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The Marine Virtual Laboratory: enabling efficient ocean model configuration

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The technical steps involved in configuring a regional ocean model are analogous for all community models. All require the generation of a model grid, preparation and interpolation of topography, initial conditions, and forcing fields. Each task in configuring a regional ocean model is straight-forward – but the process of downloading and reformatting data can be time-consuming. For an experienced modeller, the configuration of a new model domain can take as little as a few hours – but for an inexperienced modeller, it can take much longer. In pursuit of technical efficiency, the Australian ocean modelling community has developed the Web-based MARine Virtual Laboratory (WebMARVL). WebMARVL allows a user to quickly and easily configure an ocean general circulation or wave model through a simple interface, reducing the time to configure a regional model to a few minutes. Through WebMARVL, a user is prompted to define the basic options needed for a model configuration, including the: model, run duration, spatial extent, and input data. Once all aspects of the configuration are selected, a series of data extraction, reprocessing, and repackaging services are run, and a “take-away bundle” is prepared for download. Building on the capabilities developed under Australia’s Integrated Marine Observing System, WebMARVL also extracts all of the available observations for the chosen time-space domain. The user is able to download the take-away bundle, and use it to run the model of their choice. Models supported by WebMARVL include three community ocean general circulation models, and two community wave models. The model configuration from the take-away bundle is intended to be a starting point for scientific research. The user may subsequently refine the details of the model set-up to improve the model performance for the given application. In this study, WebMARVL is described along with a series of results from test cases comparing WebMARVL-configured models to observations and manually-configured models. It is shown that the automatically-configured model configurations produce a good starting point for scientific research.

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1 Introduction

Increasingly, model simulations supported by data are becoming fundamental to marine research. Data alone is usually too sparse to provide the complete picture of time and space variations common to the marine environment. Likewise, models by definition are an approximation to the real world and need to be informed by data. Tools combining models and observations offer the researcher or manager ways to optimise and synergise the benefits offered by both data streams.

Setting up models and bringing together the necessary data for initialisation, forcing and validation is a time-consuming and frequently laborious activity, often taking months to achieve a starting point for scientific investigation. Real-time applications, including support for defence services and search and rescue, motivated the development of tools enabling the rapid configuration and deployment of regional ocean forecasts (Rosebrock et al., 2015). Building on this capability, a new infrastructure – called the Web-based Marine Virtual Laboratory (WebMARVL; www.marvl.org.au; portal.marvl.org.au) – has been developed. A schematic diagram showing the services and options offered by WebMARVL is presented in Fig. 1. Automated and semi-automated components of the WebMARVL workflow increases functionality and significantly reduces the startup time of any project involving simulation studies of the ocean.

WebMARVL allows a user to quickly and easily configure an ocean general circulation or wave model through the web-based portal. The user is prompted to select the model, temporal extent of the model run, spatial extent, and input data. WebMARVL currently supports three community ocean general circulation models, and two community wave models, namely:

- Regional Ocean Modelling System (ROMS; Shchepetkin and McWilliams, 2005);
- Modular Ocean Model (MOM; Griffies, 2009);
- Sparse Hydrodynamic Ocean Code (SHOC; Herzfeld, 2009);

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- Simulating WAVes Nearshore (SWAN; Booij et al., 1999); and
- WaveWatch III (WW-III; Tolman, 2002).

The temporal extent of the model runs are limited to historical periods – not currently permitting forecasts.

Once all aspects of the configuration are selected, a series of services automatically perform the data extraction, reformatting, and repackaging. WebMARVL produce a “take-away bundle” that contains all of the input fields and forcing fields in the correct format to be immediately used to run the chosen model (i.e., ROMS or MOM etc.). The take-away bundle also includes all available observations in the chosen time-space domain, exploiting capabilities developed under the Australian Integrated Marine Observing System (IMOS; www.imos.org.au; Hill et al., 2010; Proctor et al., 2010; Hidas et al., 2015). The observations are intended to be used for model assessment and/or data assimilation. The take-away bundle is available to the user via direct download from WebMARVL. If a user is to manually undertake each step of gathering topographic data, ocean input data (from a global ocean model run or reanalysis, for initial conditions and nesting), surface forcing data (from an atmospheric model run or reanalysis), and observational data – and then write a series of scripts to “massage” the data into appropriate formats, the process of setting up a model can take days for an expert and months for a non-expert. By contrast, it takes 5–10 min, depending on the computer load, to generate a take-away bundle using WebMARVL. The model configuration from the take-away bundle is intended to be a starting point. It is expected that the expert user will refine the model set-up (e.g., mixing schemes, adjustments to topography or coastlines etc.) to improve the model performance for the given application.

The WebMARVL developments are motivated to deliver benefits to the marine community by enabling:

- efficient configuration of a range of ocean and wave models;
- efficient model inter-comparisons;

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- assessment of the sensitivity studies, comparing model results with different model parameterisations (e.g., mixing schemes) and configurations (e.g, oceanic and atmospheric forcing);
- efficient configuration of ensemble prediction (in a historical sense) – to help quantify uncertainty – using a single model with different input data, or using multiple models;
- comprehensive model evaluation through model-observation comparisons;
- downscaling of large scale model runs, including climate projections and seasonal forecasts; and
- efficient access to and consolidation of observational data for a selected time-space domain.

In this paper, we describe WebMARVL in more detail in Sect. 2, followed by results in Sect. 3. The results presented below typically compare output from manually-configured models to WebMARVL-configured models. Some test cases also compare WebMARVL-configured models to observations. We seek to demonstrate that the WebMARVL-configured model runs are credible – providing a good foundation for scientific research. We expect that an expert modeller can generate a take-away bundle using WebMARVL, and subsequently refine the model setup to produce model results of suitable quality to permit high-quality scientific research. Indeed, it is shown in this paper that the automatically-configured model configurations produce credible results. The paper concludes with a short discussion and summary in Sect. 4.

