OCEANOGRAPHIC OBSERVATIONS OF THE AUSTRALIAN CONTINENTAL SHELF AND SLOPE WATERS USING AUTONOMOUS OCEAN GLIDERS

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ABSTRACT

Ocean gliders are autonomous vehicles designed to operate in water depths up to 1000 m. By changing its buoyancy, the glider is able to descend and ascend. The Australian National Facility for Ocean Gliders (ANFOG) has been established as part of the Integrated Marine Observation System (IMOS) for Australia. ANFOG will develop a fleet of gliders using two different types of gliders. The Slocum glider is designed to operate to a maximum depth of 200m whilst the Seaglider is able to operate to a maximum depth of 1000m. Both gliders have the same suite of sensors to measure conductivity (for salinity), temperature, dissolved oxygen, fluorescence, turbidity and CDOM (dissolved organic matter) with depth. In this paper, operation of the ocean gliders will be highlighted using deployments from the entrance to Spencer Gulf; shelf waters off Sydney (NSW) and Fremantle (WA) and, shelf and slope waters off Tasmania.

INTRODUCTION

Oceanographic sampling has been traditionally undertaken using ships; however the high costs of operating a research vessel of the order of $50,000 per day and limitations of working in adverse weather conditions have resulted in difficulties in data collection in particular where sustained observations are required to examine long-term variability. Ocean gliders provide an alternative measurement platform and, due to their relatively low cost and extended deployment durations, allow for the collection of sustained long term observations, even during periods of extreme weather conditions. These data sets enable researchers to document the natural variability of the ocean and coastal ecosystems. The Australian National Facility for Ocean Gliders (ANFOG) has been set up as facility within the Australian Integrated Marine Observation System (IMOS) and provides a near-real time data stream from the continental shelf and slope waters of Australia. In particular, the gliders sample the main boundary current systems around Australia: East Australia Current along the east coast; the Leeuwin Current along the west coast and the Flinders current along the south coast.

Ocean gliders are autonomous vehicles designed to operate in water depths up to 1000 m. By changing its buoyancy, the glider is able to descend and ascend. This momentum is converted to forward motion by its wings. Pitch adjustments are made by moving an internal mass (battery pack) and steering is done using a rudder and/or battery packs. Moving at an average horizontal velocity of 0.25 – 0.40 ms^{-1} the glider navigates its way to a series of pre-programmed waypoints using GPS, internal dead reckoning and altimeter measurements. The gliders are programmed to provide data through satellite communication when it is at the surface and it is also possible to control the path of the glider during its mission. Depending on the type of glider (Table 1) and the number of vertical 'dives', the endurance of a glider ranges between 1 and 6 months. ANFOG currently has a fleet of 9 gliders (with 6 additional gliders on order) using two different types of gliders. The Slocum glider, manufactured by Webb Research (US) is designed to operate to a maximum depth of 200m and a maximum endurance of 30 days, whilst the Seaglider, manufactured by the University of Washington and iRobot is able to operate to a maximum depth of 1000m and a maximum endurance time of up to 6 months (Table 1). The gliders have a suite of sensors to record temperature, salinity, dissolved oxygen, turbidity, dissolved organic matter and chlorophyll fluorescence. Currently, the Slocum gliders are instrumented with a Seabird-CTD, WETLabs BBFL2SLO 3 parameter optical sensor (measuring Chlorophyll-a fluorescence, CDOM & 660nm Backscatter) and an Aanderaa Oxygen optode. The Seagliders are equipped with a Seabird-CTD, WETLabs BBFL2VMT 3 parameter optical sensor (measuring Chlorophyll-a fluorescence, CDOM & 660nm Backscatter) and a Seabird Oxygen sensor. ANFOG has deployed ocean gliders at the entrance to Spencer Gulf, a hyper saline gulf along the south coast of Australia; shelf waters off Sydney (NSW) and Fremantle (WA) and, shelf and slope waters off Tasmania.

