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The Scottish Marine Robotics Facility: Use of unmanned vehicles for environmental measurement, monitoring and decision making

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Abstract: Advances in marine technology are essential to allow us to study the marine environment on which life on our planet depends. The Scottish Association for Marine Science is the world's largest independent marine research organisation with a long history in marine technology development. In 2015, the institute announced the opening of its new marine robotics facility. The facility pools together a broad range of technology's spanning deep sea, coastal, surface and aerial platforms. The facility specialises in the integration of new and novel technologies into fundamental marine research to improve measurement, monitoring and decision making. Each case study presented in this paper highlights the importance of autonomous systems within marine research, the diversity of applications being developed within the robotics facility, and the significance of science communities working in conjunction with technology developers to test, evaluate and support autonomous system development.

Keywords: Autonomous Vehicles, Co-operation, Data, Ecology, Marine Systems, Monitoring

1. INTRODUCTION

The Scottish Marine Robotics Facility (Scot-MRF), based at the Scottish Association for Marine Science (SAMS), was formed in 2015. Scot-MRF is a science led facility, drawing on existing expertise in using cutting-edge technologies to answer pressing environmental science questions. Unique in the UK, the facility applies an exceptional range of robotic capabilities to support academic, regulatory or commercial projects. From aerial mapping, to surface fluxes and the properties of deep water. In this paper we present four case studies from Scot-MRF, highlighting the adoption of unmanned systems in environmental measurement, monitoring and decision making in marine science.

2. LONG-TERM OCEANOGRAPHIC MONITORING

Scot-MRF plays host to the North Atlantic Glider Base (NAGB). NAGB is part of a world leading programme to support and develop the scientific application of robotic technologies. Since its formation in 2009, NAGB has reinforced a number of renowned national and international oceanographic research programmes including; Fluxes Across Sloping Topography of the North East aTlantic (FASTNET), the Extended Ellet Line (EEL), and, more recently, the Overturning in the Subpolar North Atlantic Program (UK-OSNAP). Through these programmes, NAGB has developed novel observational techniques, combining autonomous robotic systems with more traditional ocean monitoring tools i.e. fixed moorings and CTD transects) (Sherwin *et al*., 2014).

Located on the west coast of Scotland, NAGB is perfectly positioned to provide access to the UK continental shelf edge, and the wider north Atlantic. NAGB operates a fleet of seven deep water (1000m) Seagliders. Funded through Natural Environment Research Council (NERC) national capability, NAGB is part of the Marine Autonomous Robotic Systems (MARS) group, acting as the centre for deep water glider operations across the UK.

2.1 Case Study: UK-OSNAP

UK-OSNAP is part of an international collaboration to establish a transoceanic observing system in the subpolar North Atlantic (the OSNAP array). International OSNAP is led by USA and includes 10 further partner groups in Canada, France, Germany, the Netherlands and China. The OSNAP array is designed to complement the RAPID array (http://www.rapid.ac.uk/) and NACLIM observations (http://www.naclim.eu/), thereby providing measurements to evaluate inter-gyre connectivity within the North Atlantic.

There is mounting evidence of the importance of the transports of heat and freshwater by the North Atlantic Subpolar Gyre for impacts on European and global climate via temperature, precipitation and wind strength. It is also highly significant for the region's marine ecosystems, the

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formation of hurricanes, and rainfall in the Sahel, the Amazon and parts of the USA. The Subpolar Gyre is presently inadequately measured, and no ocean general circulation or climate model represents it accurately.

The UK-OSNAP team is developing a new observing system and innovative modelling techniques to characterise the ocean circulation and fluxes of the North Atlantic Subpolar Gyre. UK-OSNAP is a partnership between SAMS, NOC, and the Universities of Oxford and Liverpool. The first aim of the programme is to provide a continuous record for four years (2014–18) of full-depth, trans-basin mass, heat, and freshwater fluxes in the Subpolar Gyre.

Since July 2014, gliders have been deployed in the framework of the UK-OSNAP glider programme as part of the Eastern Boundary array (Fig. 1.). The goals of this glider survey is to quantify the flux of northward-flowing warm and saline water across the Rockall-Hatton Plateau (one section every month). To do this, NAGB manages the deployment, operation and recovery of Seagliders, thus maintaining a 365 day presence in the Atlantic Ocean. Each glider is capable of measuring temperature, salinity, dissolved oxygen, pressure, fluorescence and backscatter. As well as supporting scientific objectives, the data is fed to third parties (i.e. The UK Met Office) to support planning and decision making.