2 WebMARVL

The development of WebMARVL was largely funded under the Australian National Collaborative Research Infrastructure Strategy, through the National eResearch Collabo-

ration Tools and Resources (NeCTAR; www.nectar.org.au) program. NeCTAR is a program motivated to establish research software infrastructure to promote and support collaborative research outcomes between Australian researchers. Consequently, the initial version of WebMARVL is restricted to Australian-based researchers, with user authentication provided securely via the Australian Access Federation (AAF; Fig. 2). This means that researchers with logins at Australian Universities (e.g., UTAS), and Australian research organisations (e.g., CSIRO) simply use their institutional login name and password to log into WebMARVL. An incomplete list of the eligible universities is evident in Fig. 2. This aspect of WebMARVL can easily be changed to include international users (e.g., by including AAF Virtual Home, who.aaf.edu.au) with a modest additional development.

After logging in, a user is prompted to select the model (i.e., ROMS, MOM etc.) from the list of supported models (see Sect. 1), and is prompted to generate a model grid (Fig. 3). The initial version of WebMARVL is restricted to the generation of rectangular grids, so a user effectively needs to specify the corners of the model grid, the angle of rotation, and the grid resolution. This can be done manually – by typing in the desired reference points etc. – or by a graphical user interface. The user can zoom in and out of the map in the interface to carefully define the grid of choice. WebMARVL also offers the option to import files containing your own model grid and bathymetry (for ROMS and SHOC only at this stage).

The user is then prompted to define the temporal extent of the model run using a sliding bar (Fig. 3). As the user modifies the temporal extent, the choice of input data – including the surface forcing data and ocean data – automatically updates. WebMARVL maintains a number of data products that can be used for surface forcing and ocean data. The available atmospheric data sets, to be used for surface forcing, include:

- archived fields from analyses and nowcasts using Australia’s operational global and regional atmospheric prediction systems (ACCESS-G and ACCESS-R; Puri et al., 2010); and

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- the NCEP/NCAR atmospheric reanalysis (NCEP1; Kalnay et al., 1996).

The global wave forcing available through WebMARVL is a reanalysis of AUSWAVE (Durrant et al., 2013), a global configuration of WW-III, (Tolman, 2002). The available ocean data sets, to be used for initial conditions and nesting, include:

- version 3p5 of BRAN (BRAN3p5; Oke et al., 2013);
- archived nowcasts and analyses from OceanMAPS (Brassington et al., 2007), Australia's operational short-range ocean forecast system;
- the UK Forecasting Ocean Assimilation Model (FOAM; Blockley et al., 2012); and
- the Mercator Ocean GLORYS reanalysis (Ferry et al., 2007).

Of these ocean data sets, OceanMAPS and FOAM are archives of nowcasts produced operationally by the Australian BoM and the UKMet Office; and others are from model runs performed under Bluelink, a partnership between CSIRO, the BoM and the Royal Australian Navy Schiller et al. (2009), or provided by the Mercator consortium. As the user adjusts the temporal domain, only the data sets that span the full requested temporal extent are available for selection. Once the user selects the input data, the request is submitted to WebMARVL, and a series of scripts are run automatically to perform the following steps:

- data verification – checking that the chosen data sets have the mandatory variables for the chosen model;
- data extraction – including the forcing data and observations;
- reformatting – to put the netcdf files in the format required by the chosen model, including variable and dimension names, grid constructions etc.; and
- repackaging – to collate all of the required data into a single, easy-to-download package.

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After all WebMARVL tasks are complete, the user can access their take-away bundle directly from the web portal. The user is then free to use and modify the data in the take-away bundles as needed for their specific application.

3 Results

In this section, we present results from a series of test cases (Fig. 4) performed by researchers from different Australian research institutions for a range of applications. The MARVL project is a community project – with developers working with users (ocean modellers) to develop a tool that is fit for purpose. Part of the project has involved testing by users in realistic scenarios, with feedback provided to the developers. The results presented below are examples of the test cases performed under this project during the development of WebMARVL. This includes one test case using SHOC, one using MOM, two using ROMS, and two using SWAN. Although WebMARVL supports applications with WW-III, a test case for WW-III is not presented in this paper. The results presented here typically compare output from manually-configured models to WebMARVL-configured models. Some test cases also compare WebMARVL-configured models to observations. We seek to demonstrate that the WebMARVL-configured model runs are credible. We expect that an expert modeller can generate a take-away bundle using WebMARVL, and subsequently refine the model setup to produce model results of suitable quality to permit high-quality scientific research.

3.1 Southern Great Barrier Reef – SHOC

Motivated to better understand what factors affect upwelling and cross-shelf exchange on the Southern Great Barrier Reef (SGBR), particularly near Heron Island, a run with a manually- and WebMARVL-configured SHOC is performed for a domain over the SGBR (Fig. 4) for the period November 2008 to March 2009. This period spans a series of events when cold water, observed in temperature records obtained from in situ

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moorings is uplifted onto the reef, representing strong cross-shelf exchange. Results from BRAN3p5 (Oke et al., 2013), with ~ 10 km grid spacing, do not show this same uplift as observed. To determine the extent to which BRAN3p5 represents the dominant processes, a high-resolution regional model is configured to see if it could represent the uplift. The model grid is 2 km in both configurations. The manually-configured run is forced at the surface by wind stress and bulk heat fluxes using fields from ERA-Interim, and the model initial conditions and boundary fields are derived from BRAN3p5. The WebMARVL-configuration is forced at the surface by wind stress and bulk heat fluxes using fields from ACCESS-R, and ocean fields from BRAN3p5. Unlike the BRAN3p5 runs, the regional configuration of SHOC includes tidal forcing at the boundaries. Neither configuration includes freshwater fluxes.

