Model Comparison for Transatlantic Ocean Glider Flight: Student Analysis of Modern Circumnavigation

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Abstract- **Oceanic forecast models are imperative to understand the Earth's ocean. Current oceanic forecasts assimilate satellite sea surface height and temperature data along with temperature and salinity profiles from Argo networks of over 3000 drifters. Even though assimilation of these datasets are reliable, they have limitations because areas that provide critical data to ocean forecast models are often under sampled. Autonomous Underwater Gliders (AUGs) can be used as a solution to reduce under sampled regions of the ocean. Over the last decade, AUGs have successfully been used to carry out regional deployments to conduct scientific expeditions throughout the Earth's Ocean. Through the Challenger Glider Mission, coordinated flights covering 128,000 kilometers are planned around the five ocean basins. A range of international institutions and agencies can participate in the mission using interactive tools developed by the U.S. Integrated Ocean Observing System (IOOS) and the education outreach tools of the U.S. National Science Foundation's (NSF) Ocean Observing Initiative (OOI). These interactive tools are programmed to display real time glider data with interactive browser-based access, enabling student participation in global ocean exploration and predictive skill experiments. During the summer of 2015, student research teams participated in the second leg of the South Atlantic Challenger Glider Mission (named RU29). The aim is to show the usefulness of RU29's in situ datasets in ocean forecasting by comparing salinity, temperature, and sea surface current observations to the predictive readings of ocean models (RTOFS, MyOcean) and data generated by the Argo Float program. The students' involvement contributes to the assessment of current scientific and oceanographic models, courtesy of the Challenger Glider Mission.**

Keywords – Ocean forecasting; Autonomous Underwater Gliders; Challenger Glider Mission

I. INTRODUCTION

In November 2013, Glider Mission RU29 was deployed in the South Atlantic. It was deployed off Cape Town South Africa, stopped in the Ascension Islands before it was recovered off Sao Paulo, Brazil, ending the 4,420 km crossing in May of 2014. During the summer of 2014, data from RU29 was used to analyze the skill of the American RTOFS ocean model and the European MyOcean ocean model. Students observed the differences between data collected from the glider and the data predicted by the models. This comparison is useful in analyzing oceanographic elements, such as the Brazil Current, that the glider might encounter during its second deployment.

On June 23, 2015, RU29 embarked on its second leg of its circumnavigation of

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the South Atlantic Ocean. It was deployed from Ubatuba, Brazil and is traveling back to Cape Town, South Africa. This trip is expected to take one year, and will span at least 6,500 kilometers. The glider, subject to ocean currents and necessary energy efficiencies, can travel approximately 7,000 kilometers. If needed the glider will be able to stop at the remote island of Tristan da Cunha for repairs. In order to maximize distance traveled and minimize energy usage, a potential track will be determined for the glider to follow based on the currents predicted with global ocean models, as well as wind and wave forecasts. Throughout RU29's deployment, data collected will be compared to the output from two ocean models, RTOFS and MyOcean, as well as the Argo float program. Based on the analysis of these comparisons, a better understanding of the oceanic conditions within the South Atlantic will be provided to help the glider transit the entire South Atlantic Ocean.

II. METHODS

To assess the forecasting capabilities of existing international suite of oceanic models and devices, the comparison between the US Model, RTOFS, The European model, MyOcean, the Argo float data program and RU29 data was conducted. The collaboration between European countries such as the United Kingdom, France, Germany, and Denmark resulted in the development of the MyOcean model and RTOFS (Real Time Ocean Forecast System) is a United States model created by the National Center for Environmental Predication. Through primarily satellite data assimilation, RTOFS and MyOcean provides integrated oceanic information, which is accessible from internet databases.

In situ data from the Argo floats were compared to both glider and modeled profiles. Argo floats profile the ocean from the surface to as deep as 2000m once every 10 days. Each profile samples ocean temperature, salinity, and density along with other oceanic parameters based on the drifter configuration. There are thousands of Argo floats deployed around the world today including around the area along the glider's track. By comparing a glider and an Argo float profiles to each other, the quality of the glider's measurements of the water column can be determined. These comparisons between RU29 and an Argo float datasets verify the glider CTD data.