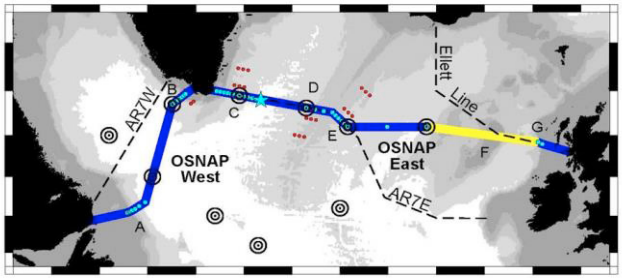

Fig. 1. Full extent of the OSNAP monitoring transect. Section F permanently occupied by Seagliders. (Source: UK-OSNAP)

3. HIGH-RESOLUTION SEABED SURVEYING

In 2015, Scot-MRF acquired a Teledyne Gavia surveyor Autonomous Underwater Vehicle (AUV) in partnership with MARS. The AUV supports SAMS ongoing marine mapping objectives, coordinated through the Marine Environmental Mapping Programme (MAREMAP), a NERC national capability initiative (http://www.maremap.ac.uk/). Scientists within SAMS use the AUV to compile high resolution maps for habitat assessment, glacial mapping, artificial reef monitoring, ship wreck classification, and many other applications. In addition, SAMS are at the forefront of examining how capabilities, unique to AUVs, can support ongoing UK marine monitoring obligations.

2.3 Case Study: MPA Mapping

Increasingly, autonomous and remote sensing technologies are being seen as an important tool by which MPAs are monitored in the future (Wynn *et al*., 2012). As part the new NERC centre for doctoral training (NEXUSS), Scot-MRF and SAMS are working in partnership with Heriot Watt University to test and evaluate the use of AUV technologies to survey and monitor benthic habitats in Marine Protected Areas (MPAs).

Scientists within the project aim to test the suitability of AUVs to monitor MPAs on the west coast of Scotland and to develop viable strategies for their use. AUVs have a unique capability to fly closers to the seabed, using less power to provide greater detailed maps at relatively low cost. This capability allows end-users to identify features previously invisible during traditional boat based surveys (Fig. 2.). The project will also explore novel technologies and models to develop a 'toolbox' of AUV-based approaches that can be applied to a wide range of vulnerable benthic habitats. Novel algorithmic approaches combing new high resolution AUV acoustic bathymetric data with existing models will generate predictive habitat maps at unprecedented spatial resolutions for a range of MPA habitats.

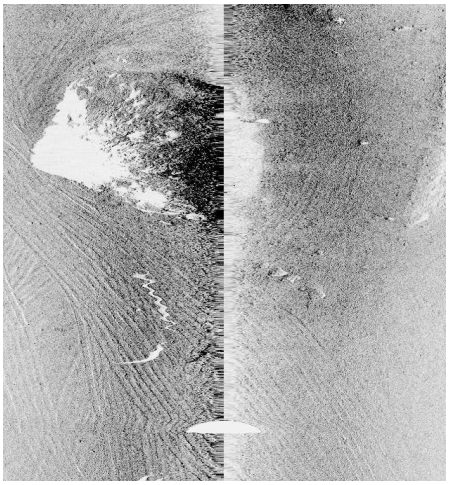

Fig. 2. AUV side-scan data showing extensive trawl damage around a rock outcrop in the Firth of Lorn.

The objective is to develop generic approaches which can be applied in other dynamic inshore coastal environments. The aim will be to develop approaches which are readily reproducible and defensible, supporting the renewables, subsea cabling and fish farm site selection and development.

4. REMOTE PILOTED AIRCRAFT SYSTEMS

Advancement in remote airborne technologies has permitted the capability to observe and monitor areas that would otherwise require complex and expensive solutions. Since 2012, Scot-MRF has been developing remote piloted aircraft systems (RPAS), providing platforms, sensors and qualified flight groups to develop measurement capabilities for research scientists throughout the UK. The facility is