Results are shown in Fig. 5, showing initial conditions (panels a and b) and model fields after 18 days of integration (panels c and d), during a strong upwelling/uplifting event. Note that although the model resolution is the same in the manually-configured and the WebMARVL-configured model, the grids are slightly rotated relative to each other. Due to this rotation the bottom topography along the two cross-shelf transects are slightly different at the offshore end.

Recall that the goal of these comparisons is to establish the credibility of WebMARVL. To this end, we note that the initial conditions are comparable in both configurations (Fig. 5a and b). In part, the differences in initial conditions is because the WebMARVL-configured run is initialised 4 days earlier to allow the tides to somewhat equilibrate. The sub-surface model fields during the upwelling/uplifting events are also very similar (Fig. 5c and d) – both showing sub- 22°C temperatures uplifted onto the reef (around 50 m depth). However, the near surface temperatures are quite different, with the WebMARVL-configured run showing warmer surface temperatures, owing to known biases in the fluxes derived from ACCESS-R.

Based on these results, we conclude that the ~ 10 km resolution model lacks sufficient resolution to represent the uplift of cold water onto the reef over the SGBR. Additionally, the comparisons demonstrate that for this case, the WebMARVL-configured

model reproduces results that compare well to results from a manually-configured model with comparable resolution and forcing.

3.2 Southeastern Australia – ROMS

Motivated to assess WebMARVL in a region of complex topography in the presence of a strong western boundary current – namely the East Australian Current (EAC) – a 1 km resolution configuration of ROMS is applied to a region off Coffs Harbour (~ 30° S; Fig. 4) in the vicinity of the Solitary Island Marine Park. This region is of particular interest because it is the focus of several national and state programs (e.g., National Environmental Science Programme, www.environment.gov.au/science/nesp) and is the location of both state and federal marine reserves. The region is also covered by an array of land-based High Frequency (HF) radars – returning high spatial and temporal resolution observations of surface currents.

Briefly, WebMARVL is used to configure ROMS with 1 km horizontal resolution, 14 vertical levels, with surface forcing from ACCESS-R, and ocean initial conditions and forcing from BRAN3p5. The model is run for the period April to July 2012.

When compared to results from BRAN3p5, the WebMARVL-configured ROMS run produced alongshore currents that are more baroclinic (with 50% stronger alongshore currents) and with more variability in surface temperature (ROMS ranging from 11.2–26.7 °C; and BRAN3p5 ranging from 18–25.5 °C), due to better-resolved processes.

The model results (Fig. 6a) agree reasonably well with observations from different platforms, including satellite sea surface temperature (with differences of 0.5–0.8 °C), moorings (with upper ocean temperature differences of 0.8 °C and correlations of 0.86; and velocity differences of 0.11–0.26 m s⁻¹, with correlations of 0.41–0.45), and with HF radar-derived surface velocities. In particular, the WebMARVL-configured ROMS run shows very detailed sub-mesoscale variability. Figure 6a shows an example of the EAC instabilities at the inshore edge. These frontal vortices and eddies are important for driving vertical dynamics and ultimately nutrient supply and biological activity. Both the modelled and observed velocity fields derived from HF radars show such a sub-

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mesoscale eddy structure on the edge of Coffs Harbour (Fig. 6b and c; see also Fig. 3 in Roughan et al., 2015). Although the precise location of the eddy differs, its size and intensity compare qualitatively well. This test case demonstrates that a WebMARVL-configured high-resolution ROMS run can realistically reproduce both the mesoscale and sub-mesoscale variability in a complex region of strong currents. Analysis of the WebMARVL-configured ROMS is ongoing, and promises to provide important insights into the cross-shelf processes, upwelling and connectivity in the Solitary Island Marine Park area off eastern Australia.

3.3 Southwestern Australia – ROMS

To assess the performance of a WebMARVL-configured model for a very high-resolution application, WebMARVL is used to configure ROMS with ~ 500 m horizontal resolution, 13 vertical levels, with surface forcing from ACCESS-R, and ocean initial conditions and forcing from BRAN3p5. The model is set up to cover part of the Perth Canyon and Rottnest continental shelf, off southwestern Australia (Fig. 4). The model is run for the period July to October 2011. At the time of testing, WebMARVL did not provide fields of evaporation and precipitation. For this case however, the users supplemented the WebMARVL take away bundle with these fields from ERA-Interim. The model is also forced at the boundary with tidal forcing, using eight primary harmonic constituents (specified by the user – not from WebMARVL).

Model results are compared to near-surface velocities from HF radar and sub-surface velocities from a moored Acoustic Doppler Current Profiler (ADCP). Results of comparisons between modelled and observed fields are presented in Fig. 7. This includes a comparison of daily-averaged modelled and observed near-surface velocities on 13 and 16 July 2011 – when there is a distinct cyclonic eddy present on the shelf edge (Fig. 7a and b). These comparisons show that the model realistically reproduces this dominant feature, with good agreement in the location, strength, and size of the eddy. A comparison of time-series of the velocity at 10 m depth, measured by a moored ADCP, from the IMOS Rottnest Island National Reference Station, is presented in

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Fig. 7c and d. These comparisons show very good agreement between the observed and modelled velocities.

The results from this test case demonstrate that with some additional refinement of the WebMARVL-configured very high resolution ROMS, model results in excellent agreement with observations can be achieved. Fields from these model runs are being analysed in detail to examine the dynamics of deep water overflows that frequently occur off Western Australia due to winter cooling Pattiaratchi et al. (2011).