RU29 is a G2 glider equipped with a SeaBird pumped Conductivity, Temperature and Depth (CTD) sensor to collect temperature and salinity profiles. Using a process from Kerfoot et al. [5] to correct the thermal inertia of the conductivity sensor, the dataset of RU29 can be compared to an Argo float and sections of the RTOFS and MyOcean models taken along the glider's path (Figure 1). A series of MATLAB scripts facilitated the data processing and profile creations of the temperature and salinity data gathered by the models, the Argo float program and RU29.

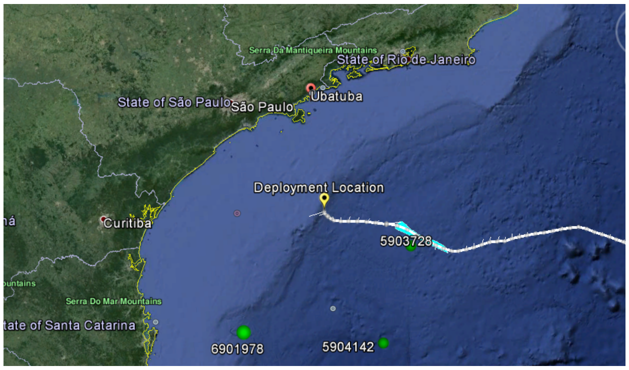

Figure 1: RU29's deployment location and the portion of its track off the coast of Brazil used for the comparison to the models and an Argo float.

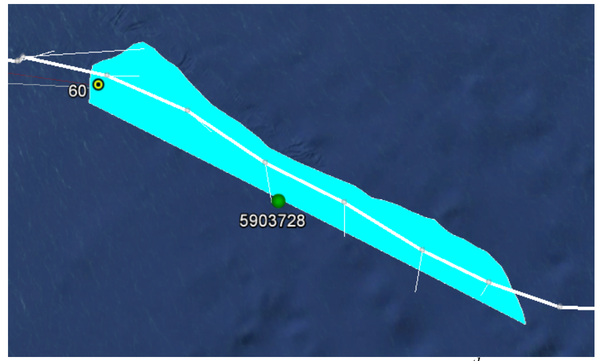

Figure 2: Argo# 5903728 completed its 60th cycle on July 1st approximately 3.44km from where RU29 surfaced on June 29th. The blue shading indicates where RU29's profiles were extracted.

III. RESULTS

On June 29th, RU29 passed by an Argo float (Argo#5903728) that completed its 60th cycle on July 1st several days later. These data were used to compare the glider CTD with RTOFS, MyOcean, and the Argo float (Figure 2). This study will focus on the deeper measurements below the more variable surface layer. In these deeper waters the spatial variability of temperature and salinity are longer. The temperature collected by Argo#5903728 and RU29 did not show any disparity but rather congruency throughout the water column (Figure 3). This cannot be said for salinity. While the profiles compared well in the beginning of the study, on June 30th the glider moved into a water mass with saltier water at depth. Glider profiles 18 to 20 are saltier at depth than the available Argo float data and the profiles sampled by the glider in the days prior (Figure 3).

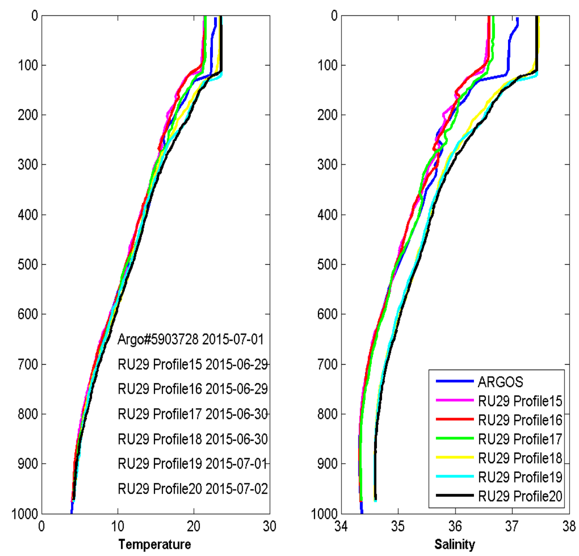

Figure 3: Temperature and salinity depth profile comparison between Argo#5903728 and RU29. Temperature on the left and salinity on the right

