

# USE OF ENVISAT RA2 SEA LEVEL OBSERVATIONS IN THE BLUELINK OCEAN MODELLING SYSTEM

David A Griffin<sup>(1)</sup>, Peter R Oke<sup>(2)</sup>, Madeleine L Cahill<sup>(3)</sup>

<sup>(1)</sup>CSIRO Wealth from Oceans Flagship, GPO Box 1538, Hobart, Tas 7001, David.Griffin@csiro.au

<sup>(1)</sup>CSIRO Wealth from Oceans Flagship, GPO Box 1538, Hobart, Tas 7001, Peter.Oke@csiro.au

<sup>(1)</sup>CSIRO Wealth from Oceans Flagship, GPO Box 1538, Hobart, Tas 7001, Madeleine.Cahill@csiro.au

## ABSTRACT

Satellite and in-situ components of the Global Ocean Observing System are assimilated into the Bluelink mesoscale-resolving global ocean model in order to produce both hindcasts and forecasts of the three-dimensional physical state of the ocean. Sea level anomaly estimates provided by the RA2 altimeter embarked on Envisat are an essential inclusion (along with data from Jason-1 and -2) in the data set. We show that with three altimeters in use, the basic features of many rapidly evolving mesoscale features can successfully be simulated in a global ocean model. This has been verified using un-assimilated surface-drifting buoys, and other data. Many successful applications of the system have now been made. Here, we describe how the search for a WWII wreck off Brisbane was assisted by information on ocean currents, and discuss an interesting case of coastal water temperatures near Sydney exceeding climatology by 4° in May 2010.

## 1. The Bluelink global ocean model.

Bluelink is a partnership of three Australian government agencies (the Royal Australian Navy, the Bureau of Meteorology and the Commonwealth Scientific and Industrial Research Organisation - RAN, BoM and CSIRO respectively) to develop data-assimilating modelling systems for the ocean at a range of scales - global, regional, and littoral-zone.

The global model is run operationally in forecast mode by BoM, presently generating a one-week forecast twice a week [1]. The model has also been run in hindcast mode (for the period from 1992 to the present) a number of times by CSIRO as part of the model development cycle and as an end in itself [2, 3]. The model presently has spatial resolution of 0.1° horizontally and 10m vertically in the near-surface waters in the Australasian region. Outside this region and below 250m the resolution becomes gradually coarser but the model does span the entire globe (excluding the Arctic Ocean) to full depth. A new version is in the final stages of preparation, with 5m layers at the surface and 0.1° x 0.1° resolution globally.

A wide variety of data types (principally sea level and temperature from satellites, and *in situ* observations of temperature and salinity by Argo, XBTs, moorings and

ships) are assimilated using a multivariate, ensemble optimal interpolation technique, whereby observations of any particular physical variable are projected onto all the model state variables, and not just at the location of the observation. A long (eg, 1992-2008) run of the model without any data assimilation provides an ensemble of intra-seasonal anomalies from which the inter-variable spatial covariance functions, needed for the mapping, are computed as required for the available observations.

The resulting homogeneous, four-dimensional datasets (both the forecasts and the hindcasts) are available online via OPeNDAP servers that allow the user to extract whatever subset of the entire dataset they require (see [4]). The salient features of snapshots of the model are the ubiquitous ocean eddies. The model's ability to simulate the boundary currents at the edge of the continental shelf is shown in Fig. 1.

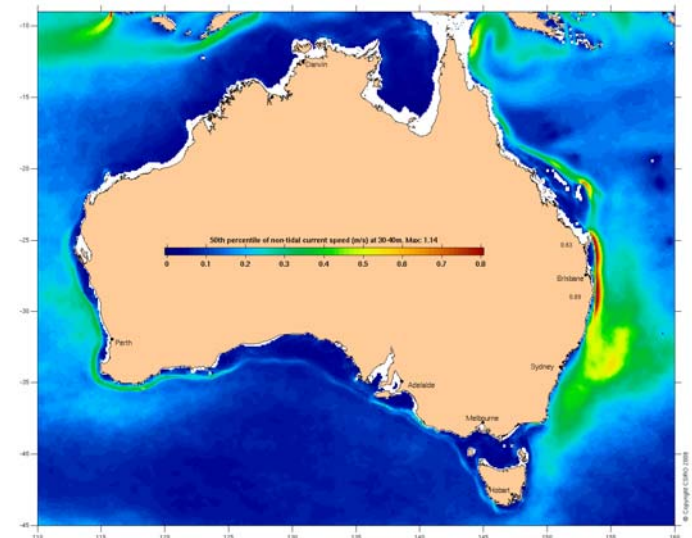


Figure 1 Median speed of the ocean currents at 30-40m depth as simulated by the Bluelink global ocean model.