Table 1: Glider specifications

	Slocum	Seaglider
Type	Coastal	Open Ocean
Depth Range	20-200m	Up to 1000m
Length	1.8 m (2.15 m inc. antenna)	1.8 m (2.85 m inc. antenna)
Mass	52 kg	52 kg
Batteries	250 Alkaline C-Cells Energy:8 MJ Mass: 18kg	81 Lithium D-Cells (in 2 packs) Energy: 10 MJ Mass: 9.4kg
Volume Change	Max 460 cc	Max 840 cc
Communication	Iridium GPS Navigation Freewave RF-modem (30km range) ARGOS transmitter	Iridium GPS Navigation
Steering	Active rudder	Rotating internal mass
Endurance	30 days	6 months (650 dives to 1000m)
Range	500 km	4600 km
Speed	40 cm/sec	25 cm/sec

Between November 2008 and September 2009 ANFOG has completed 12 successful Slocum glider deployments (Table 2). During this time the Slocum gliders traversed more than 5500 km and collected over 32,000 vertical profiles of oceanographic data.

Table 2: Slocum deployment summary (June 2009)

Glider	Project	Location	Date Deployed	Date recovered	Duration	Distance	Casts
unit109	NSWIMOS	Port Stephens, NSW	25-Nov-08	11-Dec-08	16 days	1002.8 km	1484
unit104	SAIMOS	Marion Bay, SA	15-Jan-09	05-Feb-09	21 days	518.4 km	3594
unit106	WAIMOS	Fremantle, WA	20-Jan-09	10-Feb-09	21 days	486.9 km	2937
unit106	WAIMOS	Fremantle, WA	20-Feb-09	13-Mar-09	21 days	445.0 km	3225
unit104	WAIMOS	Fremantle, WA	13-Mar-09	27-Mar-09	14 days	347.6 km	2232
unit109	NSWIMOS	Harrington, NSW	17-Mar-09	09-Apr-09	23 days	705.6 km	1721
unit104	WAIMOS	Fremantle, WA	02-Apr-09	27-Apr-09	25 days	517.3 km	3939
unit109	WAIMOS	Fremantle, WA	15-May-09	03-Jun-09	19 days	380.0 km	4300
unit104	SAIMOS	Marion Bay, SA	28-May-09	24-Jun-09	27 days	600.0 km	3712
unit130	WAIMOS	Fremantle, WA	03-Jun-09	25-Jun-09	22 days	459.4 km	3914
				TOTAL	209 days	5463 km	31058

Three Seaglider deployments have been completed, off Tasmania (Figure 1d) and South Australia a total of 2075 km during their 123 days at sea and collected (Table 3).

Table 3: Seagldier deployment summary (June 2009)

Glider	Project	Location	Date Deployed	Date recovered	Duration	Distance	Casts
SG154	BLUEWATER	Maria Island, TAS	13-Feb-09	14-Apr-09	60 days	1200 km	860
SG151	BLUEWATER	Bicheno, TAS	22-Apr-09	24-Jun-09	63 days	875 km	1060
SG155	SAIMOS	Portland, VIC	26-May-09	*	30 days*	410 km*	450*
				TOTAL	213 days	2485 km	2350

* Deployment in progress

Spencer Gulf is a reverse estuary located along the south coast of Australia (Figure 1a). High evaporation in the upper reaches of the estuary results in the formation of a high salinity water mass which exists the Gulf as a gravity current which is modulated by the spring/neap tidal cycle. In Spencer Gulf, the general water circulation is clockwise, with shelf waters flowing into the gulf along the western coast and the outflow is generally confined to the eastern side. The outflow flows out the mouth of the gulf and across the continental shelf. Sea surface temperature fronts are usually present along the entrance of the Gulf. Ocean glider data obtained at the entrance to the Bay in January 2009 did not indicate a constant near bed outflow of water: higher salinity water was present at mid-depth and was modulated by the tidal cycle.

