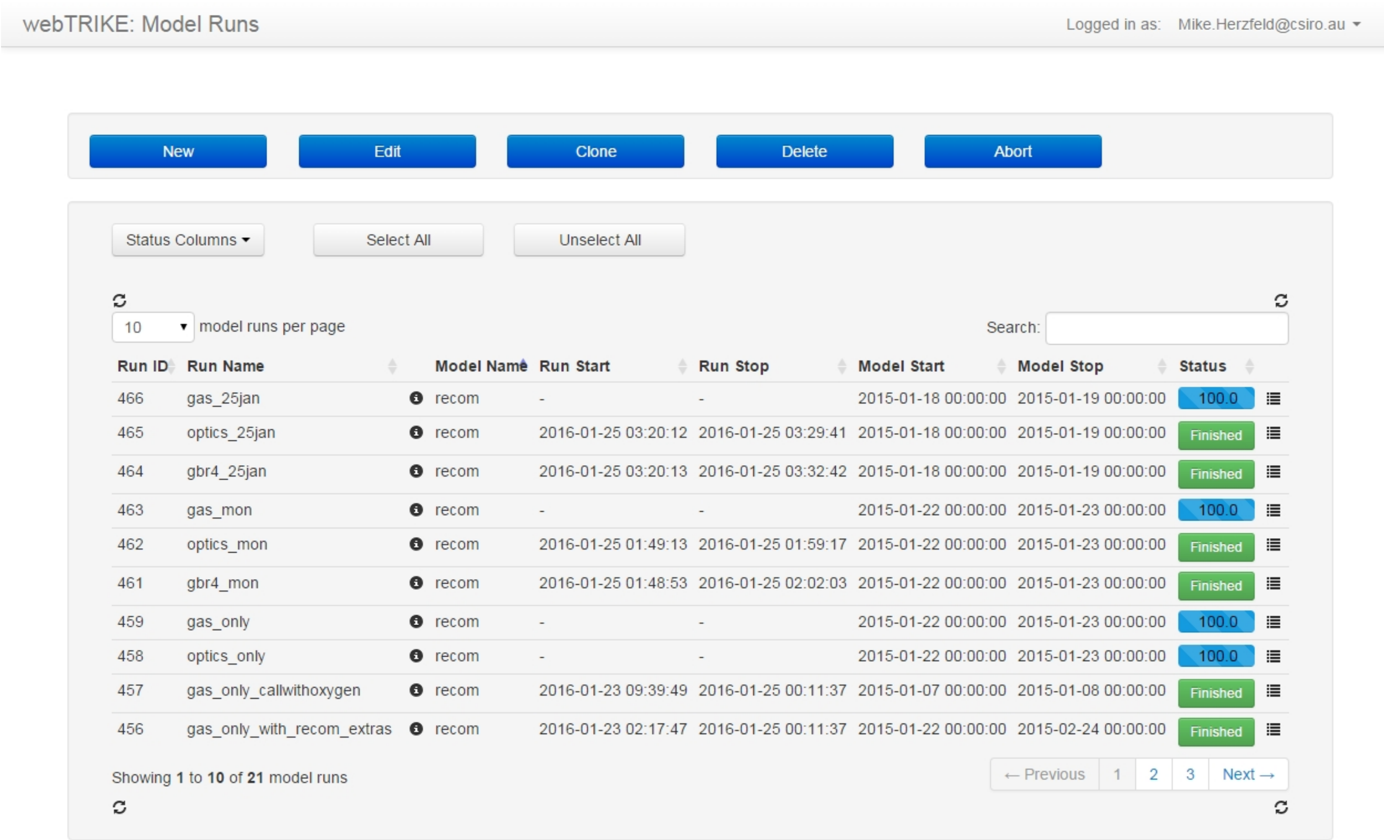

Figure 12. Screenshot showing list of model runs.

9 References

Beaman, R. 2010. Project 3DGBR: a high-resolution depth model for the Great Barrier Reef and Coral Sea. Final Report to Marine and Tropical Sciences Research Facility Final Report, June 2010.

Herzfeld, M., J. Andrewartha, M. Baird, R. Brinkman, M. Furnas, P. Gillibrand, M. Hemer, K. Joehnk, E. Jones, D. McKinnon, N. Margvelashvili, M. Mongin, P. Oke, F. Rizwi, B. Robson, S. Seaton, J. Skerratt, H. Tonin, K. Wild-Allen (2016). eReefs WP3 Marine Modelling: Final Report, Jan. 2016, CSIRO, Hobart, 464pp.