## 2. The search for AHS Centaur

AHS Centaur was sunk off Brisbane on the east coast of Australia during WWII in 1943, just where Fig. 1 shows the median (non-tidal) current speed to be the highest (nearly 1m/s) over the Australian continental margin. The known prevalence of the strong southward flow of

the East Australian Current cast doubt over the navigator's estimate of the ship's position because it was south-west, not north, of where survivors were rescued. Inspection of the Bluelink hindcast, however, showed that reversals of the flow at the sinking position have occurred about 5% of the time since 1993, suggesting that the navigator's position could be correct. Search director David Mearns used this fact to argue the case for conducting a search in the vicinity of the navigator's position. The depth there is 1400m.

The search commenced in December 2009 and a forecast of the ocean current conditions on site was required to plan how and when the sonar equipment was to be towed. Satellite observations enabled a forecast to be made that the flow at the site would reverse when a southward advecting cyclonic eddy reached that latitude. Fig. 2 shows the Bluelink analysis for 5 Dec, featuring a cyclonic eddy at 25.8°S on the upper continental slope, which is where both a descending Jason-2 track and an ascending Jason-1 track provided observations that were assimilated. Good (cloud-free) SST imagery exists for 8 Dec (Fig. 3) and this shows that the eddy was rotating and advecting in general agreement with the model. On-site vessel operations confirmed the slackening and reversal of the flow as the eddy passed through (Fig. 4)

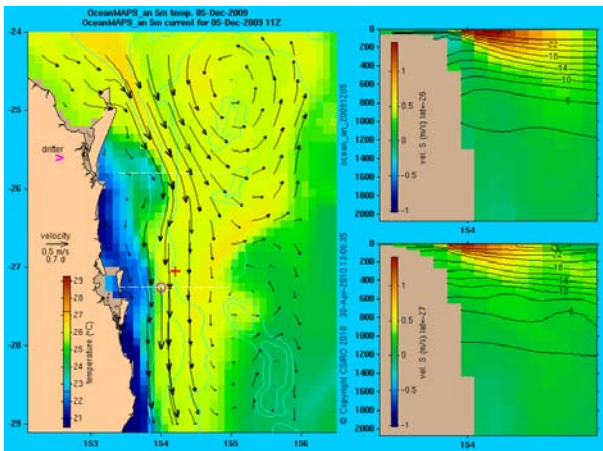


Figure 2. Bluelink model near-real-time hindcast for 5 Dec 2009. Left panel: near-surface (5m) temperature and current velocity, and locations of AHS Centaur (magenta circle) and where survivors were rescued (red cross). The arrows show Lagrangian paths over 17h, half the time the survivors were adrift. Right panel: zonal velocity (southward in red, northward in blue) and isotherms along the two dashed lines in the left panel.

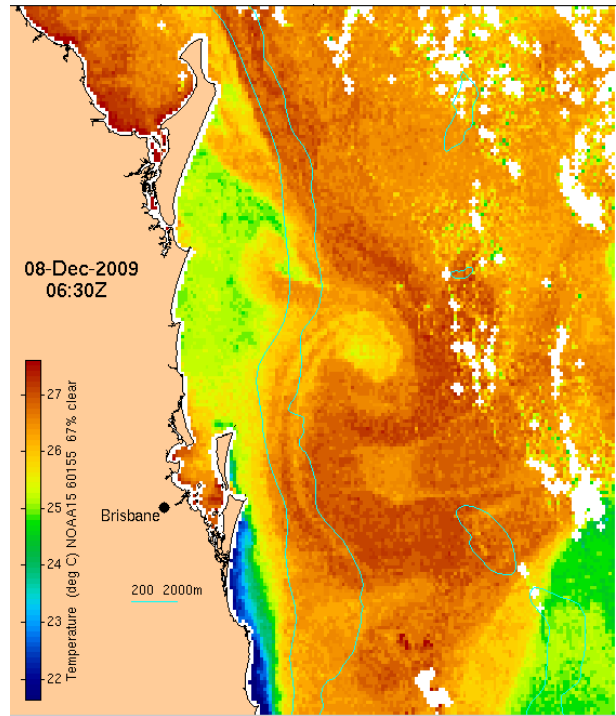


Figure 3. Sea surface temperature image (NOAA 15 AVHRR HRPT) for 8 December.

