AIR DEPLOYABLE PROFILING FLOATS

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ABSTRACT

We describe the development of a small profiling float that can be air launched from a variety of aircraft and which offers the opportunity to monitor the upper-ocean thermal structure over a time span of many months. These Argo-type profiling floats can be deployed from any variety of aircraft equipped with an A-sized (Airborne EXpendable BathyThermograph – AXBT) launch tube, or from the stern ramp of a C-130. The floats have same dimensions as an AXBT and weigh about 8.5 kg. Upon launch, the floats parachute to the surface, detach and automatically begin their programmed mission. The recorded temperature data is subsampled to bins that are reported back via the Iridium satellite phone network, which is then automatically processed and posted to the Global Telecommunications System.

1. INTRODUCTION

Profiling floats have found wide use in the oceanographic community since their original design in WOCE (Davis et al., 1992) to their current widespread usage in the Argo program (Riser et al., 2016). The utility of profiling floats comes from their relative affordability and their autonomous nature once they are deployed. The ALAMO float works on the same principals as the ALACE (Autonomous Lagrangian Circulation Explorer) profiling float designed by Davis et al. (1992), which later further developed into the SOLO (Sounding Oceanographic Lagrangian Observer) profiling float used in the Argo program today (Davis et al., 2001). Indeed, the ALAMO float represents a natural engineering progression of those original designs.

Much of the basic float design is similar to the SOLO float (Figure 1). There is a mechanical pump that moves oil from an internal bladder to an external bladder allowing the float to change its buoyancy causing it to rise or fall in the water column. The change in volume for an ALAMO float is 400 ml, giving a $\Delta V/V$ of 4.7%, compared with 3.4% for SOLO-2 floats, and <2% for APEX floats (Izawa et al., 2002). An ARM controller, with built-in GPS location and Iridium communications chips, controls the float. A set of foldable fins on the bottom of the float act to stabilize the float at the ocean's surface in the same manner as the damping disk on other profiling floats (Davis et al. 1992). The pressure case is rated to 1200 meters. The initial set of floats was equipped with temperature and pressure sensors from RBR. Bin-averaged data is sent back via Iridium Short Burst Data (SBD) messages. The behaviour of the float is programmable, including: frequency of profiling, profiling depth, profiling speed, drift depth, and bin size. The floats are reprogrammable via the two-way communication afforded by Iridium.

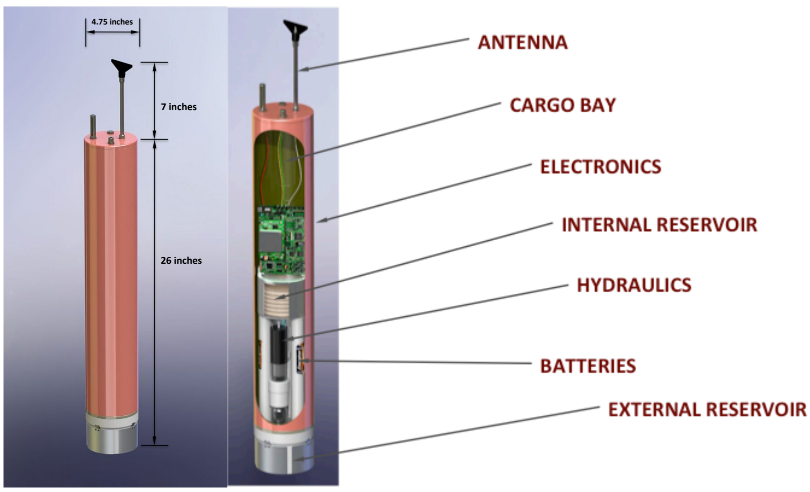

Figure 1: Diagram of the dimensions and basic engineering design of the ALAMO.

In designing the ALAMO, we followed the specification (MIL-S-81478C) for an "A-size" sonobuoy with is 123.82 mm (4.875 in) in diameter and an overall length of 914.39 mm (36 in) and weight of no greater than 9 kg (Figure 1). While weight is not a primary concern, the strict size requirements and the float's need to be near neutrally buoyant in the ocean, drives the weight of the float to conform as well. The displacement volume is roughly 8.1 liters and giving it a rough weight in air of approximately 8.4 kg before final ballasting.

