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Ocean Glider Observations Around Australia

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INTRODUCTION

Autonomous ocean gliders have become an integral component of ocean observation systems, and their use is increasing globally (Liblik et al., 2016; Rudnick, 2016). Gliders are typically deployed over periods of weeks to months, operate under a wide range of weather conditions, and provide high spatial and temporal resolution measurements (Glenn et al., 2016). Ocean glider deployments in Australia commenced in 2007 with the establishment of the Australian National Facility for Ocean Gliders (ANFOG) as part of the Integrated Marine Observing System (IMOS). This paper summarizes the development of a single facility covering all aspects of glider operations in Australia and a decade of operation.

IMOS (http://www.imos.org.au) was established in 2006 by the Australian Government to develop an integrated national system for multidisciplinary ocean observing (Hill et al., 2010). It includes infrastructure facilities that acquire and provide free, open, and timely access to data for use by the Australian and global ocean science communities. IMOS observations are guided by science planning and are undertaken collaboratively across the scientific community with input from government, industry, and other stakeholders.

AUSTRALIAN NATIONAL FACILITY FOR OCEAN GLIDERS

ANFOG (http://anfog.ecm.uwa.edu.au) is the facility within IMOS that operates the Australian ocean glider fleet in Australian waters (Figure 1). This ANFOG glider fleet consists of: (1) Teledyne Webb Research Slocum gliders (Webb et al., 2001) deployed mainly on continental shelf waters, and (2) Seagliders (Eriksen and Perry, 2009) deployed in deeper waters. All ANFOG gliders are equipped with similar suites of sensors that include a Sea-Bird CTD (pumped and non-pumped), a WET Labs Eco puck three-parameter optical sensor (measuring chlorophyll *a* fluorescence, chromophoric dissolved organic matter [CDOM], and particle backscatter), and a dissolved oxygen sensor (Aanderaa optode for Slocum and Sea-Bird SBE 43 for Seagliders). The Slocum gliders are also equipped with a Satlantic four-channel downwelling irradiance sensor.

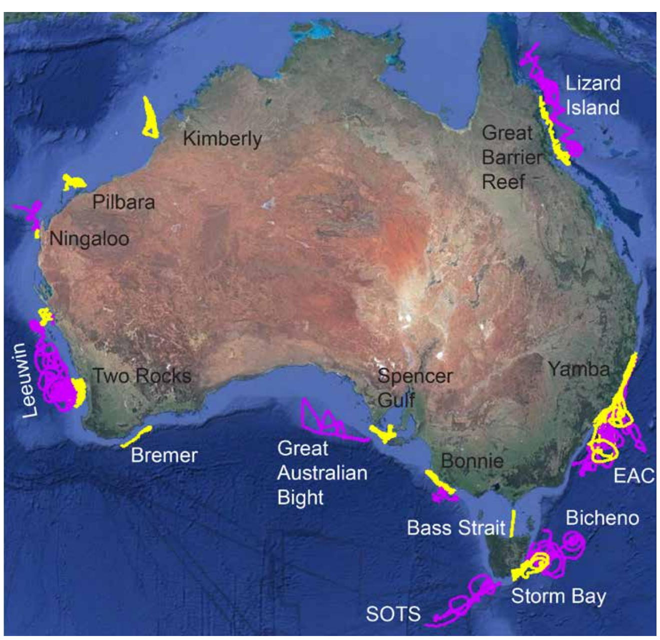

FIGURE 1. Locations and tracks of ocean glider deployments around Australia. Yellow tracks indicate repeat Slocum glider and magenta tracks repeat Seaglider missions.

DATA MANAGEMENT AND VISUALIZATION

IMOS data streams are provided in NetCDF-4 format, with ocean glider data files containing metadata and scientific data for a single glider mission. Data transmitted by the gliders via the Iridium satellite communications system are subject to QA/QC procedures prior to being available to users through the IMOS portal (Woo, 2017). The ANFOG data processing pathway is in two phases: (1) near-real time (NRT) where after the glider transmits the data to the base station, a subset of the data is available in digital and graphical mode (http://www.anfog.uwa.edu.au), and (2) delayed mode (DM), subsequent to glider recovery, when the full data set is subject to QA/QC procedures (Woo, 2017). ANFOG has also developed *GLIDERSCOPE,* a software package for visualization of ocean glider data via a graphical user interface (Hanson et al., 2017, in this issue). *GLIDERSCOPE* allows users to easily access NetCDF files and apply a variety of graphical visualization techniques to examine the data and export it for use in other applications.

