THE WEST AUSTRALIAN INTEGRATED MARINE OBSERVATION SYSTEM (WAIMOS):INTERACTIONS BETWEEN THE LEEUWIN CURRENT AND THE CONTINENTAL SHELF

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ABSTRACT

A regional observation system located offshore south-west coast Australia to monitor the main boundary current, the Leeuwin Current and its impacts on shelf currents and associated ecosystems is described together with a summary of the current system in the region. The system consists of HF Radar (CODAR and WERA systems) for surface current measurements; Ocean gliders (Slocum and Seagliders) for subsurface water properties; continental shelf moorings (ADCP, thermistor and water quality loggers); passive acoustic sensors for whale monitoring; and, remotely sensed data products (SST and ocean colour) and is part of Australian Integrated Marine Observing System (IMOS).

INTRODUCTION

The West Australian Integrated Marine Observation System (WAIMOS) covers the continental shelf and slope regions offshore Fremantle extending northwards to Guilderton. WAIMOS is part of Australia's Integrated Marine Observation System (IMOS). Within this region there important topographic features such as the Rottnest Island and Perth Canyon and the circulation is dominated by the southward flowing Leeuwin Current (LC) with the northward flowing Leeuwin Undercurrent (LU) beneath the (LC) and the wind driven Capes Current (CC) located on the shelf, particularly during the summer months.

Leeuwin Current

The LC is a shallow (< 300 m) narrow band (< 100 km wide) of relatively warm, lower salinity water of tropical origin that flows southward, mainly above the continental slope from Exmouth to Cape Leeuwin [1, 8, 9]. The maximum flow of the current is located at about the 500m isobath. At Cape Leeuwin it pivots eastward, spreads onto the continental shelf and flows towards the Great Australian Bight. It is now accepted that the Leeuwin Current signature extends from North West Cape to Tasmania as the longest boundary current in the world [8].

The meridional pressure gradient in the southeast Indian Ocean, set up by the Indonesian Throughflow (ITF) in the tropics and by latent heat fluxes (cooling) in the mid-latitude, accounts for the existence of the LC. The source of the Leeuwin Current water is from the tropical/subtropical Indian Ocean from the west and a component from the North West continental shelf. The South East Trade Winds, in the Pacific Ocean, drive the South Equatorial Current westwards advecting warm surface waters towards Indonesia. This results in the flow of warm, low-salinity water from the western Pacific Ocean through the Indonesian Archipelago into tropical regions of the Indian Ocean. The lower density water (lower salinity, warmer) off the north-western Australia and higher density water (higher salinity, colder) off south-western Australia results in a surface slope between latitudes of 15°S and 35°S which is of the ~4 x 10^{-7} (from north to south), corresponding to a sea level difference of 0.55 m between North West Cape and Cape Leeuwin.

During October to March the Leeuwin Current is weaker as it flows against the maximum southerly winds, whereas between April and August the Current is stronger as the southerly winds are weaker [4]. The LC has weaker transport (~1.5 Sv; 1 Sv = 10^6 m^3s^{-1}) during October–March (summer) and stronger transport (up to 7 Sv) in winter season [9]. The mean volume transport is estimated to be 3.4 Sv [2]. The location of the 'core' of the current also changes seasonally – in winter the core of the current located close to 200m contour whilst under the action of the southerly wind stress, the Current is pushed offshore.

The Leeuwin Undercurrent

Thompson [10] indicated that there was an equatorward undercurrent flowing beneath the Leeuwin Current. Current meter data from the LUCIE experiment (Leeuwin Current Inter-disciplinary Experiment, [9]) confirmed the observations of Thompson [10] and indicated that the equatorward undercurrent was narrow and situated between 250 m and 450 m depth contours, adjacent to the continental slope.

The LU is driven by an equatorward geopotential gradient located at the depth of the Undercurrent [10,11]. The LUC is closely associated with the sub-Antarctic mode water (SAMW) formed in the region to the south of Australia. A feature of this water mass, resulting from convection, is high, dissolved oxygen concentration; thus the core of the LUC can be identified from the dissolved oxygen distribution: a dissolved oxygen maximum (252 μM/L) centred at a depth of approximately 400 m [11].

