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A western boundary current eddy characterisation study

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ABSTRACT

The analysis of an eddy census for the East Australian Current (EAC) region yielded a total of 497 individual short-lived (7–28 days) cyclonic and anticyclonic eddies for the period 1993 to 2015. This was an average of about 23 eddies per year. 41% of the tracked individual cyclonic and anticyclonic eddies were detected off southeast Queensland between about 25 °S and 29 °S. This is the region where the flow of the EAC intensifies forming a swift western boundary current that impinges near Fraser Island on the continental shelf. This zone was also identified as having a maximum in detected short-lived cyclonic eddies. A total of 94 (43%) individual cyclonic eddies or about 4–5 per year were tracked in this region. The census found that these potentially displaced entrained water by about 115 km with an average displacement speed of about 4 km per day. Cyclonic eddies were likely to contribute to establishing an on-shelf longshore northerly flow forming the western branch of the Fraser Island Gyre and possibly presented an important cross-shelf transport process in the life cycle of temperate fish species of the EAC domain. In-situ observations near western boundary currents previously documented the entrainment, off-shelf transport and export of near shore water, nutrients, sediments, fish larvae and the renewal of inner shelf water due to short-lived eddies. This study found that these cyclonic eddies potentially play an important off-shelf transport process off the central east Australian coast.

1. Introduction

In-situ observations from Western Boundary Current (WBC) regions indicate that cyclonic eddies (CEs) are important for fisheries (Kasai et al., 2002; Govoni et al., 2009; Suthers et al., 2011; Matis et al., 2014; Mullaney et al., 2014; Everett et al., 2015). Forming on the near-coast side of WBC regions, CEs become enriched in fish larvae and primary productivity stimulating nutrients due to the entrainment of near-shore coastal water. The East Australian Current (EAC) CEs observed to the south of the EAC intensification zone (Ridgway and Dunn, 2003) where found to be usually short-lived (2–4 weeks). The eddies were more frequent and of smaller scale than anticyclonic eddies (ACEs) and ranged in size from about 10 km to 100 km (Mullaney and Suthers, 2013; Everett et al., 2015). Observed CEs propagated close to the coastal zone, often generated a near-shore northward flow (e.g. Huyer et al., 1988; Roughen et al., 2011; Everett et al., 2011) and were located at the coastal side of the EAC. CEs were also usually cold-core eddies, i.e. characterised by a negative sea surface temperature anomaly (SSTa), and Chlorophyll-a (Chl-a) concentrations were about twice than those observed for ACEs (e.g. Govoni et al., 2009; Suthers et al., 2011; Everett et al., 2011, Everett et al. 2014, 2015; Mullaney et al., 2014; Everett et al., 2015). Studies of EAC CEs are few and limited to the southern regions of the EAC (e.g. Oke and Griffin, 2010; Macdonald et al., 2016), which is referred to as the EAC separation zone (Ridgway and Dunn, 2003). This study aimed to provide a census for short-lived eddies (7–28 days) along the east Australian coast with a particular focus on CE off the coast of southeast Queensland. This region is part of the EAC intensification region (Fig. 1).

Everett et al. (2012) and Pilo et al. (2015) performed the only two eddy characterisation studies of long-lived eddies (>28 days) for the EAC. Both studies utilised data from the same global eddy census conducted by Chelton et al. (2011). Pilo et al. (2015) compared the eddy statistics for three WBC regions, i.e. the Agulhas Current, the Brazil Current and the EAC region. The study expanded on Everett et al.'s (2012) analysis by estimating also average lifetime, propagation speed and distance travelled. A census of short-lived CEs (7–28 days) propagating within close proximity to the shelf, which appear to be more important for primary productivity and fisheries due to the entrainment of near coast shelf water, recruitment and retention is lacking for the EAC

