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Authors:	Matthew Donnelly, Roseanna Wright
Quality Controllers:	Romain Cancouët, Sylvie Pouliquen
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¹ As indicated in the "Technical and Scientific description of the Euro-Argo ERIC" July 2013 attached to the Euro-Argo Statutes.

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1. INTRODUCTION

This document describes the efforts made by the British Oceanographic Data Centre (BODC), which is part of the National Oceanography Centre (NOC), to improve the opportunities for deploying Argo floats in the Southern Ocean. The Delayed-Mode Quality Control (DMQC) of Argo floats is dependent on having suitable reference data to conduct an at-sea comparison of a given float with reference data. DMQC operators routinely use both high quality ship-based measurements and comparison to other Argo floats to undertake this assessment.

In the Southern Ocean, with ship-based measurements being particularly scarce and the Argo float array currently being under-populated, it is essential to ensure Argo floats are continuously and sustainably deployed into the future to enable the inter-comparison of float data into the future, including for MOCCA floats already at-sea. As a result, BODC has worked to identify sources of data that will enable the identification of more vessels of opportunity to support the deployment of core Argo floats. As this need is common with other observing networks, this work was pursued through both liaison and cooperation with the Southern Ocean Observing System (SOOS – www.soos.aq) project office and Jcommops (www.jcommops.org), but also through an assessment of Argo float metadata to examine existing platforms used in float deployments.

This work was undertaken as part of BODC's role as the coordinating partner of the Southern Ocean Argo Regional Centre (SOARC). SOARC is responsible for ensuring the sustainability of the Argo array in the Southern Ocean and the reliability of the data available in this dynamic, complicated and under-sampled region of the global ocean. In doing so, BODC has enhanced European leadership in the region, and has improved the sustainability of the array in the Southern Ocean beyond the life of the MOCCA project.

2. ASSESSING DEPLOYMENT OPPORTUNITIES

2.1. The Southern Ocean ‘cold spots’ in Argo coverage

The Southern Ocean represents a significant challenge to the Argo community due to its remoteness; challenging conditions, which include seasonal sea-ice cover; and the comparatively low-level of float deployment opportunities. As a result of this, the Southern Ocean, particularly at very high latitudes remains under-sampled, as indicated by the hot spot analysis in figure 1.

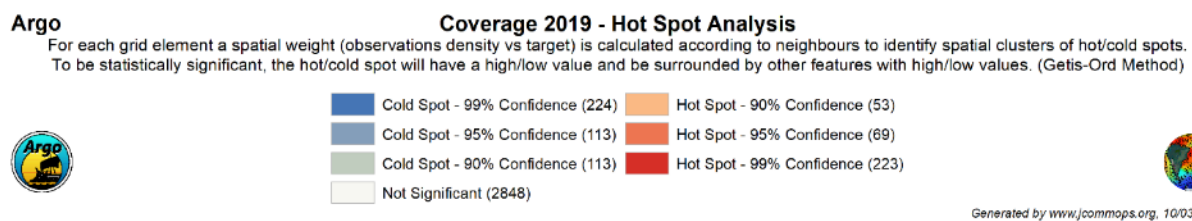
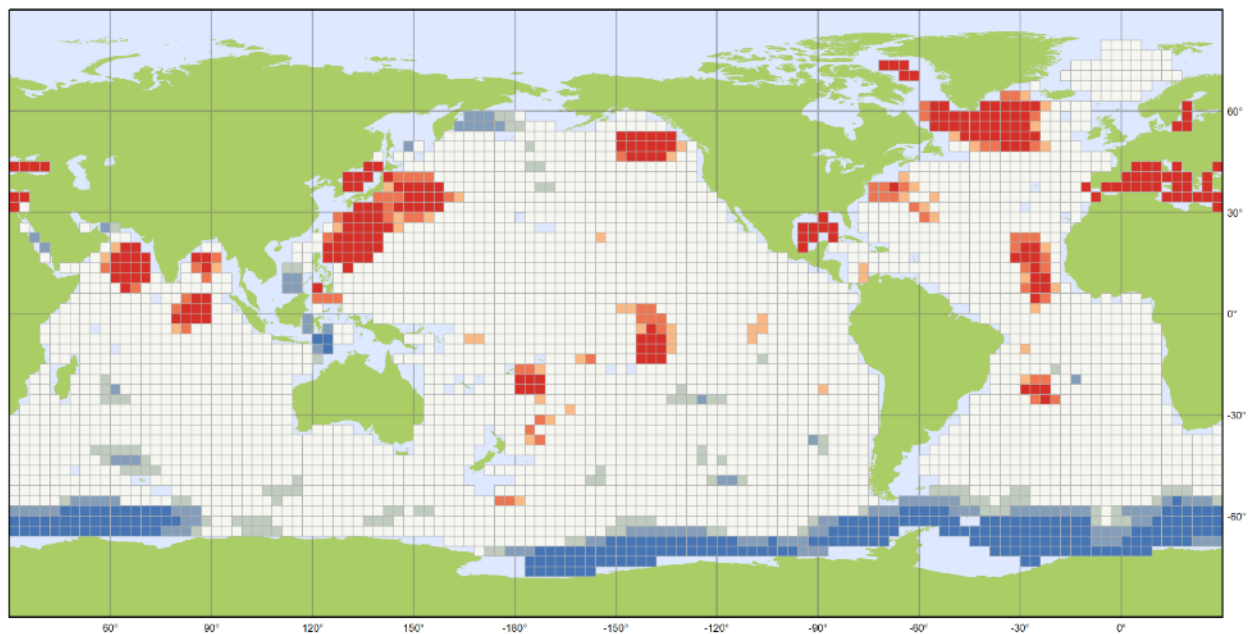