3.4 Southeastern Australia – MOM

To assess the performance of WebMARVL for setting up a high-resolution configuration of MOM4p1, a 2 km resolution model off southeastern Australia (Fig. 4) is set up. The model has 51 vertical levels and is nested within OceanMAPS and forced at the surface with atmospheric fields from ACCESS-G. The fields presented in Fig. 8 show the initial conditions – representing an interpolation from the ~ 10 km resolution grid of OceanMAPS, to the 2 km resolution grid of the regional domain. Also shown in Fig. 8 are the model fields after 16 days of simulation. Evident in Fig. 8 is that the high-resolution model adds significant detail to the fields – with the generation of fine-scale filaments and sub-mesoscale eddies. Although this demonstration does not assess the skill of the high-resolution configuration, it does demonstrate that the WebMARVL can be used as a starting point for a regional configuration of MOM.

3.5 Southeastern Australia – SWAN

To assess the suitability of WebMARVL to configure a very high-resolution regional wave model, two domains are considered. One domain is off Sydney ($\sim 33.75^\circ$ S), and the second is off Coffs Harbour ($\sim 30.3^\circ$ S). The approximate locations of the model domains are shown in Fig. 4. The Sydney test case is motivated to assess the performance of the WebMARVL-configured SWAN model near the coast, in shallow water.

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The Coffs Harbour test case is motivated to assess the performance farther offshore, in deeper water.

5 The Sydney configuration has 50 m horizontal resolution, spanning a $\sim 13 \text{ km} \times 22 \text{ km}$ rectangular grid offshore of the northern beaches of Sydney. Two WebMARVL configurations are tested for this domain: one forced by 12 km-resolution ACCESS-R winds (hereafter MARVL SWAN: BoM) and one forced with 20 km-resolution NCEP winds (hereafter MARVL SWAN: NCEP). These runs were compared to a manually-configured SWAN model by Cardno (2011) and Kinsela et al. (2015), hereafter Manual SWAN: OEH (NSW Office of Environment and Heritage). MARVL SWAN: BoM is forced
10 with winds from ACCESS-R and nested inside AUSWAVE Durrant et al. (2013). Manual SWAN: OEH is forced with winds from the NCEP/NCAR atmospheric reanalysis and nested inside a series of four coarser grids (a SWAN “transfer” grid and state, national and global configurations of WW-III). Established in 2011, the Manual SWAN: OEH model is carefully configured and tuned for the NSW coastline (including Sydney and Coffs Harbour regions) including adjustments to NCEP/NCAR wind speeds within
15 100 km of the NSW coast. Time series of observed significant wave height approximately 1 km offshore in 21 m of water are compared with Manual SWAN: OEH model time series at the same location and MARVL SWAN: BoM from the nearest available wet cell (1.4 km seaward of the wave buoy) in Fig. 9. Although the WebMARVL configured SWAN run produces results that are qualitatively consistent with observations (i.e., generally following the “shape” of wave episodes measured by the wave buoy), the automatically-configured model significantly under-predicts peak wave heights for individual storm events in shallow water. Similar performance was observed with the MARVL SWAN: NCEP model (not shown). The key reason for this difference is errors
20 in topography and the position of the model coastline which is generally located several kilometres offshore of the true coastline (i.e., 0 m contour). WebMARVL extracts topography from the Australian Bathymetry and Topography Grid Whiteway (2009) produced by Geoscience Australia, which has resolution of 9 arc seconds ($\sim 280 \times 280 \text{ m}$), and
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is too coarse to be useful for very high-resolution applications in shallow water, close to the coastline in this region.

The Coffs Harbour configuration has 100 m horizontal resolution, spanning a $\sim 39 \times 31$ km rectangular grid offshore off Coffs Harbour. Two WebMARVL configurations are again tested – one forced by 12 km-resolution ACCESS-R winds (hereafter MARVL SWAN: BoM) and one forced with 20 km-resolution NCEP winds (hereafter MARVL SWAN: NCEP). These runs are compared to a another manually-configured SWAN model forced with adjusted winds from the NCEP/NCAR atmospheric reanalysis (hereafter Manual SWAN: OEH). Like the application off Sydney, the location of the model coastline is misaligned with the true coastline position. This leads to errors like those described above near the coast (not shown). Time series of modelled and observed significant wave height about 12 km offshore, in 72 m of water, are compared in Fig. 10. These results show that the WebMARVL-configured model results are in good agreement with observations at an offshore site in deep water under ambient wave conditions (significant wave heights less than 3 m). These comparisons demonstrate that the automated model configurations produce overall results that are comparable to those produced by the manually developed SWAN model in this area over an extensive period of time.

The test cases presented here lead to the conclusion that the WebMARVL-configured wave model is suitable for operational climate science modellers (i.e., relatively deep water applications, say > 50 m depth), but is not recommended for engineering design and/or shallow water applications. The primary reasons for this conclusion are due to limitations in the topography and less reliable performance under extreme storm wave conditions (infrequent events). The topography that currently underpins WebMARVL is too coarse (~ 280 m resolution) for very-high resolution (50–100 m grids) near the coast – where the location of the coastline is often poorly represented in the automatically-configured models. However, in order to overcome this limitation, WebMARVL also enables the user to upload their own topography if necessary.

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4 Discussion and summary

A new web-based tool, called WebMARVL, has been developed to increase the efficiency of configuring a regional ocean model. The development of WebMARVL was undertaken by CSIRO and UTAS, and tested by a cross-section of the Australian coastal ocean modelling community. Tests of the system were performed by researchers from seven different research organisations, using five different community models (i.e., SHOC, ROMS, MOM, SWAN, and WW-III). The time taken to configure any of the chosen regional models using WebMARVL is just a few minutes. This contrasts to the traditional manual approach, taking days to months – depending on the proficiency of the modeller.

