NIWA
Taihoro Nukurangi

Memorandum

To:	Ministry for the Environment	Date:	24 March 2014
From:	Richard Gorman Graham Rickard	Our Ref:	MFE13305
Copy:			

Subject: **Review of the report "Astrolabe Reef Metocean Conditions: Wave, ocean current and wind statistics "**

Executive summary

A report on meteorological and oceanographic conditions at Astrolabe Reef prepared by MetOcean Solutions Limited has been reviewed by NIWA.

The report describes conditions at a representative location adjacent to Astrolabe Reef in the form of climate statistics for wind, waves, currents and sea temperatures. These statistics are derived from numerical model simulations, which were first validated against available data for winds, waves and currents.

Our review finds that the methods used in preparing these statistics are in general suitable, and the results presented are appropriate for the stated purpose, with no significant gaps identified. The validation results against available data are generally sufficient to give confidence in the validity of the results. Some specific improvements have been suggested.

1 Introduction

A report on meteorological and oceanographic conditions at Astrolabe Reef was prepared by MetOcean Solutions Limited in September 2013 for the purposes of evaluating options for the removal or partial removal of the wreck of the *MV Rena*. The Ministry for the Environment has commissioned NIWA to provide an external review of that report. That review is presented below.

2 Summary of the report

The report describes meteorological and oceanographic conditions in the form of climate statistics for wind, waves, currents and sea temperatures at a representative location adjacent to Astrolabe Reef. These are derived from a set of numerical simulations, using the following models:

- Weather Research and Forecasting (WRF) model for surface boundary conditions (including air temperature, humidity, precipitation, short and long wave radiation, and winds), using the National Centres for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) products for WRF boundary conditions
- Nested Wavewatch III and SWAN simulations for waves
- Princeton Ocean Model, using TPXO7.2 boundary conditions, for depth-averaged tidal currents
- Regional Ocean Modelling System (ROMS), with CFSR boundary conditions, for 3D baroclinic non-tidal currents

The model simulations were first validated against available data for winds (one site in the South Taranaki Bight), waves (at Pukehina, Tauranga and Astrolabe Reef) and currents (at Pukehina and Astrolabe Reef).

Climate statistics presented include:

- annual, monthly and/or seasonal univariate statistics (mean, maximum, percentiles) for relevant variables (wind speed, significant wave height, tidal and non-tidal current speeds)
- joint probability distributions of wind speed and direction, significant wave height and peak direction, and current speed and direction
- annual and monthly exceedance values for wind speed
- annual and seasonal persistence non-exceedance for significant wave height
- density plots for joint distributions of relevant combinations of wave parameters

In the case of wave statistics, a partitioning into swell and wind sea components was performed, so the above results were presented separately for total, swell and/or wind sea components.

3 Review comments

The methods used are in general suitable, and the results presented are appropriate for the stated purpose of producing accurate hindcast statistics for winds, waves and currents applicable to the vicinity of Astrolabe Reef. The range of statistics produced is sufficient to provide adequate support to the evaluation of options for the possible removal or partial removal of the MV Rena from the reef. The validation results against available data are generally sufficient to give confidence in the validity of the results. Some improvements can be suggested, however, as indicated below.

The Numerical Models

Good descriptions of the models and techniques are provided. The only thing missing seems to be specification of the number of vertical levels used in the MSL-ROMS 3D models (both the NZ wide model, and the regional Bay of Plenty model).

Verification

While it is noted that the WRF Reanalysis has been validated at “various locations around New Zealand”, results are presented in the form of a Q-Q plot for wind speeds at a site in the South Taranaki Bight. This figure did not reproduce correctly in the document, so these results cannot be readily evaluated. In any case, a location more representative of winds in the Bay of Plenty (e.g. from Tauranga Airport) would be preferable.

The verification of significant wave heights against measurements is satisfactory. It might be noted that this gives some confidence in the accuracy of the hindcast winds, in the absence of direct verification at a nearby location in the Bay of Plenty.

Larger errors are found in the verification of hindcast currents, but these are still reasonable. Only the non-tidal currents from the 3D baroclinic mode were validated, with no validation presented for the tidal model. In places it could be clarified whether measured velocities compared with the model refer to total currents or just the non-tidal component. The text of the second paragraph of Section 2.3.3, and the caption of Figures 2.11 ad 2.15 suggest the latter, but this is not specified in Figures 2.12, 2.13, 2.14 and 2.16. Given that non-tidal currents were found to be much larger than tidal currents, this may not be an important distinction in practice. But if, as implied, tidal components have been extracted from the measured records, it should be possible to provide some verification of the tidal model, or else a comment on why this was not done. It could be noted, though, that the results appear consistent with the tidal model verification of Stanton et al. [1].

Comparison with single point measurements as performed here for the 3D flows are notoriously difficult, especially in geophysical systems of this scale with numerous processes contributing to the point by point variability (and the fact that the model is not itself being run in data assimilating mode, but is forced externally with real-time information). The inner model has an approximate horizontal grid resolution of around 1.5 to 2 km, and so will indeed struggle to capture near-field processes around Astrolabe Reef (as noted in the report). In terms of reproducing variability within the Bay of Plenty itself, the comparison with in-situ ADCP data is of course valuable, but perhaps some reference to past work might have given a wider context to the baroclinic flows generated. For instance the papers of Longdill et al. [2] and references therein, and Bradshaw et al. [3], present examples of flows sensitive to wind and freshwater inputs observed in the vicinity of the Rena, and along the adjacent coast, that will presumably influence the accuracy to which dispersal of material properties can be simulated by the model.