Figure 1- Global ‘Hot Spot Coverage Analysis’ for 2019 showing the under-sampling of the high latitude Southern Ocean, from www.jcommops.org

The Argo coverage ‘cold-spot’ in the high latitude Southern Ocean persists despite the efforts of various European nations, EU-funded floats including some from the MOCCA project (see figure 2), and the significant contribution from the USA SOCCOM project (socc.com.princeton.edu). As a result of this, BODC has pursued several lines of investigation to identify more deployment opportunities in the Southern Ocean, both to increase the frequency and spatial distribution of float deployments. These efforts have been focused on 3 main areas:

1. Assessing an example of a routinely occupied research vessel survey line;
2. Assessing the metadata regarding past float deployments in the Argo Data System;
3. Investigating the potential to deploy floats from ships of opportunity, such as cruise ships as part of the International Association of Antarctic Tour Operators (IAATO).

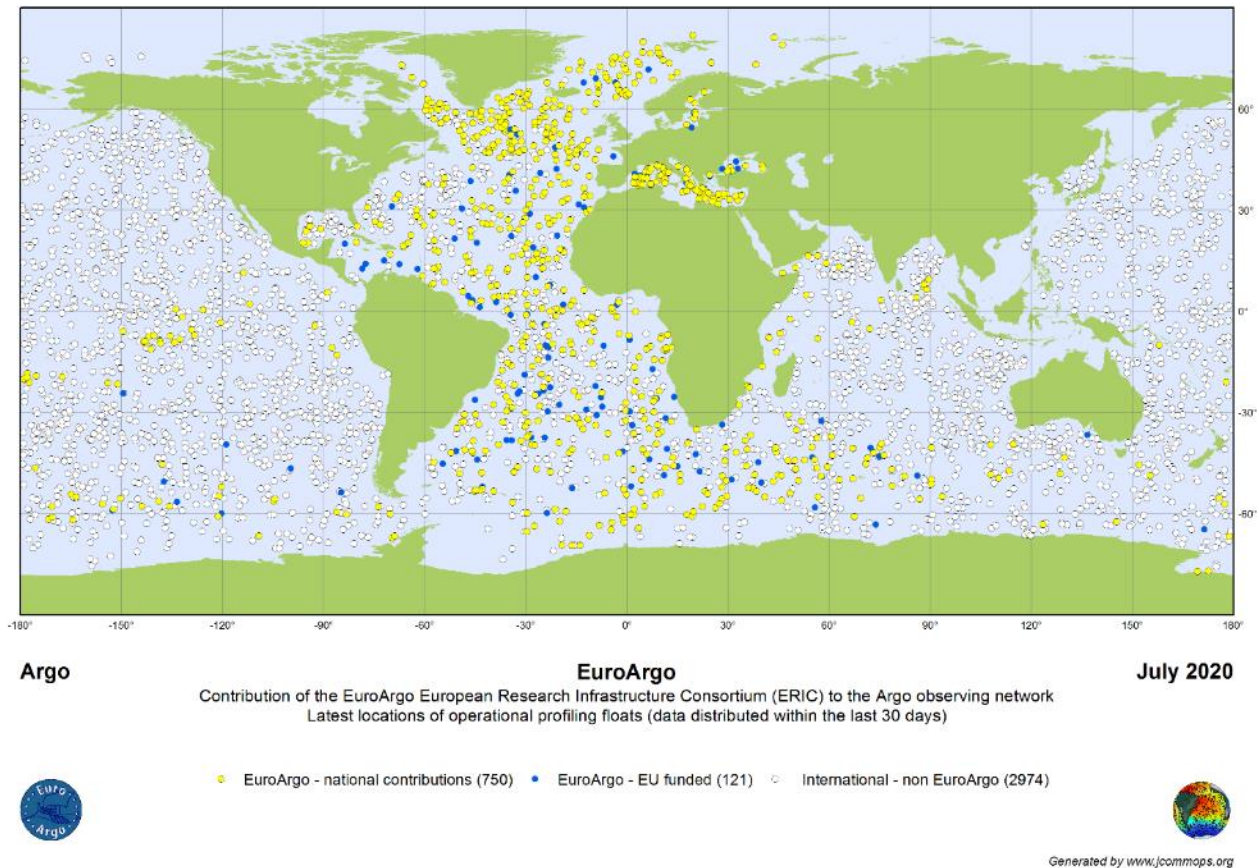


Figure 2 – Global map of current Argo float coverage, including EU funded including MOCCA floats (blue), European national contributions (yellow) and other non-European floats (white) during July 2020, from www.jcommops.org

2.2. Assessing an example of a routinely occupied research vessel survey line

As part of assessing and improving deployment opportunities in the Southern Ocean, BODC have reviewed the frequency with which the SR1b survey line, which is surveyed annually as part of the UK's national capability programme supporting sustained ocean observations. This line in Drake Passage has been occupied 22 out of 24 summers since November 1993 (projects.noc.ac.uk/drake-passage/) and it was thought this opportunity to deploy floats had been intensively used since the beginning of the Argo programme at the turn of the millennium.