The glider highlights spatial changes in the deep water mass not captured by the closest ARGO profile. In the spatial comparisons of the Argo float, glider and models, RU29's profile 18 indicates that at the bottom a significant increase in salinity had occurred (Figure 4). Since Argo#5903728 did not move across this change sampled by the glider and the model grids are courser than the scale sampled by the glider, they could not detect the change. Additionally at the surface, RTOFS predicted lower temperature and salinity than RU29 while MyOcean predicted a slightly higher temperature and salinity than the glider (Figure 4). In the deep ocean, the temperature gradually increases while the salinity stayed constant as the glider continues to travel eastward (Figure 4). Furthermore, Argo#5903728 measured fresher water at depth than RTOFS, MyOcean and the glider and the float and the models report lower temperatures than RU29 (Figure 4). The South Atlantic is characterized with lower precipitation and saltier surface water with strong winds. The spatial comparisons of RU29, Argo#5903728, and the models show that the surface is warmer and saltier than the deep ocean, consistent with the climatology of the South Atlantic (Figure 4).

IV. DISCUSSION

According to observing System Simulation Experiments, additional profile data, especially profile data that cross frontal features, are the most influential at reducing forecast uncertainty. This is evident as RU29's profiles 18 to 20 showed temperature similarities with Argo#5903728 but not in salinity as the glider saw a drastic increase as it moved east along its path (Figure 5). The sudden change in salinity indicates that RU29 crossed a front that the Argo float did not pick up. Since the location of Argo drifters cannot be controlled after they are deployed, they typically do not cross fronts, rather they move along fronts.

Like the glider/ARGO float comparison, the two models and RU29 comparisons highlight the potential spatial considerations needed when evaluating with the higher resolution glider data. The RTOFS and MyOcean models had some similarities with RU29, but they both did not reproduce the frontal structure apparent in the in situ glider data (Figure 6). Since the output of RTOFS and MyOcean are courser than the glider profile data, they do not represent the higher resolution of the Glider or ARGO profile data.

Consequently, the models and RU29 data can show disassociation around sharp oceanic gradients. For instance, RTOFS' June 30th projected currents showed that the RTOFS output compared to the glider was taken in an area of weaker currents in a different feature than the closest glider data and MyOcean output in time and space. (Figure 7). This likely partially explains the difference between the glider and model output. In addition, RTOFS and MyOcean generates average temperature and salinity data of the grid, which limited their ability to resolve the front.

Autonomous Underwater Gliders can be used to assimilate into or evaluate ocean forecast models because of their ability to traverse previously under sampled frontal regions of the ocean. It is crucial to the future of ocean modeling that glider-collected data be incorporated especially where areas of disagreement between the models and an Argo float occur. Over the course of this glider mission we will continue to look at features resolved by the glider to understand how they are represented in the global models. This preliminary analysis focuses on the data deeper than 500 m. As we continue this line of research we will include surface waters associated with these features.

