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SIO 176
Due: 11 June 2020

Final Report - North Atlantic ARGO

A. Setting and Data

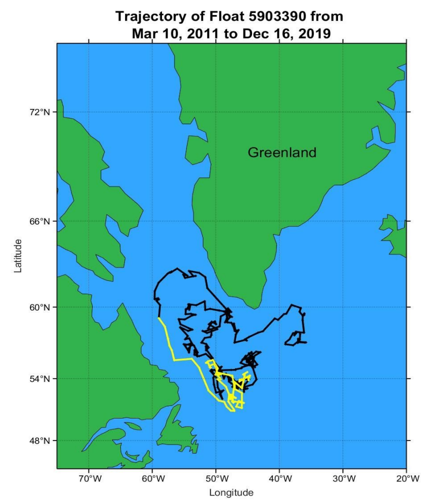


Figure 1: Trajectory of Argo Float in the Labrador and Irminger Sea from 3/10/11 to 12/16/19. Trajectory of data of interest in yellow.

1. **Float trajectory and data of interest:**
The float analyzed in this report is Float 5903390. It collected data in the Labrador and Irminger Sea from March 10th, 2011 until December 16th, 2019. The float was launched south of the tip of Greenland near 50°W, 54°N, and looped clockwise to the North entering the Labrador Current. After this, it continued to enter cyclonic motion until it reached the point southeast of the tip of Greenland near 35°W, 57°N. Our data of interest lies in the profiles that were taken by the float between January 2014 and January 2016, during which time the float collected 71 profiles. The trajectory of the float, including during the data of interest is shown in Figure 1.
Oceanographic circulation and water properties:

2. The Labrador Sea is an area of deep water convection as a result of the high density and cold waters at the surface constantly sinking into the abyss. The water sinking down in this area forms a deep water mass known as Labrador Sea Water and is characterized by salinity below 34.9 and a potential density between 27.6 and 27.9 $kg * m^{-3}$. Understanding the transport

of deep Labrador Sea Water is integral to understanding the trajectory of the float. Transport of Labrador Sea Water occurs at depths of 1000-2500m. Due to a large amount of eddy diffusivity and mixing at depth, there are three main tongues of deep water transport of LSW. One tongue in particular travels northeast from the southern Labrador Sea into the Irminger Sea, and it is this tongue of deep LSW transport that the Argo Float followed. There are additionally several surface currents in the area. The East and West Greenland Currents travel from east to west and round the tip of Greenland. The West Greenland Current then connects into the Labrador Current which travels south off the east coast of Canada near Newfoundland. The Labrador Current then connects to the North Atlantic Current travelling eastbound. These surface currents form a large cyclonic eddy type motion in the Labrador Sea area.

B. Analysis

3. Here, we analyze the data captured by our float from January 2014 to January 2016. We chose these years specifically because we identified a low temperature and low salinity anomaly at around the end of March 2014. The anomaly is seen extending from the surface to approximately 250m depth and is seen in the plots below. We decided to include data from 2015 to have it as a control to compare the anomaly to. Even in 2015, around March we observe a cool, fresh water anomaly although it is definitely not as distinct as 2014's.

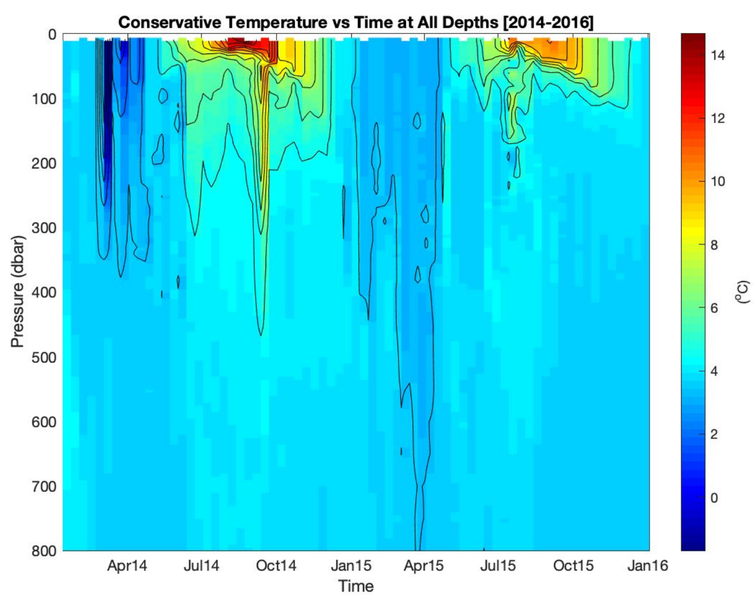


Figure 2: Conservative Temperature vs Time of ARGO profiles from 2014 to 2016 with a cutoff depth of 800m.