2. HURRICANE DEPLOYMENTS

The significant economic impact of the damage from “Superstorm” Sandy on the eastern seaboard of the U.S. spurred further efforts to improve the forecasting of hurricanes and nor’easters. It was with this goal that the development work presented here was undertaken. The objective was to enhance the capability to make targeted ocean observations before and during strong storms. Profiling floats have been air-deployed for process studies of tropical cyclones prior to this work. In particular Hurricane Frances (2004) during the CBLAST experiment (Coupled Boundary Layer Air-Sea Transfer, see Black et al. 2007; Sanford et al. 2007, 2011) and Typhoon Fanapi (2010) during the ITOP experiment (Impact of Typhoons on the Ocean in the Pacific, see D’Asaro et al. 2011; Mrvaljevic et al. 2013) were both sampled with air-deployed profiling floats. These profiling floats, with deployment packaging and parachute, are large (30–50 kgs in weight and 200–400 liters in dimension) and therefore require the ramp door on the stern of a C-130 to be opened during flight to deploy the floats. Such maneuvers are not possible during operational weather reconnaissance missions given the storm conditions. It is however possible to utilize the “sonobuoy” launch tube installed on the Hurricane Hunter planes during storm missions (i.e. that is used for AXBT launches, see Sanabia et al. 2013). Hence our driving goal of developing a versatile, fully functional profiling float that can be deployed out of a sonobuoy-sized launch tube. A-sized profiling floats were originally developed under funding from ONR, and redeveloped here under funding from NOAA Sandy Supplemental recovery act funds.

The ALAMO profiling float has the capabilities of an Argo-type float, however it is small enough to be deployed from a Hurricane Hunter plane via the launch tube during a storm mission. The usual goal of a hurricane mission was to deploy floats on storm reconnaissance flights ahead of the storm to improve estimates of the upper-ocean temperature structure (heat content) and subsequent ocean response to the storm. Sanabia et al. (2013) demonstrated the impact of real-time upper-ocean temperature profile observations from AXBTs in improving both hurricane track and intensity forecasts. However, the advantages of a profiling float over AXBTs include: multiple profiles, additional sensors (i.e. pressure and salinity), no requirement for VHF receiver equipment on the airplanes, and persistence long after the plane has left the region. Furthermore, the direct measurement of pressure alleviates the bias errors in the depth estimate induced by uncertainty in the fall-rate equation of the XBTs (for a discussion see Cheng et al., 2016).

In total 60 ALAMO floats were deployed during the 2014–2016 hurricane seasons. During the first year (2014), 6 of 10 floats (60%) worked on deployment. This relatively poor performance was traced back to the design of the parachutes and led to a reconfiguration of the air-deployment system. In 2015 the second year of the program, 27 of 30 floats (90%) worked upon deployment (Figure 2), and in the final year (2016), 19 of 20 floats (95%) worked.