In this paper, we describe the technical steps that are automated by WebMARVL to configure each regional application. We provide a series of inter-comparisons between established, manually configured models, and between models and observations. Each WebMARVL-configured model set-up is not intended to deliver an optimised model configuration. It is intended to efficiently deliver a “good starting point” for further model development and refinement. The examples presented in this study demonstrate the credibility of WebMARVL – producing model configurations that are a good starting point for scientific research. WebMARVL is freely available to researchers associated with Australian research organisations, and there are plans to make it available globally. It is anticipated that by delivering improved efficiency to the coastal ocean modelling community, WebMARVL will become a valuable research tool – helping experienced, and student modellers to more quickly get to the heart of a scientific study.

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(OEH). The authors also acknowledge J. Luick and R. Morrison, who contributed to the MARVL project as testers.

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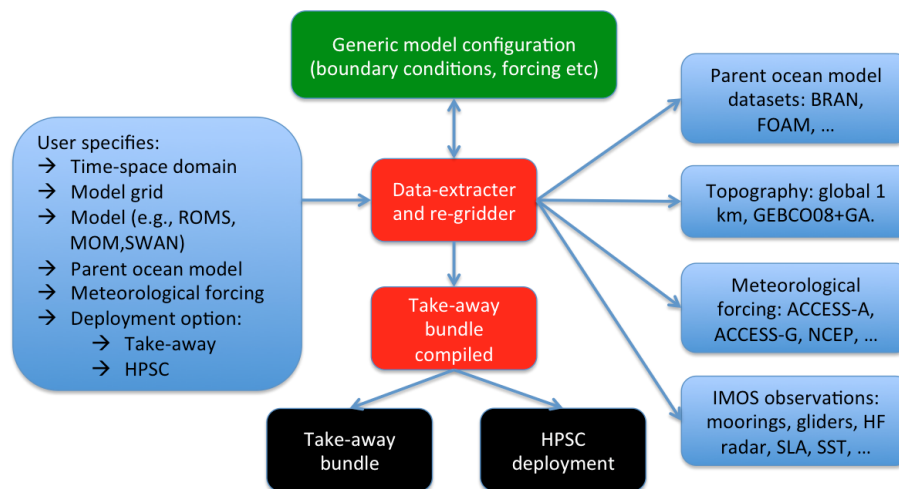


Figure 1. Schematic outlining the steps in WebMARVL. User requirements are specified through the WebMARVL interface. The system then selects the grid, the model(s), the parent model(s) for initialisation and boundary conditions, the topography and meteorological forcing. The system subsequently interpolates the inputs to the specified grid requirements. Depending on the deployment option (a) the files are bundled up as a take-away package, or (b) deployed to a High Performance Super Computer (HPSC).

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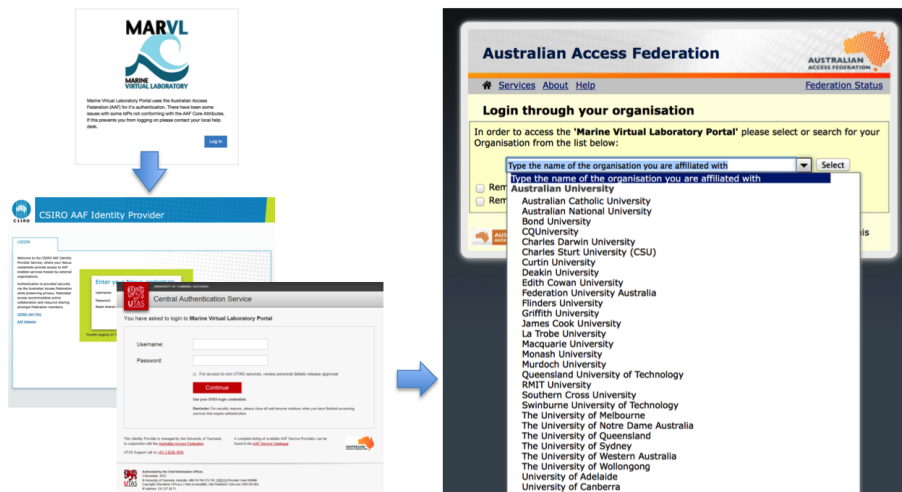


Figure 2. Screen-shots of sample WebMARVL login screens.

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The figure consists of three vertically stacked screenshots of the WebMARVL interface, connected by blue arrows indicating a sequential process.

Top Screenshot: Grid Definition
 The 'Grid' tab is active. A map shows a rectangular grid in the North Atlantic. On the right, the 'Grid Definition' parameters are:

- Type: geographic-rectangular
- Origin: X Longitude: 148.895, Y Latitude: -36.1
- Size: X pix: 60, Y pix: 70
- Spacing: X (pix/degree): 0.0452, Y (pix/degree): 0.0452
- Rotation: Angle (degrees): 335

 A 'Submit' button is at the top right.

Middle Screenshot: Temporal Extent and Forcing Data
 The 'Temporal Extent and Forcing Data' tab is active. It shows sliders for 'Temporal Extent' (2010-03-01 to 2010-06-09) and 'Atmosphere' (2010-06-04 to 2013-01-02). Below, 'Ocean' forcing data is listed with three rows:

- 2009-09-11 to 2013-01-09 (1216 days)
- 2012-10-01 to 2012-12-29 (90 days)
- 2011-11-02 to 2012-11-06 (272 days)

 Each row has a 'Submit' button.