OPERATIONAL CHALLENGES

We have encountered two main challenges in the operation of ocean gliders in Australian waters. First, biofouling that can compromise glider flight as well as data quality has been severe during southeast Australia Seaglider deployments (SOTS and Bicheno in Figure 1); gooseneck barnacles affected CTD and bio-optical data quality and made piloting challenging. Also, biofilm forms on the optical sensors toward the end of missions, but this can be easily identified through diurnal changes in dissolved oxygen and in fluctuating fluorescence. Second, the biggest challenge to both the Slocum and Seaglider deployments is shark attacks. ANFOG has evidence of shark attacks across the entire deployment region, except in the southeast (Figure 1). Although some attacks were identified through bite marks on the hull, others were evident in damaged wings, which required emergency recovery. In extreme cases, damaged sensors (CTD and optical) and hull cases required replacement.

SCIENCE HIGHLIGHTS

ANFOG glider data have contributed to many studies of shelf and offshore processes around Australia. These include: (1) physical and biogeochemical studies of offshore eddies (Baird et al., 2011), (2) characterization of internal tides and sediment resuspension (Boettger et al., 2015; Pattiaratchi and De Oliveira, 2016), and (3) examination of the influence of the East Australian Current on shelf dynamics (Schaeffer and Roughan, 2015). Schaeffer et al. (2016) compiled a shelf climatology using Slocum glider data, and Jones et al. (2012) assimilated glider data into a coastal model.

The importance of spatial and temporal data obtained from ocean gliders may best be illustrated through the discovery of dense shelf water cascades (DSWC) on the continental shelves around Australia (Pattiaratchi et al., 2011; Mahjabin et al.,

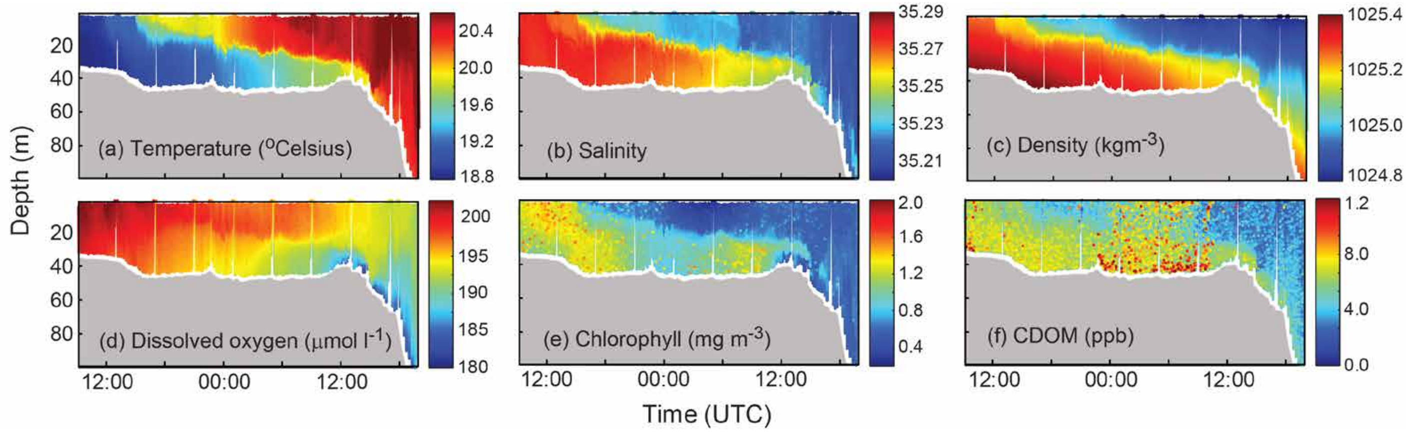

FIGURE 2. Example of a dense shelf water cascade. Cross-shelf transects of (a) temperature, (b) salinity, (c) volume backscatter coefficient (VBSC), (d) dissolved oxygen, (e) chlorophyll, and (f) chromophoric dissolved organic matter (CDOM). The transect was acquired between 0900 on August 14, 2014, and 0500 on August 16, 2014, along Two Rocks (Figure 1).

2016). Dense shelf water is formed when a decrease in temperature through cooling and/or an increase in salinity from evaporation increases the density of the inner shelf water (compared to that offshore). The horizontal density gradient drives a circulation characterized by offshore transport of denser water along the seabed, defined as DSWC (Figure 2). The glider missions revealed that DSWC were present in all Slocum deployment regions (irrespective of high tidal and/or wind mixing), except around Tasmania (Figure 1). Glider data recorded cooler and more saline water exiting the continental shelf along the seabed (Figure 2). Optical data showed that the distributions of chlorophyll, backscatter (proxy for suspended matter), and CDOM were similar to those of temperature and salinity, that is, elevated in the offshore-directed bottom water (Figure 2). Dissolved oxygen distribution also registered a decrease in regions of strong vertical stratification. Thus, the DSWC appear to play a major role in the cross-shelf exchange of water and suspended matter.

The IMOS/ANFOG glider program has been extremely successful over the past decade. Data from 225 glider missions undertaken between June 2008 and May 2017 are available through the IMOS data portal (https://portal.aodn.org.au). This represents ~6,400 glider days in the water traveling ~150,000 km (Figure 1). The missions include 185 Slocum and 43 Seaglider deployments.

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