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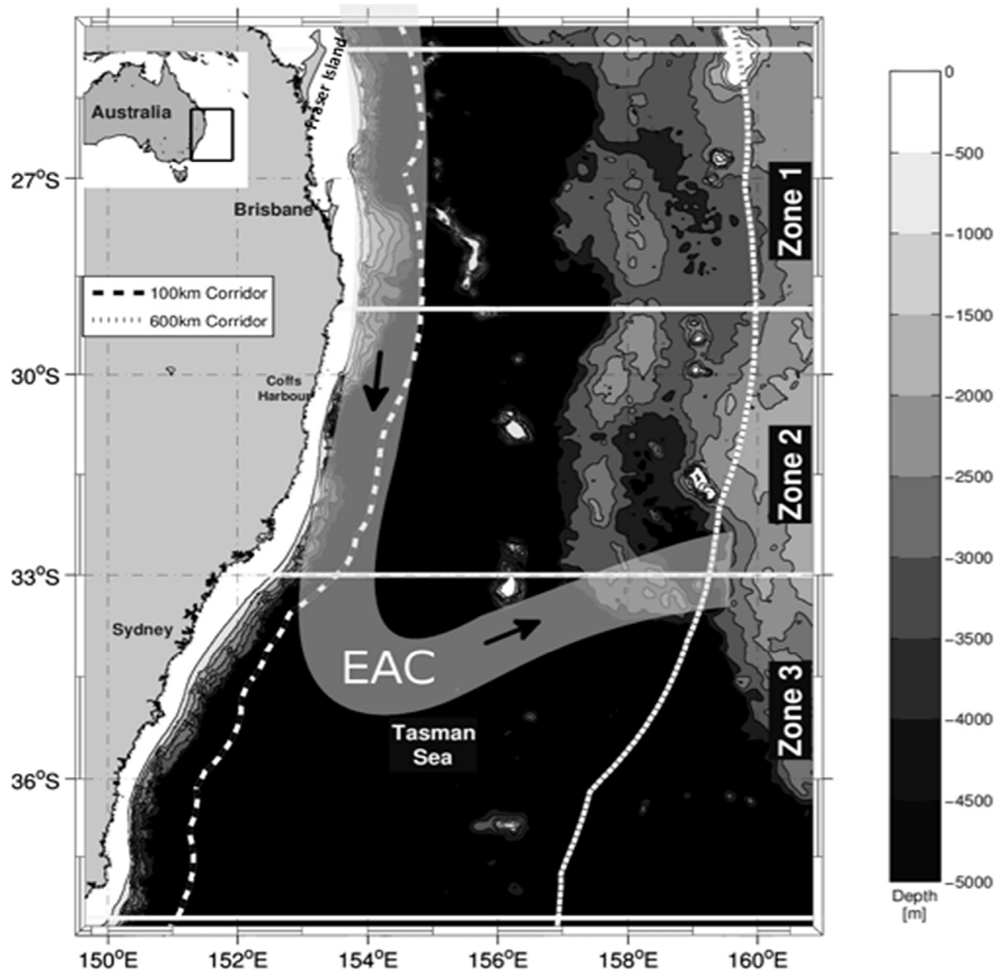

Fig. 1. Location of the study site along the east coast of Australia. The boundaries between Zone 1 (Z1) and Zone 2 (Z2) at about 29° S and Z2 and Zone 3 (Z3) at about 33° S were identified in this study from minima in eddy activity. Approximate mean path of the East Australian Current (EAC) is shown in light grey. Eddies were tracked over the whole region. An eddy census was conducted and the analysis limited to two coastal corridors of 100 km and 600 km width each (dash lines).

and other WBCs (Mullaney and Suthers, 2013). The analysis presented in this paper aimed to expand on these previous studies (Everett et al., 2012; Pilo et al., 2015). Its focus was on the analysis of eddy characteristics detected in a coastal corridor of about 100 km width, i.e. eddies that were wedged between the coast line and the EAC. We quantified the occurrences of short-lived cyclonic eddies important to fisheries and provided the first assessment of the role of these eddies for the coastal ocean off southeast Queensland.

The east Australian continental shelf is at its widest (80–90 km) off the coast of southeast Queensland between about 25 and 27 °S and to the south of Fraser Island (Fig. 1). The EAC forms to the north of this region from the South Equatorial Current and Coral Sea outflows. It intensifies forming a swift, albeit seasonally varying in strength, southward flowing current hugging the continental shelf (Ridgway and Dunn, 2003). A prominent oceanographic feature of the region is the EAC-driven Southeast Fraser Upwelling System (Brieva et al., 2015).

Ward et al. (2003) and Mullaney et al. (2014) speculated that the northern sub-tropical shelf waters (~25–27 °S) of the EAC intensification zone supply larvae of temperate fish species that are transported southward with the EAC. These return at a later stage in their lifecycle to spawn again during early winter. Gruber et al. (2011) find that eddy induced transports appeared to be close to a maximum within a near-shore 100 km wide zone. Mullaney and Suthers (2013) argued for the importance of these near-coast short-lived eddies for fisheries. The eddies were also found to be associated with the northward countercurrent and entrainment of coastal waters (Huyer et al., 1988; Mullaney and Suthers, 2013). Thus, the analysis presented in this study was focused on eddies and their characteristics identified for a narrow 100 km wide coastal corridor (Fig. 1). The characteristics were obtained from a new eddy census for the southwestern Pacific Ocean using the Halo et al. (2014) eddy detection method. It led to the identification of three zones (Zone 1 or Z1, Zone 2 or Z2 and Zone 3 or Z3) distinguished from minima in eddy activity (Fig. 1). Z1 was identified as the region with the highest number of short-lived cyclonic eddies along the east coast of Australia.

2. Data and methodology

2.1. Data

Daily estimates of Chl-a (mg·m^{-3}) and SST (°C) were disseminated via the data portal of Australian Integrated Marine Observing System (IMOS, 2015a) and were used in this study for the period 09/08/2002 to 31/10/2015. The data was gridded with a spatial resolution of 0.01° (IMOS, 2015a). The data was derived from MODerate resolution Imaging Spectroradiometer (MODIS) measurements with methodological details provided by O'Reilly et al. (2000) and Claustre and Maritorena (2003).