A review of recent utilization of this annual opportunity since the beginning of 2015 has shown that:

- Only 12 floats were deployed from this cruise line during that period;
- Of which:
 - 3 were deployed in January 2016;
 - 7 were deployed in December 2017
 - 2 were deployed in February 2020

If this is replicated across other research vessel cruise opportunities, then there is a potentially under-used resource to deploy additional Argo floats along existing repeat oceanographic survey lines.

2.3. Assessing metadata from past deployments

The following is an excerpt and summary from the report “The extent of the Southern Ocean Argo CTD on deployment metadata gap” by Roseanna Wright, BODC.

2.3.1. Introduction

Metadata associated with each Argo floats’ deployment are stored in a NetCDF (.nc) file. The metadata fields are standardised across the Argo Data Assembly Centres (DACs), and advice on how to populate these fields is given in Argo user’s manual V3.3 (Argo Data Management Team, 2019). Some fields are constrained against reference tables or controlled vocabularies, for example data centres and institution codes (Reference table 4) and instrument types (Reference table 8 from WMO table 1770). Often, a CTD profile is performed from a deploying ship at the time of deployment of Argo floats to allow calibration of the Argo float CTD. However, many fields pertaining to the deployment platform/vessel, cruise and CTD reference station are not mandatory, and/or are not controlled which can make locating the reference CTD data challenging. This analysis aims to assess the extent of the ‘CTD on deployment’ metadata gap, with a focus on Southern Ocean Argo floats.