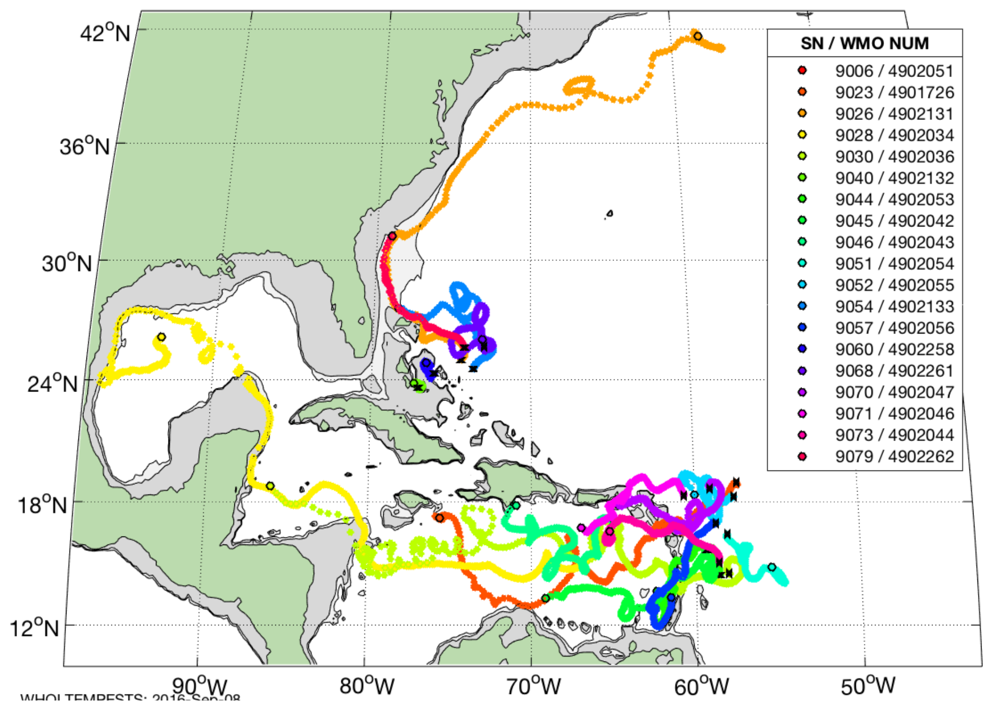

Figure 2. ALAMO float deployments and drift tracks in the Atlantic Ocean and Intra-American Seas during the 2015 hurricane season. Additional floats were deployed in the Pacific Ocean as well.

3. ARCTIC DEPLOYMENTS

ALAMO floats have been air-deployed in the Chukchi Sea region of the Arctic Ocean in collaboration with the NOAA/PMEL Arctic Heat Open Science Project. The scientific objectives of the 2016 field program include monitoring rates of upper ocean temperature change and water mass transformation over an entire summer season, from the time the sea ice begins to retreat in the spring through freeze-up in the autumn.

Considerable effort was invested in the design and implementation of an ice-avoidance scheme. Since profiling floats must surface to report their data back and provide position information, sea ice conditions of the Arctic make this difficult and hazardous for the float. In particular, a float on the surface can easily be crushed or otherwise damaged by sea ice. When sea ice is present the floats seek to determine the conditions before attempting to surface. A two-phase ice detection scheme was developed. The first part uses a modified version of a scheme based on observed mixed-layer temperature and salinity properties to predict the presence of sea ice that was developed for use around Antarctica (Klatt et al. 2007; Wong and Riser 2011). The second phase is a multiple surface approach when there is a high probability of open water (leads) conditions (Figure 3). During ice-free periods the floats function as normal profiling floats: periodically surfacing, sending back their data, and returning to the parking depth.

Test floats were deployed at the end of summer 2016 from NOAA's Twin Otter airplane through its A-sized deployment chute. Currently there are two ALAMO floats currently profiling every 5 days, however since the Arctic is currently ice-covered, their data is being stored until spring when the marginal ice zone retreats. Figure 4 shows the track and ocean temperature for one of the floats deployed in 2016 as an example.

