OceanGliders Boundary Ocean Observing Network

Society experiences the changes in the global ocean through the ocean's boundaries. These boundary regions are the nexus of societal use of the ocean for fisheries, transportation, and recreation. The boundary regions are also the regions of the most intense currents in the ocean that are key to the transport of mass, heat, salt, biogeochemical variables and plankton. In the large ocean basins, the western boundary currents dominate the poleward transport of warm water or equatorward transport of cold water and are major drivers of climate variability. The eastern boundary currents are often upwelling systems that comprise some of the most biologically productive regions in the world. Boundary currents in marginal seas provide the major means of exchange with the open ocean and impact regional ecosystems. Finally, the communication between the coast and open ocean is regulated by the boundary currents that flow along the continental slopes, affecting ecosystems, flood levels, erosion and commercial activity. To summarize, there is a great need for sustained observations of these highly dynamic boundary current regions. To uniquely address this need, we propose a global network of underwater gliders to uniquely address this need within a multi-platform observing system.

Autonomous underwater gliders developed over the last several years, and now operated routinely, offer sustained fine resolution observations in both the coastal and open ocean. In typical use gliders profile from the surface to 500-1000 m, taking 3-6 h to complete a cycle from the surface to depth and back. During the cycle the gliders travel 3-6 km in the horizontal for a speed of about 1 km/h. Deployments of 3-6 months are now routine, during which time the glider's survey track extends well over 2000 km. In a few minutes at the surface, gliders obtain location by GPS and communicate data through the Iridium satellite phone system. Sensors on gliders measure such physical variables as pressure, temperature, salinity and current, and biological variables relevant to the abundance of phytoplankton and zooplankton, and also ecologically important chemical variables such as dissolved oxygen, carbon dioxide and nitrate. As pH sensors mature, gliders will provide excellent platforms for monitoring ocean acidification. Gliders may be deployed and recovered from a wide range of platforms, including small boats and chartered fishing vessels.

The data provided by underwater gliders are a natural match for regional models of coastal ocean circulation. These regional models are necessary, as the currents and water properties in the coastal ocean vary on the relatively small scales set by topography. Accurate forecasting depends on initialization on these small scales, which can be satisfied by a network of gliders. From their earliest conception, underwater gliders were viewed as components of observing/modeling systems, and progress over the past decade has proven the efficacy of this approach.

There are now a number of sustained regional glider lines and networks, summarized here.

- The California Underwater Glider Network has occupied three lines in the California Current System for the past decade with a primary goal of monitoring the regional effect of climate variability as, for example, caused by El Niño. A fourth line off northern California has been occupied for two years.
- Sections across the California Current, immediately south of the West Wind Drift bifurcation region, were occupied continuously from 2003-2009, and then

annually, for 6-9 months per year, from 2010-2015. These observations provide data to advance understanding of the regional response to climate variability.

- The Ocean Observatories Initiative began occupying 5 sections off Oregon and Washington, starting in 2014 to address the influence of climate variability on eastern boundary ecosystems. One of these lines, off Oregon, has been occupied continuously since spring 2006.
- Repeated sections across Solomon Sea have been made for nearly a decade to monitor the low latitude western boundary current that feeds the Pacific equatorial current system from the Southern Hemisphere.
- In the Western Mediterranean repeat glider transects have been undertaken to monitor the variability of the Northern Current System, over 8 years in the north of the basin by CNRS (France) and for 6 years by SOCIB (Spain) at a circulation 'choke' point.
- The Norwegian Atlantic Current Observatory has undertaken long term glider monitoring across 2 transects over 4 years, monitoring northward flow to the Arctic regions.
- Along the East Coast of the United States, a program of routine glider surveys across the Gulf Stream is underway. Commanded to steer across strong currents of the western boundary current, gliders are able to occupy cross-Gulf Stream transects as they are advected downstream.
- European Slope Current at 56.5N as part of the sustained Ellett Line programme. Gliders have been occupying this section in winter since 2009, and several times per year since 2015.
- Eastern Branch of the North Atlantic Current ~57N west of the Rockall/Hatton Plateau under the UK OSNAP programme from 2015. This is a boundary current on the western flank of the Rockall/Hatton Plateau, transporting a significant portion of the NAC.

In addition, there are several proposed and planned efforts.

- Repeated sections from southern Vancouver Island to Station PAPA, called Line P, will be used to supplement a triannual ship-based monitoring program. This line connects the site of the OOI and NOAA open ocean moorings to the coast.
- The Canadian Atlantic Zone Monitoring Program conducts several ship-based sections from the coast to off the shelf several times a year. Gliders will be used to supplement these sections starting first with a section near Halifax, Nova Scotia.
- Repeated sections across the Kuroshio, off Taiwan and Luzon, were occupied continuously from 2011-2013 to document variability and watermass modification within the western boundary current immediately downstream of its formation region. Measurements will resume in 2017, with plans for sustained occupation of a line east of Taiwan.
- Repeated sections in the Agulhas Current to follow up on the Shelf Agulhas Glider Experiment (SAGE) conducted in 2015. The glider sections will supplement observations from the Agulhas System Climate Array (ASCA) and coastal monitoring efforts near 34^{o}S, to improve our understanding the Agulhas Current variability and its interactions with the coastal and shelf regions.

- Repeated sections in the East Australian Current (EAC) using the Australian Integrated Marine Observing System (IMOS) assets to conduct an experiment in measuring the EAC with gliders during 2017-19 in conjuction with the IMOS EAC mooring array. The objective is to understand what role gliders can play along with other technologies in cost effective monitoring of this western boundary current.
- One glider transect between Key West and North Florida, to be repeated regularly, will provide continuous information on the varying temperature, salinity, and transport values of the Florida Current. This will complement observations already in place including XBT and CTD casts, and cable measurements. The objective is to observe the causes of sea level changes on the Southeast Florida coast, including the location and intensity of the Florida Current, warming of surface and subsurface currents, and westward propagating waves.

The intention of the OceanGliders Boundary Ocean Observing Network (BOON) is to provide coordination and linkage for a global observing program. Because boundary currents invariably reside in EEZs, their observation must depend on regional efforts respectful of the coastal countries. The regional networks that comprise BOON will have the intention that their observations be sustained year-round. The regional networks will publish data in near-real time on the GTS and in CF compliant formats to a central data assembly center. One of the benefits of coordination will be improved and sustained quality control of glider data. The ultimate realization will be a global network of regional networks that monitor boundary current variability across international borders to the world's benefit.

The OceanGliders BOON complements existing ocean observing networks. Argo has transformed ocean sciences with its global coverage of the ocean. BOON connects Argo's observations of the open ocean with the coastal ocean by providing the higher profile density and cross current transects that boundary currents require. OceanSites moorings are anchors of quality high frequency measurements of many variables. BOON expands the footprint of OceanSites by repeated sections that may connect to mooring locations. Repeated surveys by ships form the backbone for many existing regional efforts, in some cases going back decades. BOON will step change our ability to observe boundary current variability in real-time, across all seasons and in difficult conditions and locations, building on the historical record and improving temporal and spatial resolution by overlapping with these ship surveys. A focus of BOON will be to identify gaps in the observation of boundary currents, with the goal of filling them by the most appropriate technology.

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