Deep-Sea Research II 100 (2014) 10–26

Contents lists available at ScienceDirect

Deep-Sea Research II

journal homepage: www.elsevier.com/locate/dsr2

In situ measured current structures of the eddy field in the Mozambique Channel

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ARTICLE INFO

Available online 21 November 2013

Keywords:
Mozambique Channel
Mesoscale eddies
Geostrophic currents
S-ADCP measurements
Wind driven circulation

ABSTRACT

Circulation and the related biological production have been studied during five cruises conducted in the Mozambique Channel (MZC) between 2005 and 2010. The circulation in the MZC is known to be highly turbulent, favouring enhanced primary production as a result of mesoscale eddy dynamics, and connectivity throughout the Channel due to the variable currents associated with migrating eddies. This paper presents the results of in situ measurements that characterize the horizontal and vertical currents in the surface and subsurface layers (0–500 m). The in situ data were analysed together with the geostrophic eddy field observed from satellite altimeter measurements. Different circulation regimes were investigated, including the "classical" anticyclonic eddy generated at the Channel narrows (16°S), the enhancement of southward migrating eddies by merging with structures (both cyclonic and anticyclonic) formed in the east of the Channel, and the presence of a fully developed cyclonic eddy at the Channel narrows. Comparison between in situ measurements (S-ADCP and velocities derived from surface drifters) and the geostrophic current derived from sea surface height measurements indicated that the latter can provide a reliable, quantitative description of eddy driven circulation in the MZC, with the exception that these currents are weaker by as much 30%. It is also suggested from in situ observation (drifters) that the departure from geostrophy of the surface circulation might be linked to strong wind conditions. Finally, our observations highlight that a-geostrophic currents need to be considered in future research to facilitate a more comprehensive description of the circulation in this area.

1. Introduction

Due to its location between Madagascar and the coast of Africa, the ocean circulation in the Mozambique Channel (MZC) is turbulent and complex (Penven et al., 2006). The contribution of the southward flow through the MZC to the Agulhas Current system (Biastoch et al., 1999; Beal et al., 2011) makes the understanding of its source, nature and variability of major interest. Extensive reviews of research conducted since the 1950s have been outlined in Di Marco et al. (2002), Schouten et al. (2003), and Lutjeharms (2006), and have highlighted important questions such as the permanent presence of a southward flow along the African coast (i.e. the Mozambique Current—MC) and the sources of variability observed at seasonal or inter-annual scales.

Initially, analysis of ship drift data (e.g. Saerte, 1985; Lutjeharms et al., 2000) and data from hydrographic cruises (e.g. Saerte and Jorge da Silva (1984); Donguy and Piton, 1991) suggested that a southward flow along the African coast did indeed exist. However, its persistence throughout the year could not be demonstrated. It has long been suspected that the seasonality of the MZC circulation is linked to the South Asian Monsoon system, at least in the northern part of the Channel. Saerte and Jorge da Silva (1984) proposed two different circulation patterns corresponding respectively to the southern hemisphere summer (northeast monsoon, from November to April) and winter (southwest monsoon, May–October) (Fig. 1). A remarkable feature of their circulation scheme was the presence of rotating cells, both in the northern and southern part of the Channel. They identified three anticyclonic gyres as major components of the circulation, two of them merging in winter. Interestingly, Harris (1972) had already proposed a similar scheme from ship drift analysis, but with eddies of varying sizes and at different locations. Saerte and Jorge da Silva (1984) mentioned cyclonic cells of smaller size

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0967-0645/$ - see front matter
http://dx.doi.org/10.1016/j.dsr2.2013.10.013