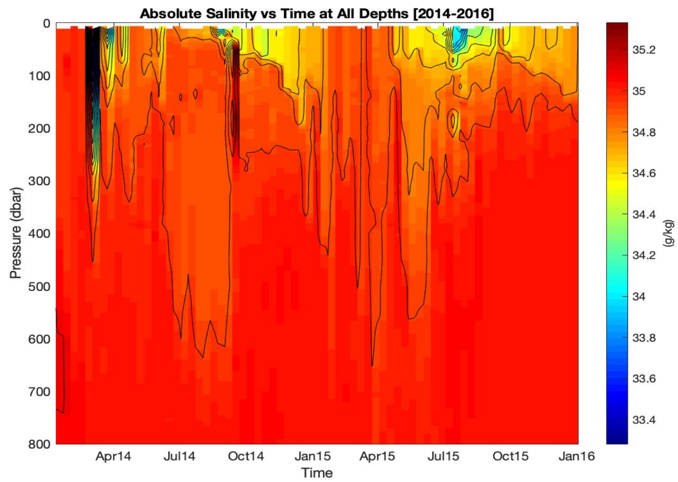


Figure 3: Absolute Salinity vs Time of ARGO profiles from 2014 to 2016 with a cutoff depth of 800m.

4. **MLD Criterion:**

The Mixed Layer Depth (MLD) has many definitions. The potential temperature (PT) definition is the point at depth which differs from 0.2C from the surface and the potential density (sigma0) definition which is the point that differs from 0.01kg/m3 from the surface. These values were taken from a paper by Brandt et al., where this definition of MLD is used in the Labrador Sea, the same region where our float is. The PT definition was not identified in this paper however, after looking through many different sources, the most used definition for MLD based on PT was 0.2C which is what we decided to use.

Evolution of MLD:

We see the MLD follow a seasonal cycle, with a minimum during the summer months and a maximum during the winter season. More specifically, the MLD starts forming at the beginning of January and reaches a maximum at the end of March.

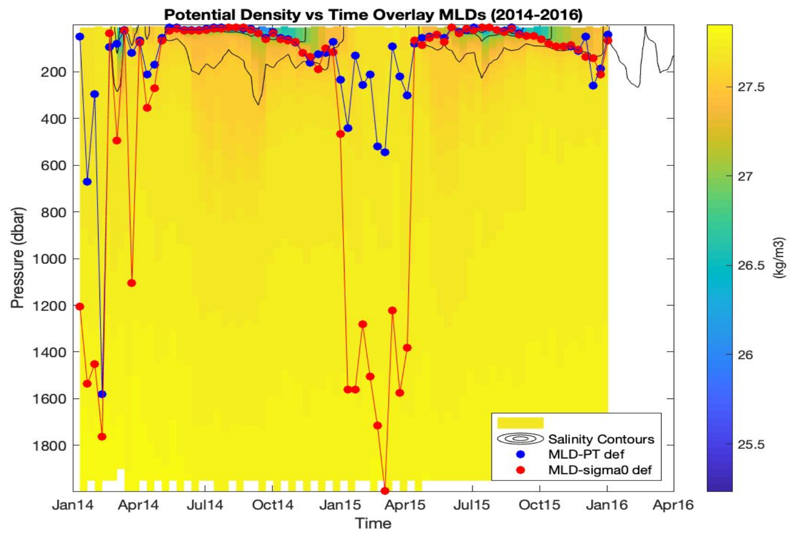


Figure 4: Absolute Salinity vs Time of ARGO profiles from 2014 to 2016 overlaid with Mixed Layer Depths definitions: PT and sigma0.