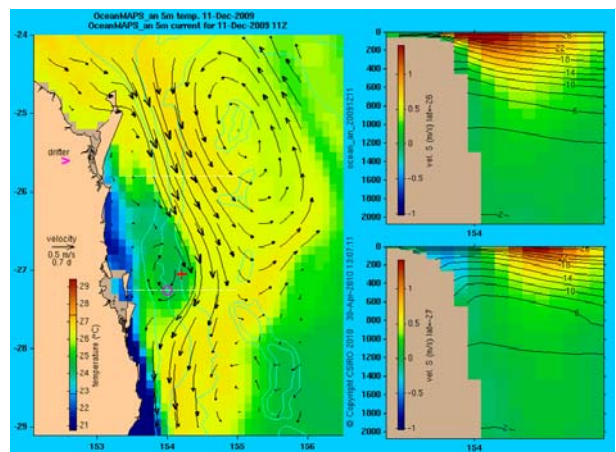


Figure 4. As for Fig. 2, but for 11 Dec 2009. We infer that the flow on 14 May 1943 was more similar to this than the more usual condition shown in Fig. 2. Had the flow been as strong as usual, more lives would probably have been lost.

Media interest in the successful search was very high because the unknown fate of the ship has caused so much grief over the last 67 years. The importance of the oceanographic information before and during the search was acknowledged by David Mearns. We are grateful to have had the chance to contribute to another (after HMAS Sydney [5]) of his successful searches.

### 3. Sydney's extended beach season, May 2010

In contrast to the relatively steady flow of the East Australian Current adjacent to Brisbane, Sydney is inshore of a very dynamic region into which the East Australian Current advances and retreats as part of a cycle of shedding and occasional over-riding or flooding of anticyclonic eddies [6]. Cyclonic features also occur both inshore and offshore of the East Australian Current [7,8], leading to this region having the highest variability of sea level and isotherm displacement in Australia's regional seas.

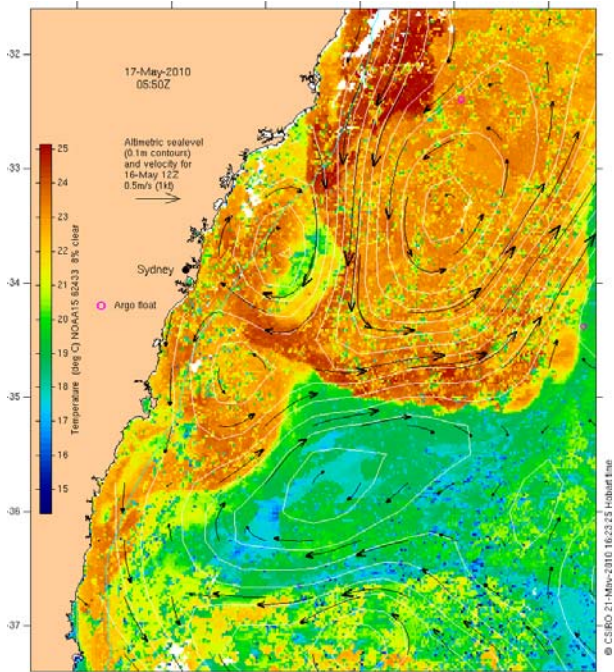


Figure 5. Sea surface temperature image (NOAA 15 AVHRR HRPT) and CSIRO's geostrophic velocity analysis from near-real-time altimetry (Jason-2 and Envisat) for 17 May 2010.

Sydney's inhabitants enjoy visiting the beaches so many people became aware of the fact that in early May 2010 the temperature was still at summer levels (~22°C), becoming 4° above climatology by mid-May. Altimetry and thermal imagery showed that the elevated temperature was due to the East Australian current diverting around an inshore cyclonic eddy just north-east of Sydney, only to flow directly onshore at the latitude of Sydney (Fig. 5). Altimetry also showed a much larger cyclonic eddy seaward of the East Australian current, southeast of Sydney. We knew that these two cyclonic eddies would soon merge, separating the warm core eddy south of Sydney from further input from the EAC, and that cold water would therefore stream towards Sydney bringing a rapid end to the beach-going season. A prediction this coming change was published in the *Sydney Morning Herald* on 22

May 2010. Fig. 6 shows that the flow changed more-or-less as expected, with the EAC suddenly ceasing to flow into the smaller warm-core eddy south of Sydney, but continuing around the larger deep-ocean warm-core eddy occupying the top-right quadrant of Fig. 6. The cold region between the two warm regions grew over the following weeks, as shown in Fig. 7, returning Sydney's coastal waters to normal June temperatures of 18°C.

