Air-Deployable Profiling Floats

By Steven R. Jayne and Neil M. Bogue

We describe the development of a small profiling float, the ALAMO (Air-Launched Autonomous Micro-Observer), that observes upper-ocean structure over a year. These floats can be launched from any aircraft equipped with an "A-sized" launch tube, or from the door of any other aircraft. Profiling floats have found wide use in the oceanographic community, from their original design in the World Ocean Circulation Experiment (Davis et al., 1992) to their current widespread usage in the Argo program (Riser et al., 2016). The utility of profiling floats derives from their relative affordability and their autonomous nature once deployed. The ALAMO float works on the same principles as the ALACE (Autonomous Lagrangian Circulation Explorer) profiling float designed by Davis et al. (1992), which developed into the SOLO (Sounding Oceanographic Lagrangian Observer) profiling floats used in the Argo program today (Davis et al., 2001). The ALAMO float represents a natural progression of those earlier designs.

THE ALAMO FLOAT

Much of the basic ALAMO float design is similar to the SOLO float (Figure 1). A mechanical pump moves oil between an internal reservoir and an external bladder, changing the float's buoyancy and causing it to rise or fall in the water column. The ALAMO design follows the specification for an A-size sonobuoy: a diameter of 12.48 cm, overall length of 91.44 cm. The ALAMO float's weight is driven by the size constraints and the float's need to be nearly neutrally buoyant in the ocean. Its displacement is roughly 8.1 liters, giving it an approximate weight in air of 8.4 kg before final ballasting. The change in volume for an ALAMO float is 400 ml, giving a ΔV/V of 4.7% (compared with 3.4% for SOLO-2 floats, and <2% for APEX floats). A set of foldable fins on the bottom of the float act to stabilize the float at the ocean's surface similar to the damping disk on other floats (Davis et al., 1992). The float has a pressure case rated to 1,200 m. An ARM (Advanced RISC Machine) processor controls the float, and the behavior of the float is programmable in real time. Upon launch, the floats parachute to the surface, detach, and automatically begin their programmed mission. Data and GPS positions are transmitted using Iridium Short Burst Data (SBD) messages, and the float's profiling mission (profiling frequency, depth and speed, drift depth, and sensor sampling characteristics) can be reprogrammed via Iridium SBD messaging. The initial set of floats was equipped with temperature and pressure sensors from RBR. Lithium batteries provide power to the pump, the controller, and the sensors. With a battery capacity of 36 amp-hours, the floats are able to perform a cumulative profile distance of 200 km. In testing, we found that the ALAMO float is capable of rising at a rate of >45 cm s^{-1} and has a descent rate of 25 cm s^{-1}.

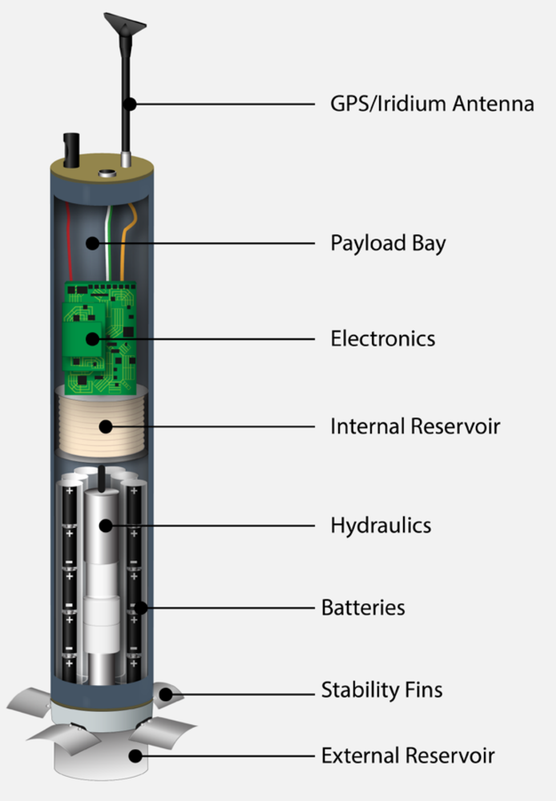

FIGURE 1. Diagram of the ALAMO float's internal components.