Bottom Screenshot: Submit
 The 'Submit' tab is active. It shows a summary of the job configuration:

- Run Name: Jarvis Bay
- Model: shoc_vf
- Grid: Type: geographic-rectangular, X: 148.895, Y: -36.1, X pix: 60, Y pix: 70, X (pix/degree): 0.0452, Y (pix/degree): 0.0452, Rotation: 335
- Temporal Extent: Start: 2010-03-01 00:00 +00, Duration: 90 days

 A table lists the forcing data:

Forcing	Dataset	Variable Name	Description
global-atmos	ncap	pslp	Mean Sea Level Pressure
global-atmos	ncap	wind_uwind_v	U direction wind speed
global-ocean	buam1-an	sal	salinity
global-ocean	buam1-an	sla	sea surface elevation
global-ocean	buam1-an	u17	Eastward current
global-ocean	buam1-an	temp	temperature

 A 'Submit Job' button is at the bottom right.

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Figure 3. Screen-shots of WebMARVL showing the steps of (top-to-bottom) configuring a grid, setting the temporal extent and selecting input data, and submitting a job.

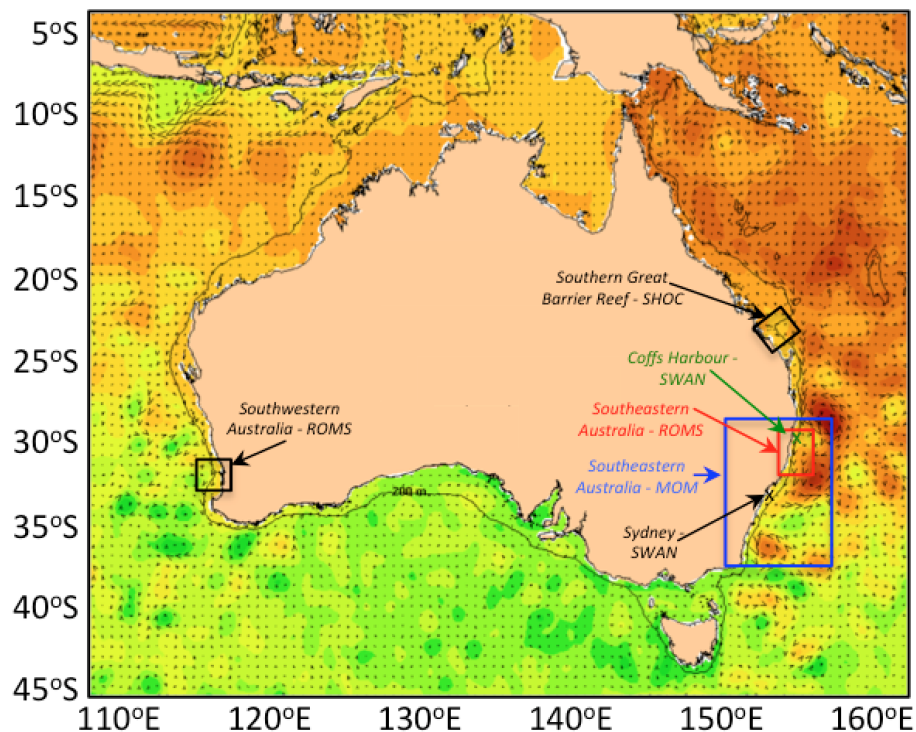


Figure 4. Map of Australia, showing the sea-level (colour) and geostrophic surface velocities (from oceancurrent.imos.org.au), with the approximate locations of each model domain used for testing. Labels, arrows, and boxes are colour-coded for clarity off eastern Australia.

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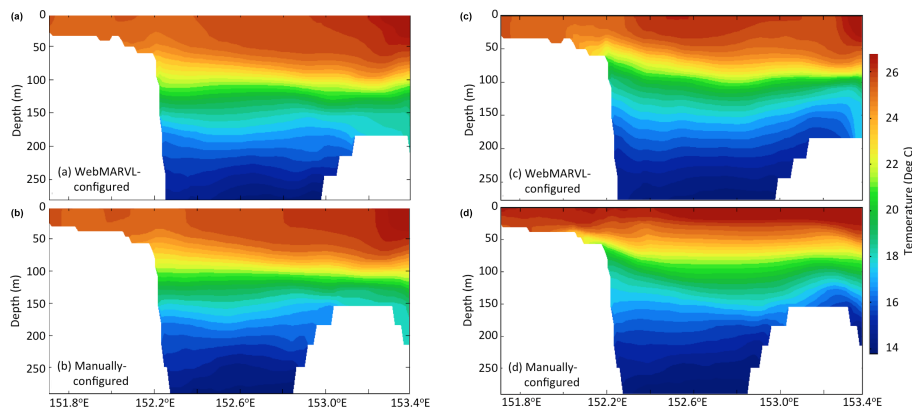


Figure 5. Comparison of a temperature section off the Southern Great Barrier Reef (Fig. 4) from the SHOC model, using **(a, c)** a WebMARVL configuration and **(b, d)** a manual configuration for **(a, b)** 1 December 2008 and **(c, d)** 18 December 2008.