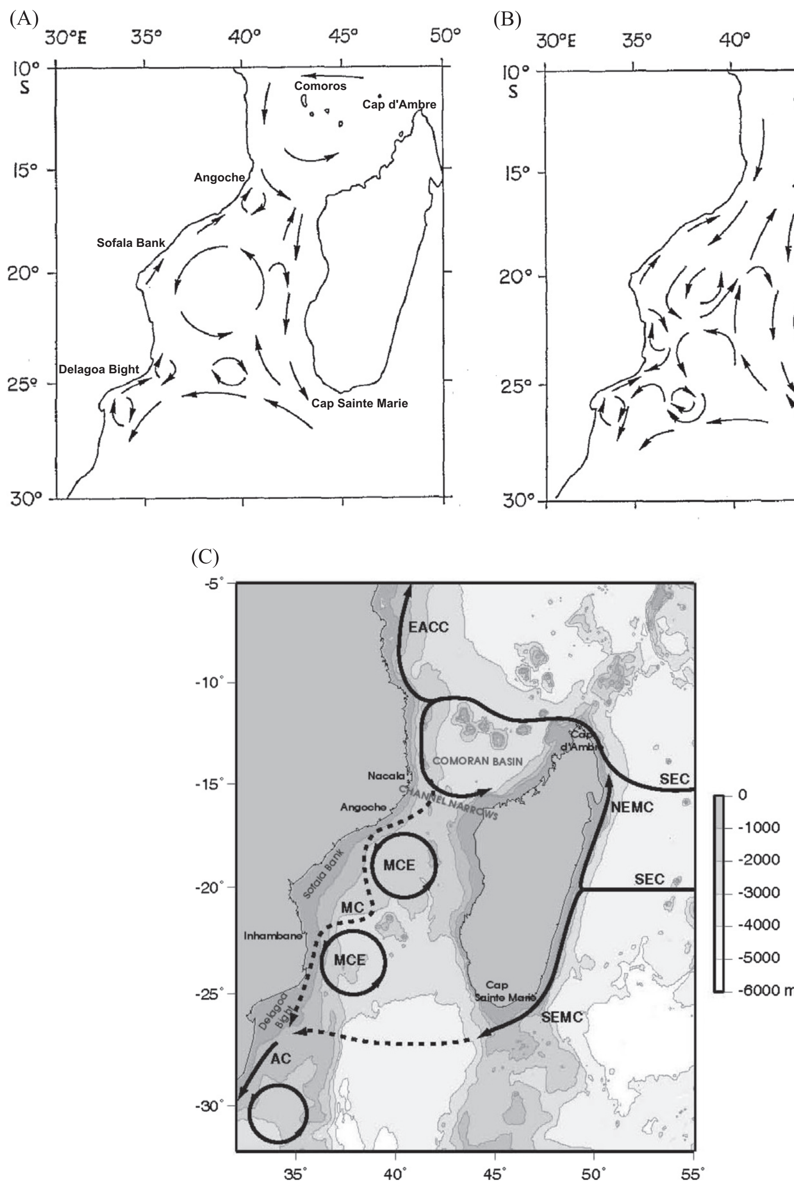

Fig. 1. Historical perspective of the circulation in the MZC, from Saerte and Jorge da Silva (1984) who proposed two schemes depending on the monsoon season: (A) northeast monsoon in austral summer, (B) southwest monsoon in austral winter, and (C) from Schouten et al. (2003), in a scheme dominated by the MZC eddies (MCE). Other currents include the South Equatorial Current (SEC), South East Madagascar Current (SEMC), North East Madagascar Current (NEMC), East African Coastal Current (EACC), and Agulhas Current (AC). Dotted lines stand for the uncertain Mozambique Current (MC) and for the unclear connection between the SEMC and AC. Geographic locations cited in the text are labelled. Bathymetry in (C) is featured in grey scale on the right.

within the Channel, some of them being quasi permanent (Fig. 1). They also depicted a northeastly coastal flow along the Sofala Bank for both seasons (Fig. 1). Accordingly, the semi-permanent cyclonic circulation near Angoche at 15°S (Lutjeharms, 2006) and in the Delagoa Bight (Quartly and Srokosz, 2004) appears to lead to a northward coastal flow. Donguy and Piton (1991), from the analysis of tide gauge records and hydrographic data, described a persistent anticyclonic gyre in the Comoran Basin (Fig. 1C), with seasonal and inter-annual variability in its intensity. However, they found that a strong southly flow exists across the narrows at ~16°S within the 0–500 m upper layer.

Mesoscale eddies have also been identified in the southern MZC, using surface drifter and hydrographic data. Gründlingh (1989) hypothesised that these features form locally near Madagascar and propagate westward, eventually reaching the Agulhas Current system (de Ruijter et al., 2004). Few observations have focused on the eastern side of the MZC. According to the circulation schemes of Saerte and Jorge da Silva (1984), the mean flow in the eastern MZC is southerly (Fig. 1) but Saerte (1985) indicated that the few observations available make this result questionable.

Modern cruises with high precision CTD and S-ADCP (Ship borne-Acoustic Doppler Current Profiler) instrumentation, as well as drifter deployments, have been conducted in this region since the mid-1990s (e.g. Di Marco et al., 2002; Chapman et al., 2003; De Ruijter et al., 2004; Swart et al., 2010). These technologies have allowed for a better description of the MZC circulation and confirmed that (1) the circulation in the MZC is highly variable and eddy driven, and (2) the variability of this circulation is remotely constrained by the basin-scale variability within the Indian Ocean. Moreover, the mesoscale dynamics in the Channel are forced by the South Equatorial Current (SEC) that splits upon reaching the east coast of Madagascar at ~12°S: The northern branch (North Madagascar Current—NMC) flows towards the equator and past the northern tip of Madagascar (Cap d'Ambre, 12°S) while the East Madagascar Current (EMC) flows south towards Cape Ste Marie (25°S) at the southern tip of Madagascar