The Capes Current

Pearce and Pattiaratchi [6] defined the Capes current as a cool inner shelf current, originating from the region between Capes Leeuwin (34° S) and Naturaliste, which flows equatorward along the south-western Australian coast in summer and extends northwards past the Abrolhos Islands. The Capes current seems to be well established around November, when winds in the region become mostly southerly because of the strong sea breezes [5], and continues until about March when the sea breezes weaken. Gersbach et al. [3] showed the Capes current source water was from upwelling between Capes Leeuwin and Naturaliste, which was augmented by water from the south to the east of Cape Leeuwin.

Gersbach et al. [3] described the dynamics of the Capes current, off Cape Mentelle. The continental shelf in Australia's south-west comprises a step structure, with an inner shelf break at 50 m and an outer shelf break at 200 m [6]. This bathymetry influences the circulation, especially in the summer. In the summer, the alongshore wind stress overwhelms the alongshore pressure gradient on the inner shelf (depths < 50 m), moving surface layers offshore, upwelling colder water onto the continental shelf, and pushing the Leeuwin current offshore. Here, the Capes current is present on the inner shelf and bounded offshore by the Leeuwin current on the lower shelf, with upwelling occurring over the inner shelf break [3]. Numerical model results showed a wind speed of 7.5 ms^{-1} was sufficient to overcome the alongshore pressure gradient on the inner continental shelf [3]. The Leeuwin current strengthens in the winter, and, in the absence of wind stress, migrate closer inshore, flooding upper and lower terraces [6].

The Perth Canyon

The Perth Canyon is an extension of the Swan River system, and cuts into the continental shelf west of Perth and Rottnest Island: it begins at the 50-m contour and is ~100 km long and ~10 km wide near the canyon head, and reaches depths more than 4000 m. It is 3 km deep at the shelf slope, and cuts 4 km deep into the continental slope. The interaction between the Leeuwin undercurrent and the canyon generates clockwise eddies within the canyon resulting in upwelling at their centre [7]. As a result of these circulation patterns within the canyon, the canyon supports a high primary and secondary production resulting in the whale (pygmy blue whales) aggregation during the summer months [7].

THE OBSERVATION SYSTEM

The infrastructure located in this region includes HF Radar (CODAR and WERA systems) for surface current measurements at 2 different scales; Ocean gliders (Slocum and Seagliders) for subsurface water properties; continental shelf moorings (ADCP, thermistor and water quality loggers); passive acoustic sensors for whale monitoring; and, remotely sensed data products (SST and ocean colour).

Here we present two examples of data obtained from the observation system.

Two CODAR Seasonde stations were deployed at Cervantes and Seabird in March 2009 to provide surface current maps of the Leeuwin Current (LC) and inshore current systems. Data obtained on 7 May 2009 is presented on Figure 1 overlain on a sea surface temperature image of the same date. The LC can be identified from its warm (red) signature flowing from north to south. To the north there is inflow from the west due to a large eddy located to the north of the study region and is reflected by the currents derived from HF Radar (Figure 1). Within the main core of the LC the strongest currents may be seen although the higher currents extend offshore of the region shown contain the highest temperatures. The maximum currents, within the LC reach 0.8 ms^{-1}. Closer to the coast the currents are weaker but follow the meandering nature of inner boundary of the LC (Figure 1).

Slocum glider tracks have been undertaken along a cross-shelf transect almost continuously since January 2009 and enables the time variability of the shelf system to be documented. Due to the low tidal range, the shelf currents are mainly wind driven except during periods when the LC may be present on the shelf. The region experiences a Mediterranean climate with hot summers and cold winters. During the summer months the inner continental shelf waters increases in salinity due to evaporation. This results in the nearshore waters having a higher density. Slocum glider tracks have clearly shown the development of these gravity currents (Figure 2). In February, the evaporation is at a maximum and due to differences in water depth across the continental shelf the shallow waters increase in salinity when compared to those offshore (Figure 2a). By March, with additional evaporation, the salinity has increased significantly when compared to that further offshore and the higher salinity water starts to exit the shelf. On 14th

March the plume is located at mid-shelf (Figure 2b) and by 21st March (Figure 2c) the plume extends across the whole shelf and occupies the bottom 20m of the water column. By April the salinity has decreased but the plume is still present across the shelf (Figure 2d). In May the overall salinity of the shelf has decreased, due to the advection of lower salinity water by the LC, however, the higher salinity plume is still present along the entire continental shelf (Figure 2e). With winter cooling the higher density waters are maintained along the shelf and the gravitational circulation is present well into the winter months penetrating to depths up to 150 m water depths.