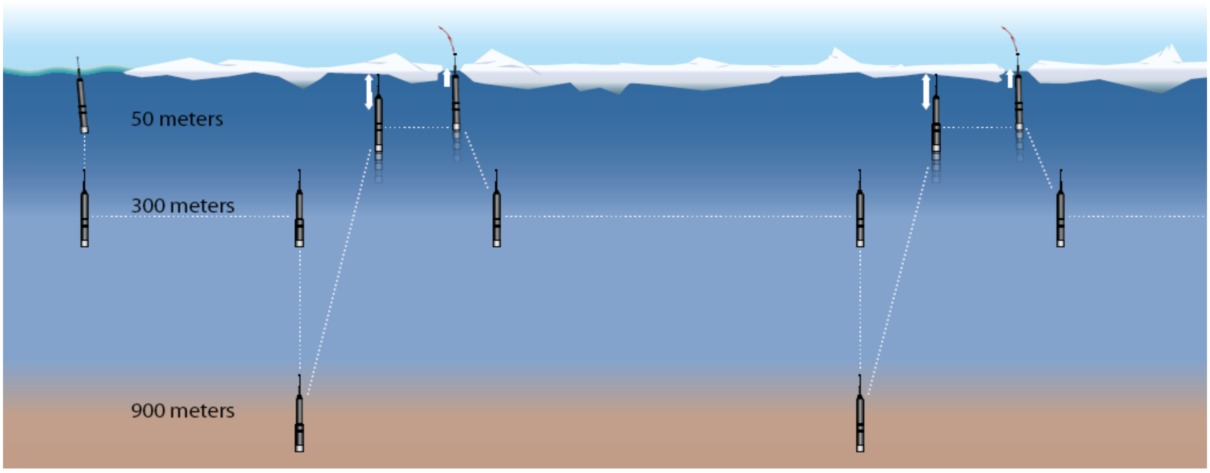

Figure 3. Schematic of the profiling float mission, including the lead-finding scheme when sea ice is present. Note the drift (here shown for illustration purposes as 300 m) and profiling depths (here shown as 900 m) are programmable and can be adjusted during the mission.

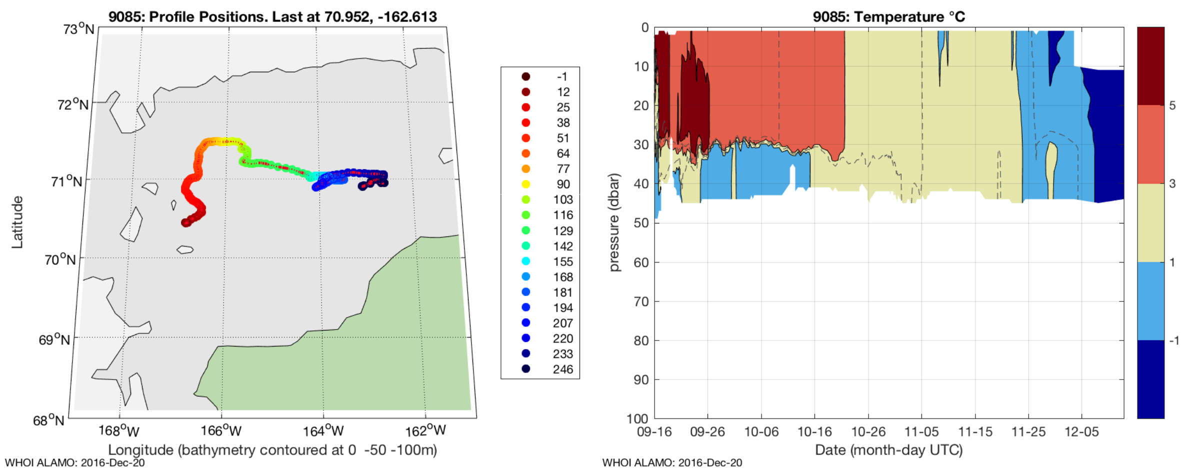

Figure 4. Drift track and temperature contour plot for an ALAMO deployed in 2016 in the Chukchi Sea as part of the Arctic Heat program (http://www.pmel.noaa.gov/arctic-heat). Note the strong stratification of a two-layer flow in September that is eroded away during October as the surface ocean cools.

4. ANTARCTIC DEPLOYMENTS

The Ross Ocean and ice Shelf Environment and Tectonic setting Through Aerogeophysical Surveys (ROSETTA) Ice Project deployed six ALAMO floats from a C-130 in the ocean along the edge of the Ross Ice Shelf off Antarctica in December 2016 (Figure 5). The goal of this element of the project is to investigate the interaction of the ice shelf and adjacent ocean. In particular, the data from the ALAMO floats will be used to assess the stability of the Ross Ice Shelf to understand how quickly Antarctica will lose ice as the ocean warms. For this work, the ALAMO floats were equipped with standard Sea-Bird Electronic profiling CTDs (SBE 41CP+) so that high-quality salinity measurements are also being obtained (Figure 6).