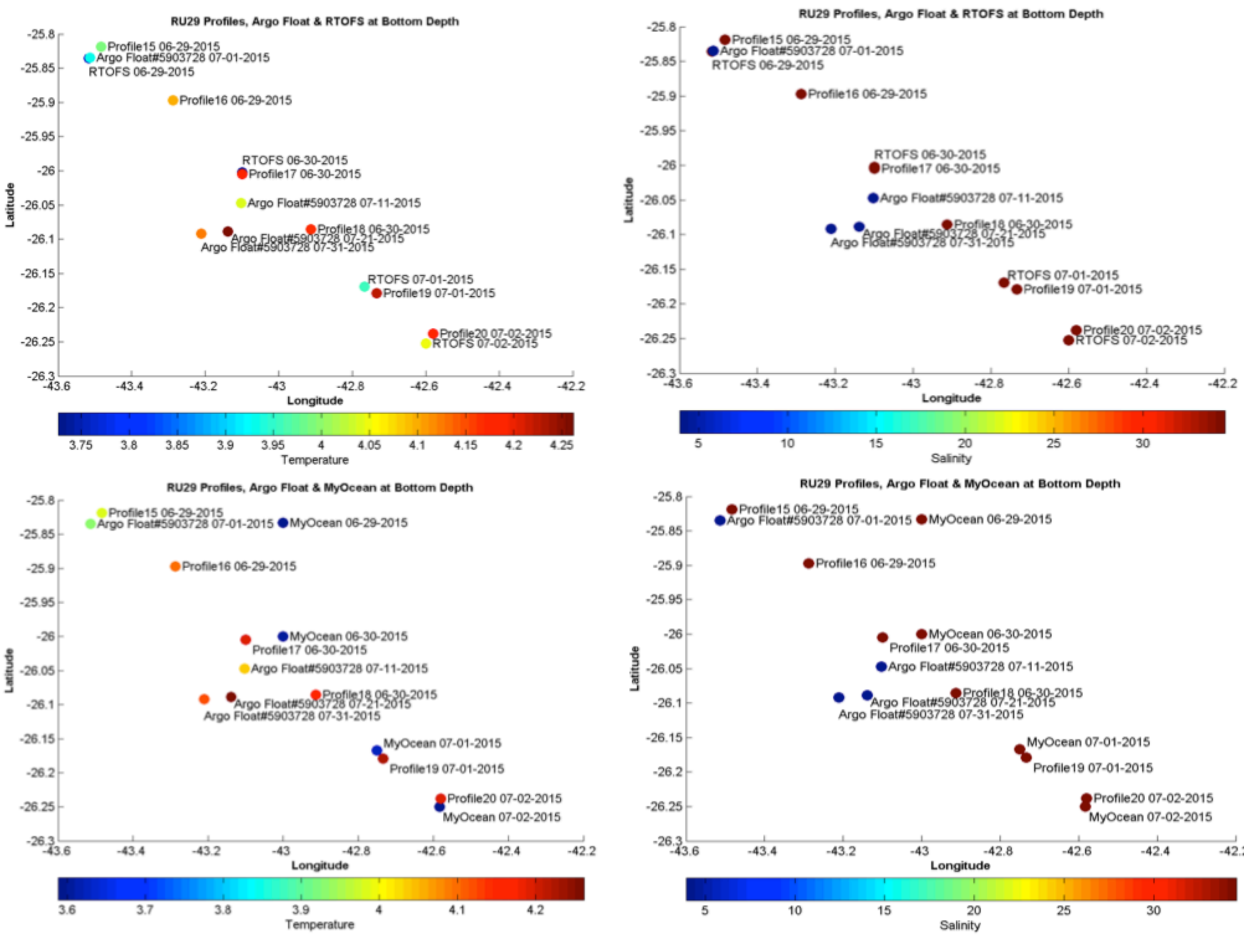

Figure 4: Location, time, and space for RU29, Argo and RTOFS (a and b) and MyOcean (c and d) model data. Time and Sources are indicated (a) bottom temperature with RTOFS, (b) bottom salinity with ROTFS, (c) bottom temperature with MyOcean, and (d) bottom salinity with MyOcean.