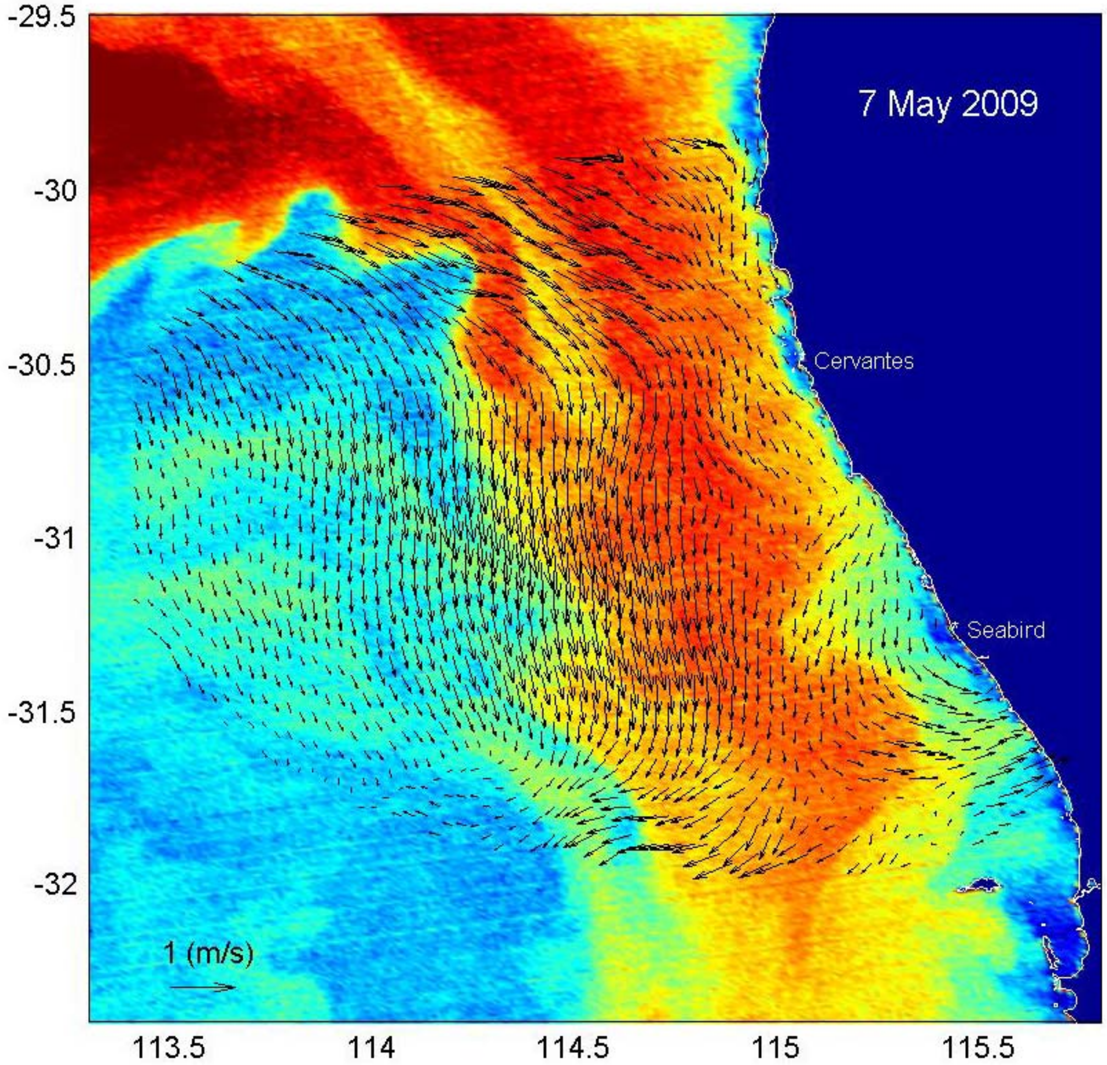

Figure 1- Surface currents derived from CODAR Seasonde stations at Cervantes and Seabird on 7 May 2009 overlain on a sea surface temperature map of the sam date.