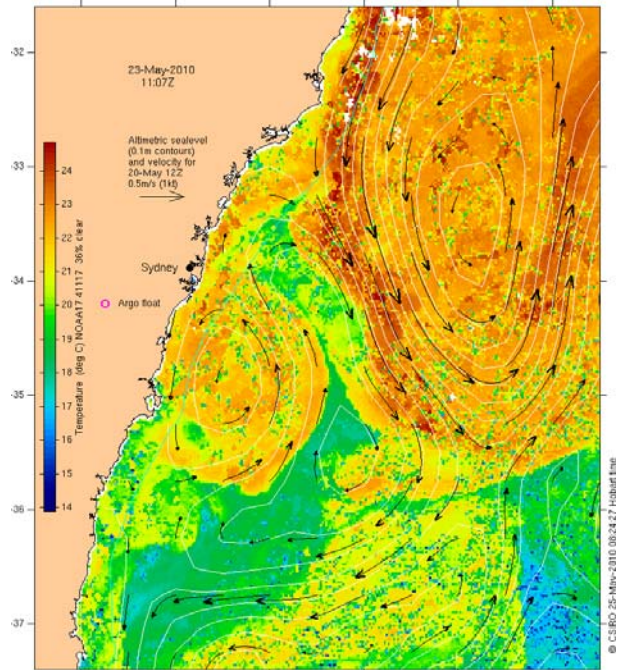


Figure 6. As for Fig. 5, but for 23 May 2010.

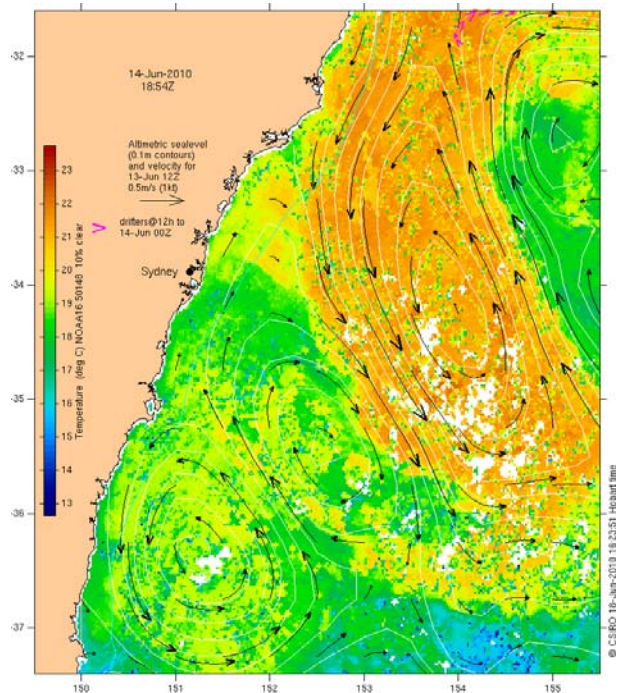


Figure 7. As for Fig. 5, but for 14 June 2010.

#### 4. CONCLUSIONS

Ocean hindcasting and forecasting at mesoscale resolution is still at an early stage, with most nations still not possessing an operational system. Australia has a greater need for such a system than many countries so we have invested in the development of the systems required to bring information about the state of the ocean to those who need it, in an accessible way. Early-adopter classes of mariners are now almost universally aware that satellite observations of ocean properties exist and these users are becoming used to the idea that the ocean 'weather' is not only knowable, but predictable. It is clear, however, that we still have a long way to go before users' needs for accuracy and spatial resolution are satisfied. The present constellation of three nadir-viewing altimeters reveals much about the mesoscale variability of the ocean but certainly not all of it, and very little of the sub-mesoscale features about which much less is known, but which are observed occasionally by rare sequences of AVHRR imagery when conditions are right (eg Fig 3).

#### 5. References

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