

Marine Resources and the need for Operational Oceanography

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Abstract - Many maritime practices follow from an assumption that the physical state of the ocean is essentially unknowable and unpredictable. In recent years, however, remote sensing has challenged this conservative assumption, with ‘early adopters’ among the marine sector depending more and more on satellite data for planning their operations. Radar altimeters (Jason-1, Jason-2 and Envisat) provide estimates of sea level, from which surface currents and sub-surface thermal structure can be inferred. Radiometers (AVHRR, MODIS) map the surface temperature and other properties of the ocean. Analysis of these data and assimilation into hydrodynamic models in near-real-time is the basis of an ocean forecasting system which promises to be as integral to marine operations as weather forecasting is to terrestrial operations. The need for, and potential usefulness of, such a system is demonstrated by a brief discussion of the extreme ocean current speeds that occurred off Sydney in the months before the conference.

Keywords: Altimetry, sea surface temperature, ocean currents, data assimilation, East Australian Current, operational oceanography.

1. INTRODUCTION

Winds and waves have, for centuries, been the major threat to the safe and economic conduct of operations at sea. This remains the case but for several marine industries the other physical properties of the ocean also bear strongly on their operations. Fishers, for example, use maps of ocean temperature, color and current speed as guides to where various species of fish are most likely to be caught at various times of the year. Racing yachtsmen use maps of the current to gain an advantage over competitors. Navies use maps of sea level as proxies for the subsurface thermal structures that affect their sonars. Many other industries could also benefit from real-time and historical information but at this point it is probably fair to say that only the early-adopters are coming close to fully exploiting the available information.

There are many reasons why operational oceanography is so far behind operational meteorology. The number of stakeholders is certainly less, as is the economic value of the information, although not proportionately so because several marine industries are major contributors to the economy. The factor we will discuss here, however, is that the technology associated with observing the ocean and delivery of fit-for-purpose data products, let alone practical advice, is still very much in its infancy.

It is often said that more is known about the surface of the moon than the ocean and in some respects that may be true. The host city for this conference has some of the finest beaches in the world, and visiting them frequently is a large part of the Sydney culture. Very few Sydney residents, however, would have any understanding of why the temperature at the beach might vary from 5 degrees above average to 5 degrees below. Even fewer would know about the swirling gyres, both cyclonic and anticyclonic, that are more energetic near Sydney than anywhere else around Australia. In this context, it is perhaps not surprising that few mariners and marine scientists claim more than a very basic understanding or knowledge of the prevailing ocean conditions, no matter how extreme they might be at any particular time.

The summer of 2010-2011, as a strong La Nina prevailed, was extraordinary in many regards, including the flooding of Brisbane and the destructive arrival of Tropical Cyclone Yasi in northern Qld. At the time of writing (February 2011), we are not yet aware of any major economic impacts of the extreme ocean conditions that also occurred off Sydney but we will briefly describe these in the following section as a way of illustrating the capabilities of the present suite of remote sensing and in situ systems that form the backbone of the Global Ocean Observing System.

2. SYDNEY'S EXTREME OCEAN EDDIES OF 2011

The East Australian Current (EAC) flows southwards along the East Australian margin from north Queensland to a point somewhere in New South Wales where it separates from the continent to flow along the Tasman Front to New Zealand. It forms a fairly stable jet along the edge of the continental shelf near Brisbane, with a median speed (Fig. 1) of about 0.9m/s within a narrow region according to the 10km-resolution Bluelink ocean model (Schiller *et al*, 2006). The flow is unstable where it separates from the shelf, going through a cycle that sees a southward meander of the main flow reach a critical size then pinching off to become an isolated warm-core eddy that may drift south, remain off the southern New South Wales coast for many months, or re-connect with the EAC (Baird *et al*. 2009). In this larger zone of variable flow south-east of Sydney, the median current speed (Fig. 1) is about half (0.4 to 0.5m/s) the value in the stable region. The 90th percentile values (not shown) are about 1.3m/s in

the stable region near Brisbane, 1.1m/s north-east of Sydney and 0.9m/s south-east of Sydney.