2.3.2. Method

For this analysis, metadata including: PLATFORM_NUMBER, DATA_CENTRE, LAUNCH_DATE, LAUNCH_LATITUDE, LAUNCH_LONGITUDE, LAUNCH_QC, DEPLOYMENT_PLATFORM/ DEPLOY_PLATFORM, DEPLOYMENT_CRUISE_ID/ DEPLOY_MISSION, DEPLOYMENT_REFERENCE_STATION_ID/ DEPLOY_AVAILABLE_PROFILE_ID was extracted from the meta.nc files for all 15,312 floats available as of the 21st of February 2020. These were narrowed down to the 4103 floats deployed in the Southern Ocean (defined as being launched at <-30° Latitude). The metadata were then assessed to determine how often the non-mandatory fields were populated, the usefulness of the information given, and the consistency of the information.

2.3.3. Summary of Results

Out of a total of 4103 Argo floats deployed:

- Only 3822 had a deployment platform populated;
- Only 1110 had the deployment platform and cruise populated;
- And only 131 had the deployment platform, cruise and CTD populated.

In cases where the deployment platform was populated, a wide variety of ship names have been used. In the most extreme example, the heavily used South African research vessels S. A. Agulhas (until 03/04/2012 when it was decommissioned) and S. A. Agulhas II (thereafter) included 35 different variations, and confusion between the two different vessels. The diversity of text used to represent cruises was just as broad, and the population of deployment CTD stations often sufficiently vague as to not aid in identification.

The full report will be presented at the next Argo Data Management Team, recommending the adoption of controlled vocabularies to help address this issue, with the aim of enabling a better understanding of existing deployment opportunities.



2.4. Ships of opportunity

In addition to research vessels, BODC identified two avenues to pursue for identifying potential deployment opportunities for Argo floats in the Southern Ocean.

2.4.1. *SOOS and IAATO*

The International Association of Antarctic Tour Operators (IAATO – www.iaato.org) is a group of organisations that operate various sizes of cruise ships and yachts around Antarctica. Whilst many of their destinations are on the northern end of the Antarctic Peninsula, some operate further south and different longitudes around Antarctica. Through liaison work, BODC identified that whilst there have been isolated examples of cooperation between oceanographers and IAATO operators, there had been no apparent sustained engagement with IAATO as an organization, nor had the opportunities presented by the organization as a whole been capitalized upon.

Simultaneously, BODC has engaged with the Southern Ocean Observing System (SOOS – www.soos.aq) - which aims to coordinate the development of ocean observations throughout the Southern Ocean - as a representative of the Argo programme. As a result of this engagement, it was identified that SOOS was investigating the potential to work with IAATO to tackle the same issue in the context of broader oceanographic observations. As a result, BODC agreed to work through SOOS to develop this relationship and gain an understanding of the range of cruise ship routes.

The COVID-19 situation has slowed progress and the final benefit will not be realized until after the end of the MOCCA project.

2.4.2. *Jcommops and AIS data*

Similar to the approach of engaging with SOOS and IAATO, BODC identified that historical ship Automatic Identification System (AIS) data was a potential source of information on other types of vessels, such as Antarctic base resupply ships and fishing vessels, operating in the Southern Ocean. Initial investigations were conducted through occasional checks on real-time data from Marine Traffic website (www.marinetraffic.com) which identified that vessels were operating at unexpectedly high latitudes around Antarctica. Access to historical data for further analysis carried significant cost, but it was identified that Jcommops (www.jcommops.org) were also interested in this data and have since established access to historical AIS data. BODC agreed to work with and through Jcommops to investigate the utility of this data.

The COVID-19 situation has slowed progress and the final benefit will not be realized until after the end of the MOCCA project.



3. FUTURE

As a result of the investigations into existing deployment metadata, liaising with SOOS regarding engagement with IAATO, and liaising with Jcommops on the use of ship AIS data, BODC is now well-placed to leverage this insight and improve deployment opportunities in the future. Such improved insight will enable funding for Argo at European and/or national level to effectively address the Southern Ocean 'cold-spot' of insufficient float observations.

The work on improving deployment metadata will be progressed as part of the H2020 EU project ENVRI-FAIR, and will make further recommendations as to how to improve the FAIRness of the Argo Data System through more extensive use of controlled vocabularies.

Further progress regarding IAATO and AIS data will be made as part of the EU H2020 project EuroArgo RISE WP5 as part of SOARC liaison work and in association with establishing regional data quality assessments, as well as through UK national capability funding which underpins BODC's contribution to SOARC.