The shelf waters of Sydney are influenced by the East Australian current (EAC), the western boundary current of the South Pacific subtropical gyre that affects the flow along much of the eastern coasts of Australia and New Zealand. Extending from the Coral Sea to the Tasman Sea, the EAC system generates numerous eddies. EAC transport (southward flow) varies between a minimum of 7 Sv in winter (July) to a maximum of 16 Sv in summer. A Slocum glider was used to monitor the physical and biological processes within a warm core eddy in November 2008 and revealed strong physical/biological interaction. The glider was flown into the centre of the eddy, and then back out again while undertaking one rotation of the eddy (Figure 1b). After deployment off Port Stephens, the glider was transported by the EAC southwards parallel to the coast. The temperature record shows colder water associated with high CDOM and backscatter and is postulated to be due to upwelling of slope water onto the shelf (Figure 2a). The warm core eddy contained a generally well mixed surface layer of 50-70 m depth. A sub-surface chlorophyll maximum was observed just below the thermocline with chlorophyll concentrations approximately an order of magnitude greater than observed in the rest of the water column (Figure 2a).

The circulation off the west Australian coast is different to that of other western continental margins. In each of the main ocean basins, the surface circulation forms a gyre with a poleward flow along the western margin of the basin and a gyre with an equatorward flow along the eastern margin. The eastern margins (off south America and south Africa, for example) are also areas of high productivity due to upwelling, except off the west Australian coast where the Leeuwin Current (LC) transports water poleward. The LC is a shallow (< 300-m-deep), narrow (< 100-km-wide) band of warm, low salinity, nutrient-depleted water of tropical origin, which flows poleward from Exmouth to Cape Leeuwin and into the Great Australian Bight. The LC signature extends from North West Cape to Tasmania as the longest boundary current in the world. The continental shelf waters off Fremantle are influences by the southward flowing warmer, lower salinity Leeuwin current generally located along the 200m isobath and during the summer months the Capes current, a colder wind driven current generally located inshore of the 50m isobath. The Capes current, has a higher productivity due to upwelling. Slocum missions have monitored the both these current systems with crossshore transects undertaken weekly to fortnightly. The glider data clearly identified the interaction between these two current systems (Figure 2b). The Fremantle 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 shown that in late summer, the higher density water exit the continental shelf as a gravity current which is ~20m thick in water depths of 40m. 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.

The Seaglider deployments off eastern Tasmania monitored the East Australian current in this region – the glider was entrained into an eddy and revealed very strong currents within the region (Figure 1d).

ACKNOWLEDGEMENTS

IMOS is supported by the Australian Government through the National Collaborative Research Infrastructure Strategy and the Super Science Initiative.