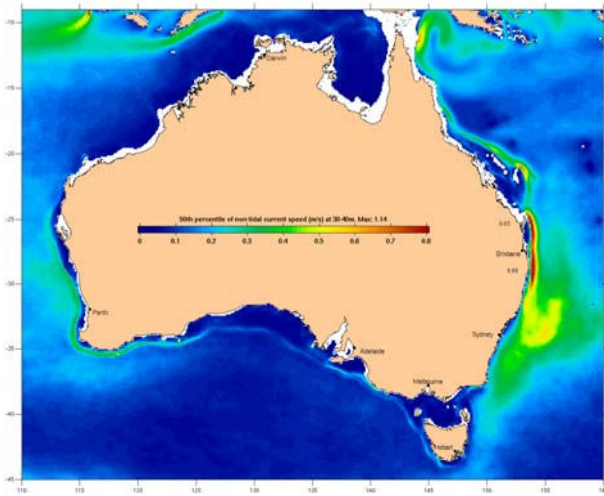


Fig.1 Median speed of the ocean currents at 30-40m depth as simulated by the Bluelink global ocean model.

The speed of the ocean current is not directly measurable by remote sensing techniques. The most directly related property that can be measured from space (at present by the radar altimeters on Jason-1, Jason-2 and Envisat) is the deviation (from an unknown average with respect to the geoid) of sea level (Cipollini *et al.* 2009, Deng *et al.* 2010, Le Traon *et al.* 2009). The warm-core eddies shed by the EAC have high sea level, and therefore high subsurface pressure in the centre. It is well established that the pressure gradients are closely balanced by the Coriolis force acting on the surface velocity, which, at geostrophic equilibrium, is along the contours of sea level. A warm core eddy rotates in the same direction as a high pressure system in the atmosphere, for the same reason.

In December 2010, a meander of the EAC developed with a central sea level anomaly of 1.1m, 250km north-east of Sydney. The speed of the geostrophic current was about 1.3m/s (Fig. 2a), 0.2m/s higher than the 90th percentile value mentioned above for that region and also, it appears, a new record or close to it. A 0.6m deep depression of sea level directly east of the warm core eddy reveals the location of a cyclonic eddy, also known as a cold-core eddy (Oke and Griffin, 2010) because it will inevitably have anomalously cold water in its center, especially in the subsurface layers not sensed by infrared radiometry.

Between 20 December and 16 January (Fig. 2b), the warm core eddy moved south-west while the cold core eddy deepened and moved north-west, causing the warm core eddy to become semi-detached from the EAC. The temperatures right at the coast ranged from very warm where the current was close to the coast, to very cold where the subsurface layers became upwelled.

Between 16 and 30 January (Fig. 2c), the warm core eddy continued to move south, becoming more completely detached from the EAC as it did so. A surface drifter encircled this eddy, reaching a speed of nearly 2m/s over one 24h interval. It is less clear what happened to the cold core eddy which was the biggest and deepest cyclonic eddy to have occurred in the region since 1994 (or close to it). It appears to have fragmented into the three isolated cyclonic features between 32S and 33S, only one of which is inshore of the EAC.