HURRICANE DEPLOYMENTS

The significant economic impact of the damage from Superstorm Sandy spurred efforts to improve the forecasting of hurricanes and nor'easters and motivated the development work presented here. The objective was to enhance the capability for making 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, air-deployed profiling floats sampled Hurricane Frances (2004) during the CBLAST experiment (Coupled Boundary Layer Air-Sea Transfer; Sanford et al., 2011) and Typhoon Fanapi (2010) during the ITOP experiment (Impact of Typhoons on the Ocean in the Pacific; Mrvaljevic et al., 2013). The profiling floats used in these two experiments, with deployment packaging and parachute, are fairly large (30–50 kg 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. Such maneuvers are not possible during operational weather reconnaissance missions given the storm conditions. It is, however, possible to utilize the A-size sonobuoy launch tube installed on the Hurricane Hunter aircraft (Figure 2) during storm reconnaissance missions (as used for Airborne eXpendable BathyThermograph [AXBT] launches; see Sanabia et al., 2013). Hence, there is a need for a versatile, fully functional profiling float that can be deployed out of a launch tube.

The usual mission of a storm reconnaissance flight is to deploy floats 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 compared to an AXBT include its ability to obtain multiple profiles, the additional sensors (i.e., pressure and salinity) on the float, no requirement for VHF receiver equipment on the airplanes, and continued recording

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 for XBTs.

In total, 60 ALAMO floats were deployed during the 2014–2016 hurricane seasons. During 2014, six of the 10 floats (60%) launched returned usable data 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, 27 of 30 floats (90%) worked upon deployment, and in the final year (2016), 19 of 20 floats (95%) worked. Figure 3 shows an example of the data collected by ALAMO #9077, displaying a rapid depression of the thermocline, followed by inertial oscillations in the thermocline and mixing and cooling of the upper ocean after the passage of Hurricane Ignacio (see also Goni et al., 2017, in this issue, for other ALAMO hurricane observations).

ARCTIC OCEAN DEPLOYMENTS

ALAMO floats have been air-deployed in polar seas as well. Considerable effort was invested in the design and implementation of an ice-avoidance scheme. Profiling floats must surface to report their data and provide position information. Sea ice makes this difficult and hazardous for floats, as a float on the surface can easily be

FIGURE 2. (below) An ALAMO being loaded into the launch tube of a Hurricane Hunter C-130J. *Photo credit: Maj. Marnee Losurdo, USAFR* (left) An ALAMO after deployment from a NOAA Twin Otter. *Photo credit: Leah Chomiak, NOAA*

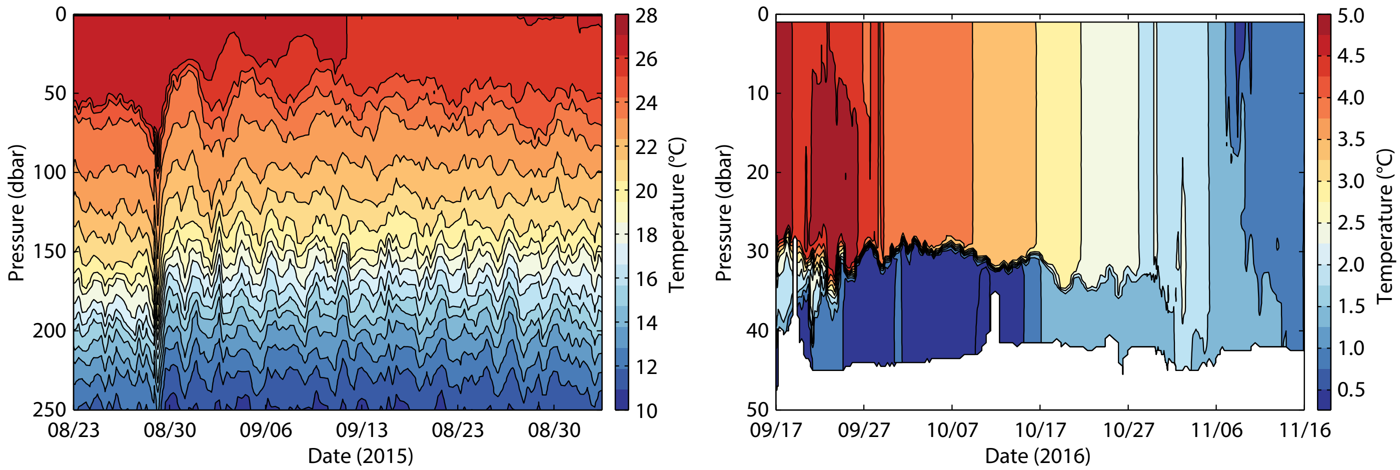

FIGURE 3. Examples of ALAMO observations. (left) ALAMO #9077 profiled the upper ocean response to the passage of Hurricane Ignacio on August 29, 2015, in the Pacific Ocean east of Hawaii. Profiles were made every two hours to 300 m water depth from August 23 to 29. (right) ALAMO #9085 measured the water column from the bottom to the surface in the Chukchi Sea from mid-September through mid-November 2016, providing four profiles per day.

crushed or otherwise damaged by ice. When sea ice is present, the floats use a two-phase ice-detection system to determine the conditions before attempting to surface. The first part uses a modified version of a scheme developed for use around Antarctica that is based on observing mixed layer temperature and salinity properties in order to predict the presence of sea ice (Klatt et al., 2007). The second phase is a multiple surface approach employed when there is a high probability of open leads. During ice-free periods, the floats function as normal profiling floats, periodically surfacing, sending back their data, and returning to the parking depth.