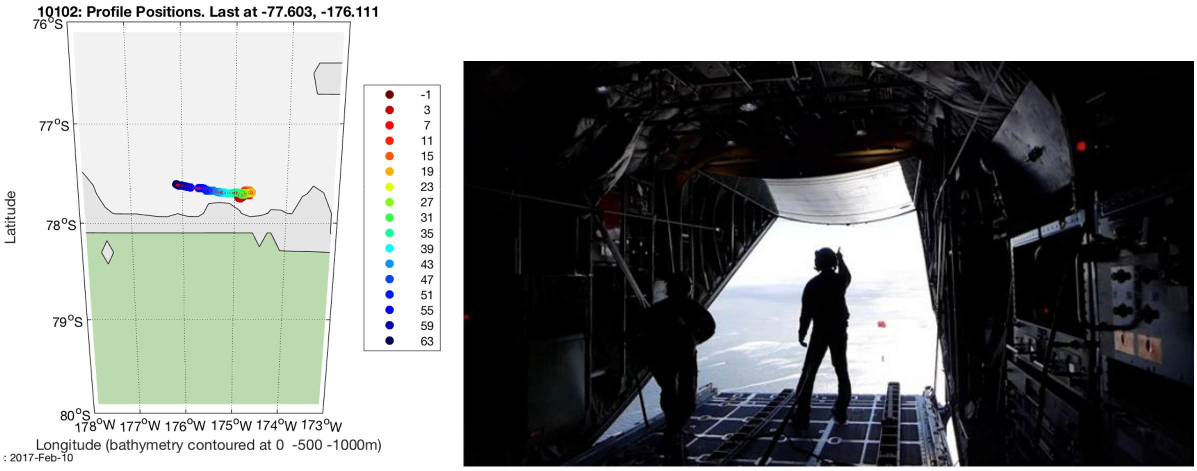

Figure 5. (Left) Location along the Ross Ice Shelf of ALAMO #10102 as part of the ROSETTA project. (Right) Air deployment of an ALAMO from the stern ramp of an Air National Guard C-130 along the coast of Antarctica (photo credit: Tej Dhakal at Lamont-Doherty Earth Observatory). (http://www.ldeo.columbia.edu/res/pi/rosetta/Alamo.html)

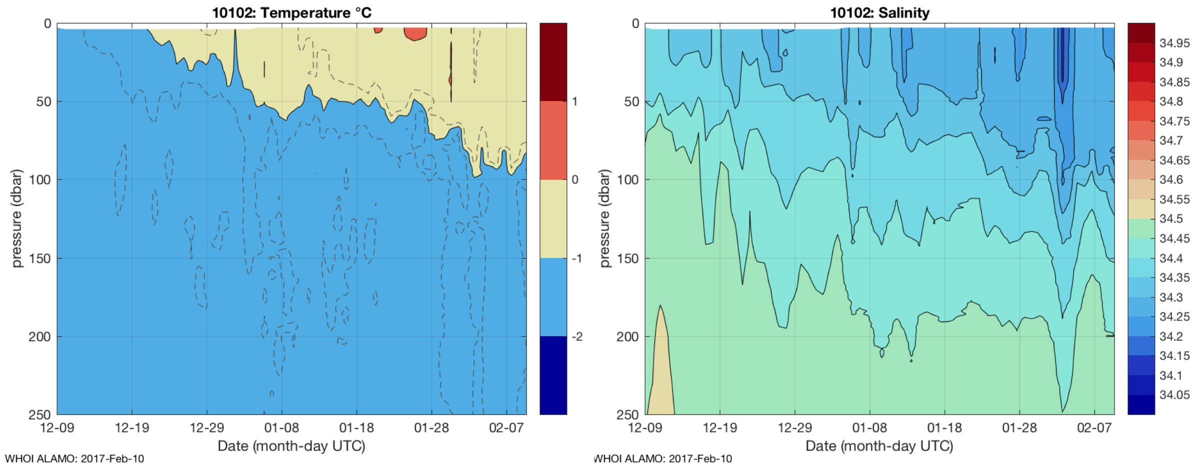

Figure 6. Temperature and salinity time series of the upper ocean adjacent to the Ross Ice Shelf from ALAMO 10102.

5. FUTURE DEVELOPMENTS

Work is underway to improve the capabilities of the ALAMO floats. Additional sensors being incorporated into the floats include: the RBR inductive CTD, photosynthetically-available radiation (Li-COR PAR), acoustical tracking for under ice applications, turbulent microstructure with Rockland Scientific fast thermistor and velocity shear probes, and an inertial motion unit (IMU) for measurement of the surface wave field's directional spectrum. The capability to directly measure currents using electromagnetics is also being considered (Sanford, 1971). Ultimately, it is hoped that the ALAMO float finds wide enough usage to reduce their price. To further that goal, cheaper sensors are actively being sought as they contribute substantially to the total cost of the floats.

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