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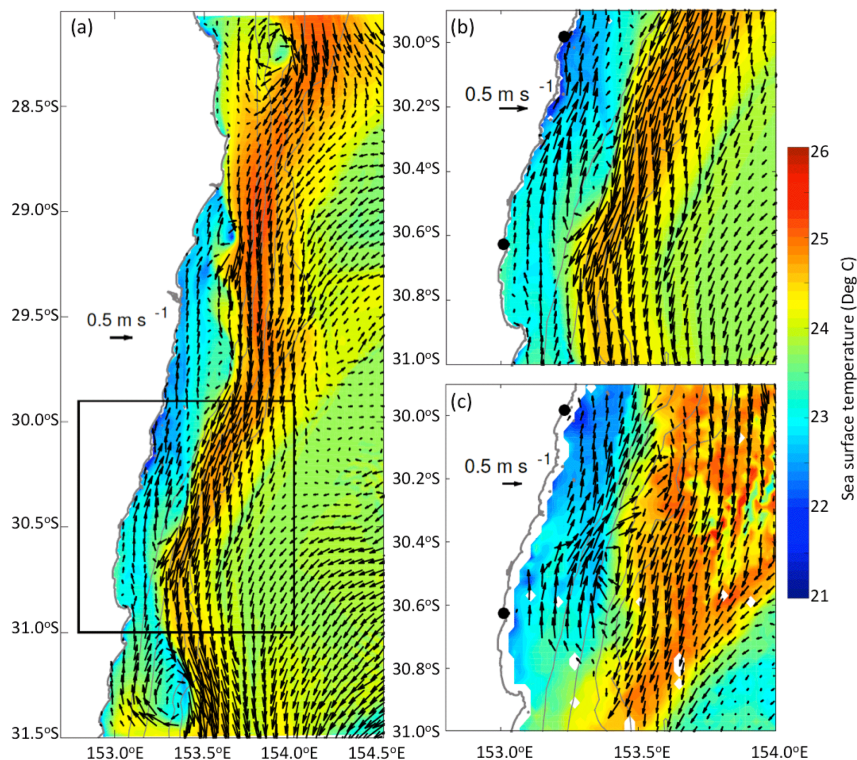


Figure 6. Snap-shots of **(a, b)** modelled and **(c)** observed surface velocity and SST for 15 May 2012. Model results are from a 1 km resolution WebMARVL-configured ROMS run off southeastern Australia (Fig. 4), and observations are from 6 day composite satellite AVHRR SST and land-based HF radar measurements (the location of the HF radar sites are shown by black dot in panels **(b)** and **(c)**). The coastline and 100, 200, 1000, 2000 and 5000 m isobaths are shown in grey. For clarity, velocity vectors are only plotted every 5th grid point in panel **(a)**, every 4th grid point in panel **(b)**, and every 3rd point for the HF radar data in panel **(c)**.

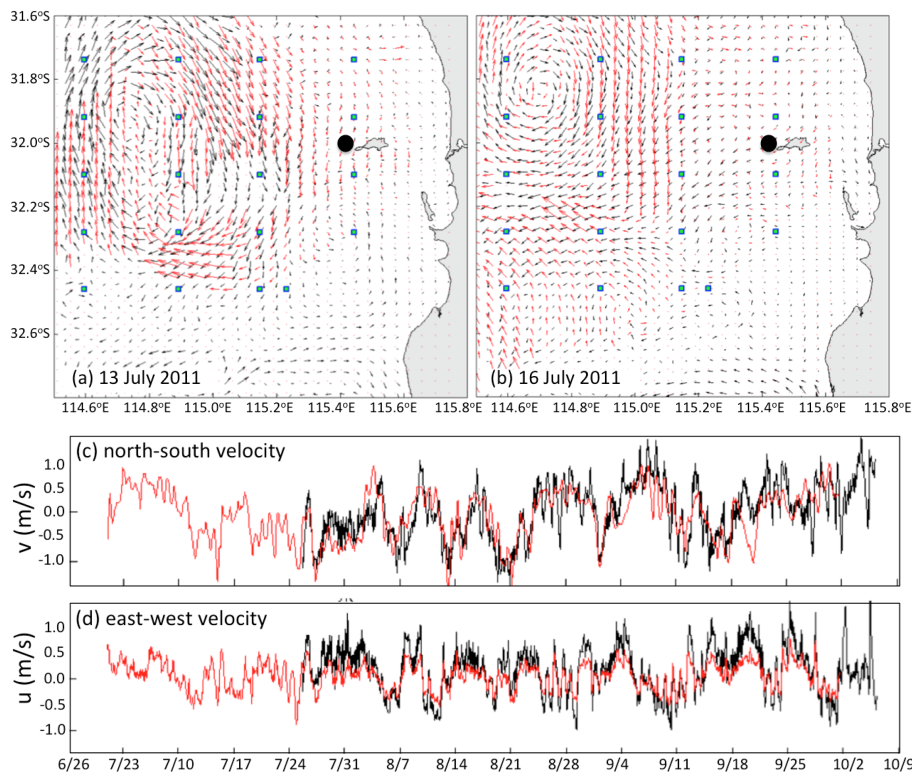


Figure 7. Comparisons between observed (HF radar; red) and WebMARVL-configured ROMS (black) surface velocity (**a**, **b**) and time-series of observed (ADCP; red) and WebMARVL-configured ROMS (black) at 10 m depth at the ADCP location, off the coast of Western Australia. The location of ADCP is denoted by the black dots in panels (**a**) and (**b**).