Two floats were deployed at the end of summer 2016 from the US National Oceanic and Atmospheric Administration's Twin Otter aircraft in the Chukchi Sea as part of the Arctic Heat Open Science Project (Figure 2). Program objectives are to monitor rates of upper ocean temperature change and water mass transformation over the summer season, from the time the sea ice begins to retreat in spring through freeze-up in autumn. Both floats survived the winter under the ice and found open water in spring 2017 as the marginal ice zone was retreating. The stored over-winter profiles are being transmitted as communications and conditions permit. Observations from one of those floats (ALAMO #9085, Figure 3) display a very sharp temperature stratification near the bottom that eroded away over the fall as the ocean cooled.

FUTURE DEVELOPMENTS

Work is underway to improve the capabilities of the ALAMO floats. Additional sensors already incorporated into the ALAMO include the RBR inductive CTD, Sea-Bird Electronics CTD (41CP+), photosynthetically active radiation, turbulent microstructure with Rockland Scientific's fast thermistor and velocity shear probes, and an inertial motion unit for measurement of the surface wave field's directional spectrum. Passive acoustics sensing, acoustic positioning and communications, and several bottom anchoring options are in development. Plots of data and tables of performance metrics can be seen at http://argo.whoi.edu/alamo.

REFERENCES

Davis, R.E., T.J. Sherman, and J. Dufour. 2001. Profiling ALACEs and other advances in autonomous subsurface floats. *Journal of Atmospheric and Oceanic Technology* 18:982–993, https://doi.org/10.1175/1520-0426(2001)018<0982:PAAOAI>2.0.CO;2.

Davis, R.E., D.C. Webb, L.A. Regier, and J. Dufour. 1992. The Autonomous Lagrangian Circulation Explorer (ALACE). *Journal of Atmospheric and Oceanic Technology* 9:264–285, https://doi.org/10.1175/1520-0426(1992)009<0264:TALCE>2.0.CO;2.

Goni, G.J., R.E. Todd, S.R. Jayne, G. Halliwell, S. Glenn, J. Dong, R. Curry, R. Domingues, F. Bringas, L. Centurioni, and others. 2017. Autonomous and Lagrangian ocean observations for Atlantic tropical cyclone studies and forecasts. *Oceanography* 30(2):92–103, https://doi.org/10.5670/oceanog.2017.227.

Klatt, O., O. Boebel, and E. Fahrbach. 2007. A profiling float's sense of ice. *Journal of Atmospheric and Oceanic Technology* 24:1,301–1,308, https://doi.org/10.1175/JTECH2026.1.

Mrvaljevic, R.K., P.G. Black, L.R. Centurioni, Y.-T. Chang, E.A. D'Asaro, S.R. Jayne, C.M. Lee, R.-C. Lien, I.-I. Lin, J. Morzel, and others. 2013. Observations of the cold wake of Typhoon Fanapi (2010). *Geophysical Research Letters* 40:316–321, https://doi.org/10.1029/2012GL054282.

Riser, S.C., H.J. Freeland, D. Roemmich. S. Wijffels, A. Troisi, M. Belbéoch, D. Gilbert, J. Xu, S. Pouliquen, A. Thresher, and others. 2016. Fifteen years of ocean observations with the global Argo array. *Nature Climate Change* 5:145–153, https://doi.org/10.1038/nclimate2872.

Sanabia, E.R., B.S. Barrett, P.G. Black, S. Chen, and J.A. Cummings. 2013. Real-time upper-ocean temperature observations from aircraft during operational hurricane reconnaissance missions: AXBT demonstration project year one results. *Weather and Forecasting* 28:1,404–1,422, https://doi.org/10.1175/WAF-D-12-00107.1.

Sanford, T.B., J.F. Price, and J.B. Girton. 2011. Upper ocean response to Hurricane Frances (2004) observed by profiling EM-APEX floats. *Journal of Physical Oceanography* 41:1,041–1,056, https://doi.org/10.1175/2010JPO4313.1.

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