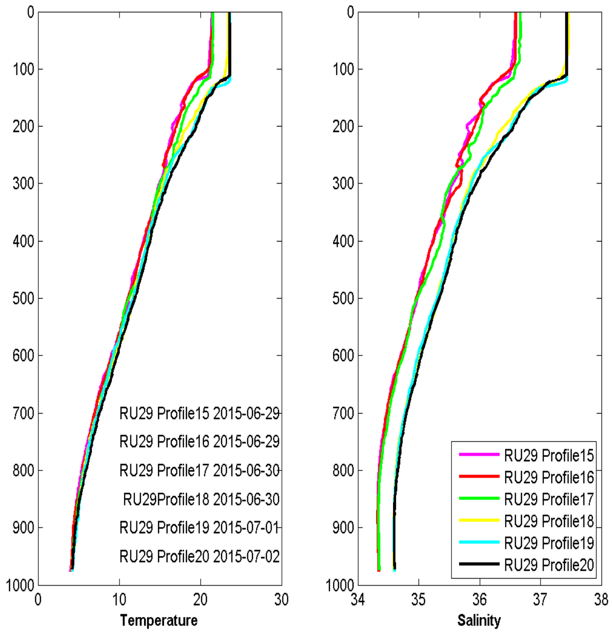

Figure 5: Temperature and salinity depth profile comparison between RU29 profiles #15-20. Temperature on the left and salinity on the right.

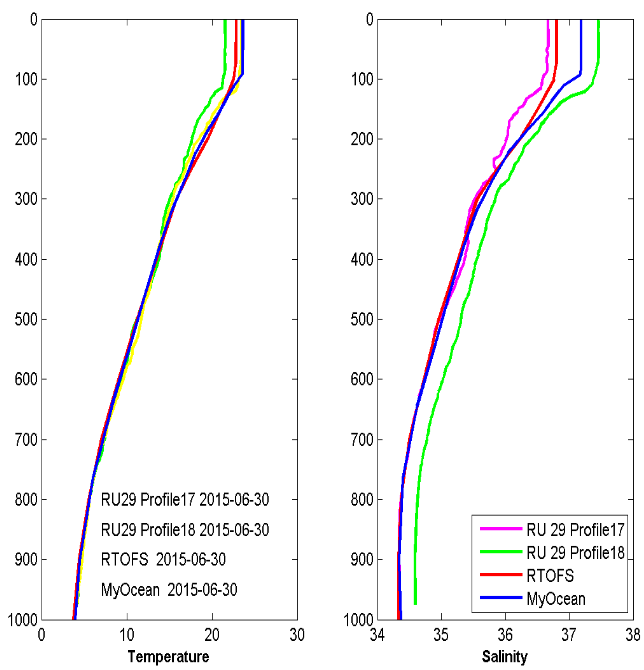

Figure 6: Temperature and salinity depth profile comparison between RU29 profiles #17& 18, RTOFS and MyOcean. Temperature on the left and salinity on the right.

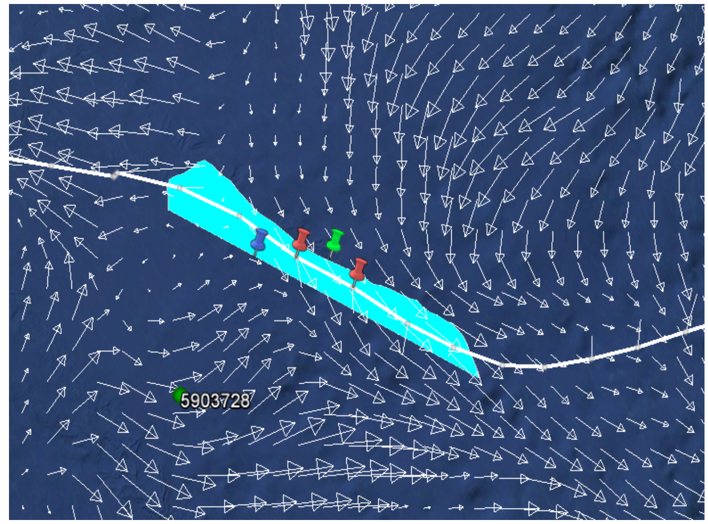

Figure 7: RTOFS projected current directions in the South Atlantic on June 30th. Pins indicate the location of where RTOFS (blue), MyOcean (green), and RU29 (red) data were taken on the glider path.

V. ACKOWNLEDGMENTS

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