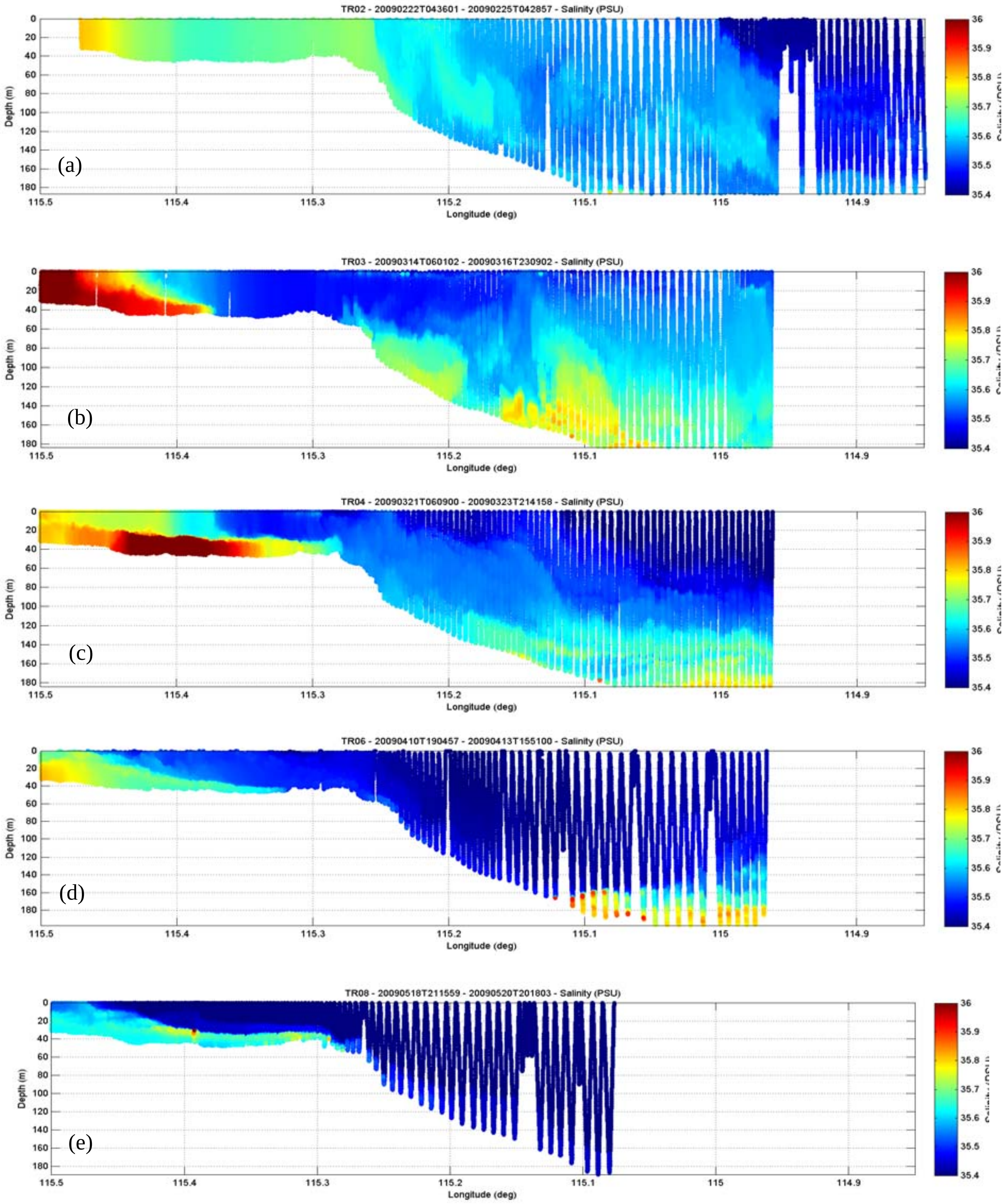

Figure 2- Cross-shore transects of salinity along the Two Rocks transect showing higher salinity plumes existing the shelf. (a) 22 February 2009; (b) 14 March 2009; (c) 21 March 2009; (d) 10 April 2009; and, (e) 18 May 2009

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