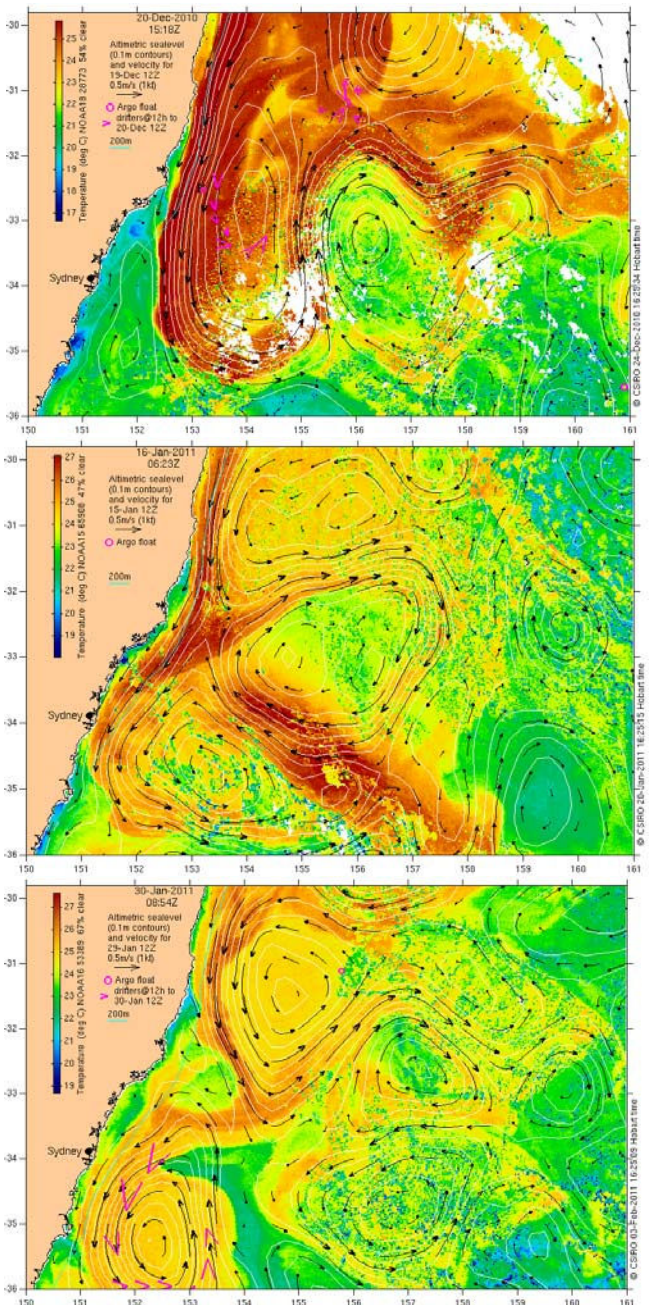


Fig. 2a,b,c. Sea Surface Temperature (see colour scale) determined from the Advanced Very High Resolution Radiometer on NOAA 18, geostrophic surface current velocity (black 24h-long streak lines), and sea level (white contours at 0.1m intervals) from Jason-1, Jason-2 and Envisat measurements. Magenta arrow heads and circles

show the positions of surface drifting buoys (at 12h intervals) and Argo floats, respectively. Panels a to c, top to bottom, are for 20 December 2010, 16 January 2011 and 30 January 2011.

3. DISCUSSION

The strong currents discussed here would certainly have been obvious to all mariners operating in the region once they were on site. We know that many of them monitor the CSIRO website (<http://www.marine.csiro.au/remotesensing/oceancurrents>) where the images for Fig. 2 were published in near real time, but detailed feedback from users other than fishers, yachtsmen, beachgoers and Navy is uncommon, probably because of the absence of significant offshore engineering in this region.

The need for operational oceanography, in Australia, is possibly greatest off the North West, where there is so much investment in offshore engineering. The present generation of remote sensing techniques, however, is less successful there than off Sydney, because 1) the intrinsic time and space-scales of the variability (much of which is associated with internal tides and short-lived currents driven by tropical cyclones) are less well matched to the scales resolved by altimetry. Sea Surface Temperature images are also less often very informative.

4. CONCLUSIONS

We have presented a recent example of exceptionally strong currents associated with counter-rotating, record-setting eddies (one warm-cored, one cold-cored) over the continental shelf and adjacent ocean near Sydney, using routinely-generated satellite data products that are made publicly available, but on a non-operational basis. The general consistency of the altimetric, radiometric and in situ (drifter) data demonstrates that the high-energy, eddy-scale features of the ocean can be deemed to be knowable quantities, thereby challenging the reigning paradigm in conservative segments of the marine sector that current-sensitive operations cannot be optimized by making use of ocean current nowcasts and, eventually, forecasts. More work is required to improve the signal-to-noise ratio of the observing system, but in the mean time we believe that society has much to gain from oceanography being made an operationally supported service.

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