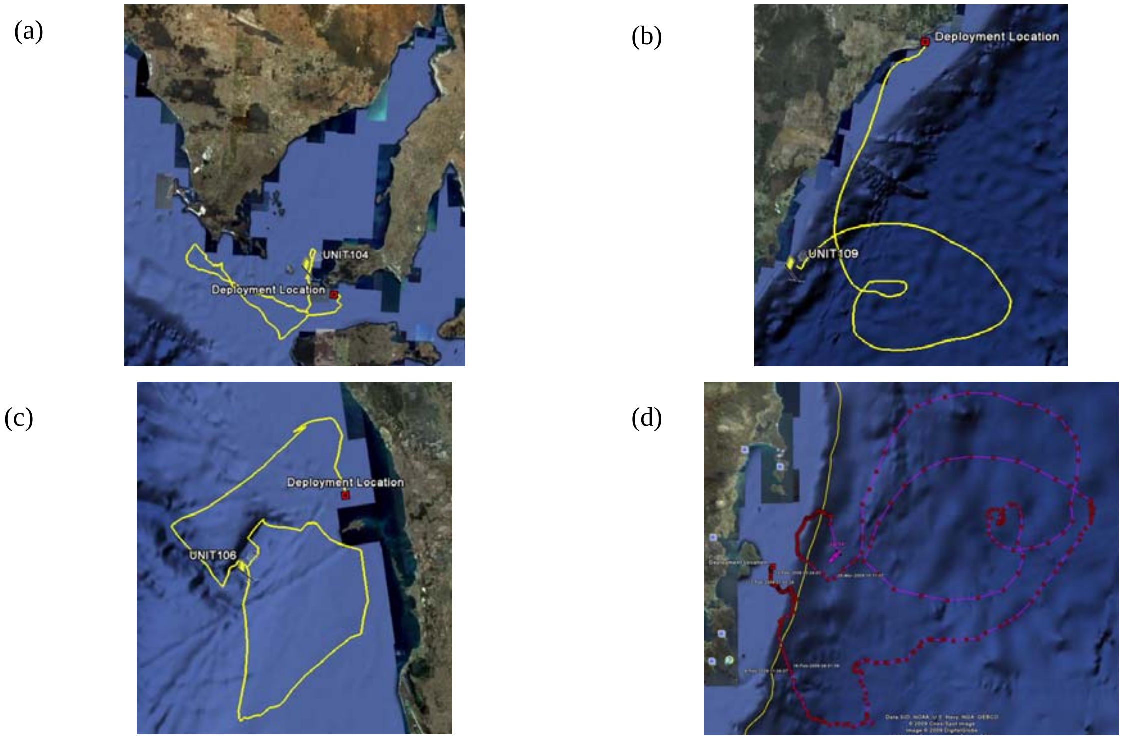

Figure 1- Glider tracks: (a) Entrance to Spencer Gulf, South Australia; (b) Continental shelf off Sydney; (c) Continental shelf and slope off Fremantle; and (d) continental shelf and slope waters off eastern Tasmania.

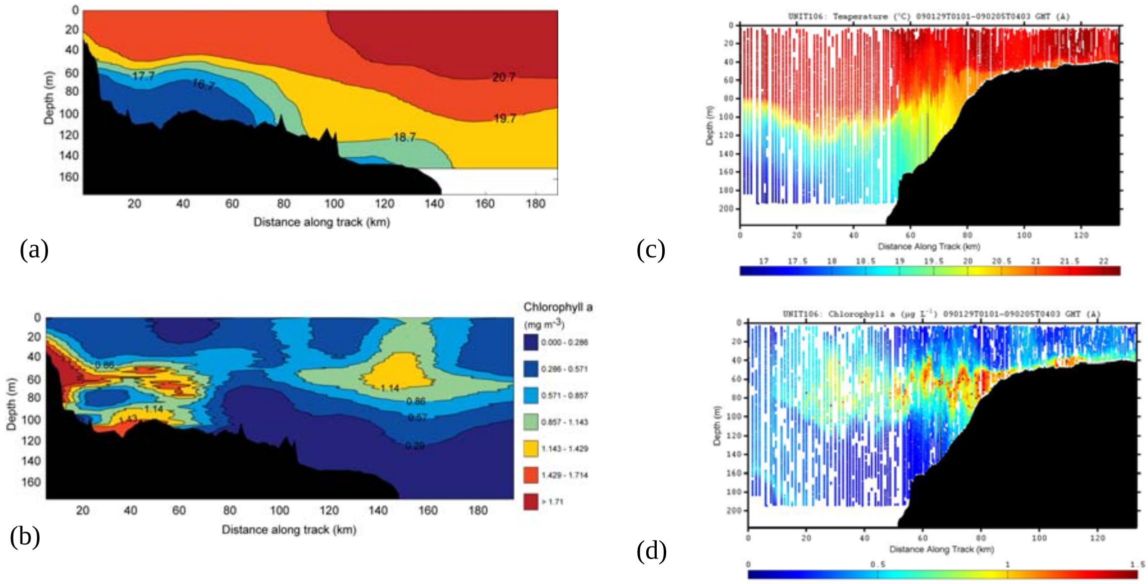

Figure 2- Temperature and Chlorophyll transects along the continental shelf off (a) Sydney; (b) Fremantle