In terms of the detailed comparison with the ADCP data it seems relevant to note:

(i) for Pukehina in Figure 2.11; that the model misses a lot of the relatively large amplitude u-component reversals, and that the u-velocity seems to be biased to positive flows relative to the observations; the bias in the v-component is much less, but still some of the relatively large amplitude flows are missed;

(ii) for Astrolabe Reef in Figure 2.12; in this case the u-component has a negative bias compared to the observations in the latter part of the record; the v-component presents a better balance of bias and variability;

(iii) for Pukehina for time-depth plots in Figure 2.13; the vertical distributions look good, but perhaps the observations suggest a greater penetration of flows with depth than modelled;

(iv) for Astrolabe Reef time-depth plots in Figure 2.14; the statistics of the modelled flows look good, but it is apparent that the u-component flows are comparatively largely underestimated by the model;

(v) for the quantile-quantile plots in Figures 2.15 and 2.16; these suggest that the model is reasonably capturing some of the statistics of the depth-averaged flow at both sites (and that also seems apparent from the patterns of variability in Figures 2.11 and 2.12).

It would also have been interesting to see how well it is believed that the CFSR products reproduce the major current systems on the New Zealand north east shelf, in particular the East Auckland Current, the transition to the East Cape Current, and the major eddies of the North Cape Eddy and the East Cape Eddy. It is believed that these systems impact the baroclinic current variability in the Bay of Plenty itself (see for instance the discussion in Chapter 2 of the Research Commons paper by Longdill, 2006, http://researchcommons.waikato.ac.nz/handle/10289/2604). Also useful would be some estimate of how well the inner ROMS model couples to the outer ROMS model, in terms of continuity of the larger systems on the wider domain grid being transferred to the inner grid. Combined, these would give estimates of the robustness of CFSR as a product for the NZ region, and also how those outer fields influence the circulation within the Bay of Plenty.

These points would provide greater confidence in the representation of the flows in the Bay of Plenty by the MSL-ROMS 3D model.

In terms of the MSL-ROMS model capturing seasonality in the Bay of Plenty, this seems apparent from the plot of mean temperature with depth in Figure 6.1., In Spring and Summer, stratification in the surface layers arises, with a clear gradient established between the surface and deep waters; this becomes eroded (as we suspect it should) in Autumn and Winter as the seasonal shift in surface heating and wind strength drive more vertical mixing of the water column.

Output location

The main sections describing the wind statistics (Section 3, page 22) and current statistics (Section 5, page 65) do not specify the output location, noted as Astrolabe Reef for wave statistics (Section 4, page 30). Although the Introduction describes this, it would be helpful to clarify this given that results at other locations are given in the intervening verification results.

Wave spectral partitioning

Section 2.2.1 on wave spectral partitioning lacks a definition of U_C. From Tracy et al (2007), this should be:

$$U_C = C_m U_{10} \cos(\theta - \theta_w)$$

The reported wave roses give rather different directional distributions for wind sea and swell, with a predominance of swell from the northeast while wind sea has stronger contributions from the north, west and east. This would appear to be consistent with the hindcast wind climate in the Bay of Plenty. But in other cases the possibility exists that the spectral partitioning method produces an artificially large distinction between swell and wind sea directions, in cases where swell and wind sea cannot be clearly resolved. The authors may wish to comment on this.

Figures

Figure 2.2 does not to appear to have been reproduced in the report to hand. The majority of figures are good and fit for purpose. However some showing critical information such as Figures 2.11 and 2.12 appear to be at rather low resolution, and would therefore serve the report better with enhanced quality. The vertical y-axes in the frames in Figure 2.13 are not detailed, but are presumed to be depth above the reference bottom in metres.

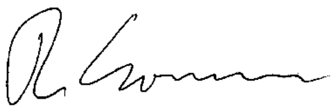
Citations

There are several discrepancies between citations and the bibliography. The following citations appear in the text, but not in the bibliography:

- Mellor (2004), in Section 2.3.1, par 1 (the hyperlink does not go directly to this)
- Orlanski (1976), in Section 2.3.1, par 2
- Marchesiello et al (2001), in Section 2.3.1, par 2
- Flather (1976), in Section 2.3.1, par 2
- Wilkins et al (2005) , in Section 2.3.2, par 1
- COARE Taylor Yelland (2001), in Section 2.3.2, par 4

Conversely, the following references in the bibliography are not cited in the text:

- Caires and Sterl (2004)
- Fetterer et al (2009)
- Hsu (2003)
- Queffeulou (2004)
- Tolman (2007) – should be cited in Section 2.2, par 1
- Young (1988)



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4 References

1. Stanton, B.R., D.G. Goring, and R.G. Bell, *Observed and modelled tidal currents in the New Zealand region.* New Zealand Journal of Marine and Freshwater Research, 2001. **35**: p. 397-415.

2. Peter C. Longdill, Terry R. Healy & Kerry P. Black (2008) Transient wind-driven coastal upwelling on a shelf with varying width and orientation, New Zealand Journal of Marine and Freshwater Research, 42:2, 181-196, DOI: 10.1080/00288330809509947

3. Bradshaw, B.E., Healy, T.R., Dell, P.M. and Bolstad, W.M., 1990. Inner Shelf Dynamics on a Storm-Dominated Coast, East Coromandel, New Zealand. Journal of Coastal Research, 7(1), 11-30. Fort Lauderdale, Florida ISSN 0749-0208.