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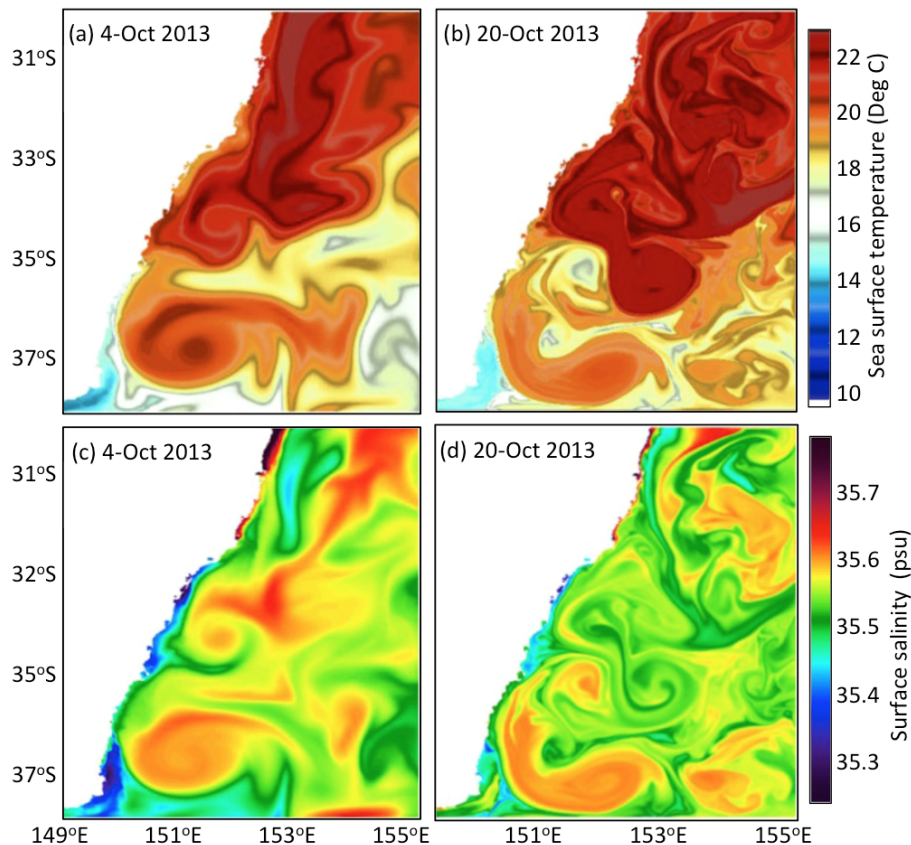


Figure 8. Snapshots of (a, b) sea surface temperature and (c, d) surface salinity for the (a, c) initial conditions, interpolated from a 0.1° -resolution model (OceanMAPS) and (b, d) the model fields after 16 days of evolution by a 2 km resolution model.

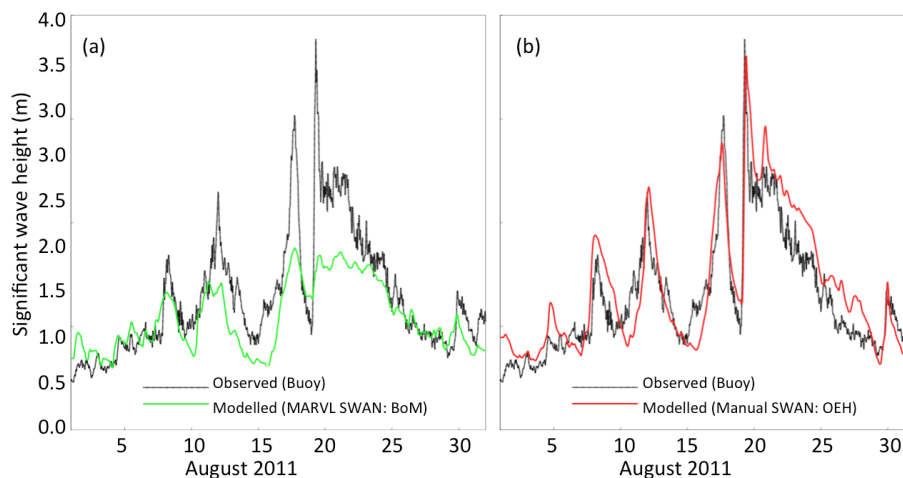


Figure 9. Time-series of modelled (colour) and observed (black) significant wave height off Sydney (~ 1 km offshore, in 21 m of water), for two different model configurations – **(a)** MARVL SWAN: BoM and **(b)** manual SWAN: OEH.

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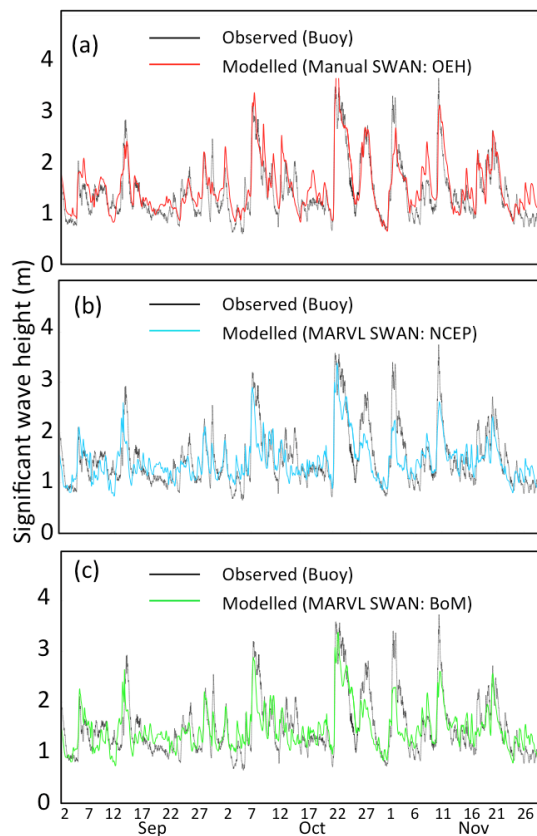


Figure 10. Time-series of modelled (colour) and observed (black) significant wave height off Coffs Harbour (~ 12 km offshore, in 72 m of water), for three different model configurations – manual SWAN: OEH (red, **a**), MARVL SWAN: NCEP (blue, **b**) and MARVL SWAN: BoM (green, **c**).

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