5. Drivers for the observed MLD (*Ignore Jan16-Apr16 cutoff on plot)

Oftentimes, you don't see a mixed layer depth greater than 1000m, but in the Labrador Sea during the winter season, the plots show MLDs greater than 1000m even reaching down to ~2000m. We hypothesized that this was the result of our location being a Deep Water formation region. The surface water at the start of January starts experiencing extreme oceanic heat loss and thus cools, becoming denser than the surrounding waters. The heat loss is due to the atmosphere being colder than the water, thus heat is lost to the atmosphere. The result is deep ocean convection and the transformation of surface water into Labrador Sea Water (LSW) or the upper part of the North Atlantic Deep Water (NADW) mass. This coincides with the paper by Brand et al., where they identify this same mechanism and observe MLD's up to 1600m deep. Thus, we believe the MLD-sigma0 definition is the more accurate parameter that defines the Mixed Layer Depth because the MLD-PT definition cuts off before 1000m at many of the years. We also display a TS plot in which you can easily identify the deep waters by the blue. At the bottom left of the TS plot, we also notice the cold (less than 0C), fresh anomaly in the winter of 2014, which we will discuss next.

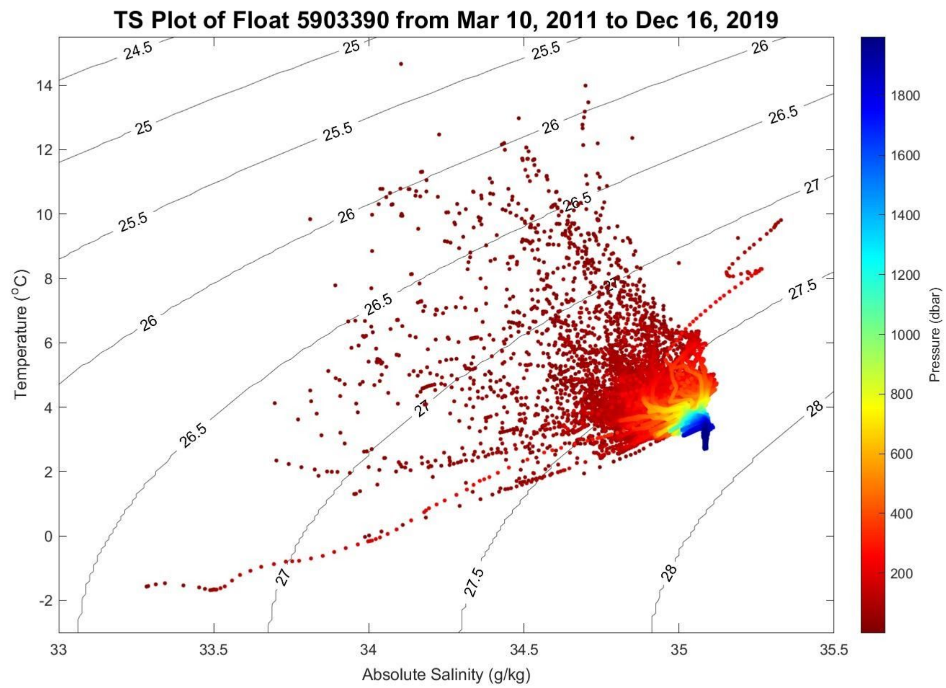
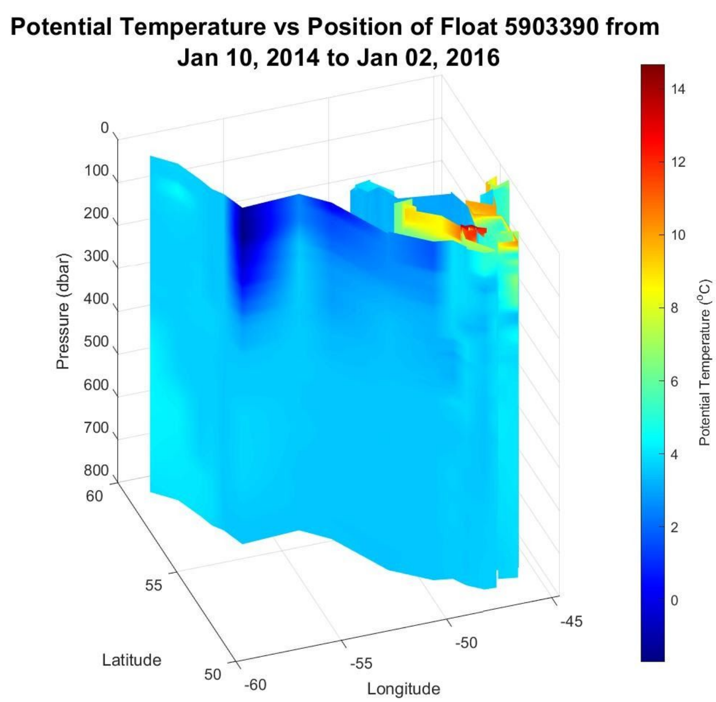
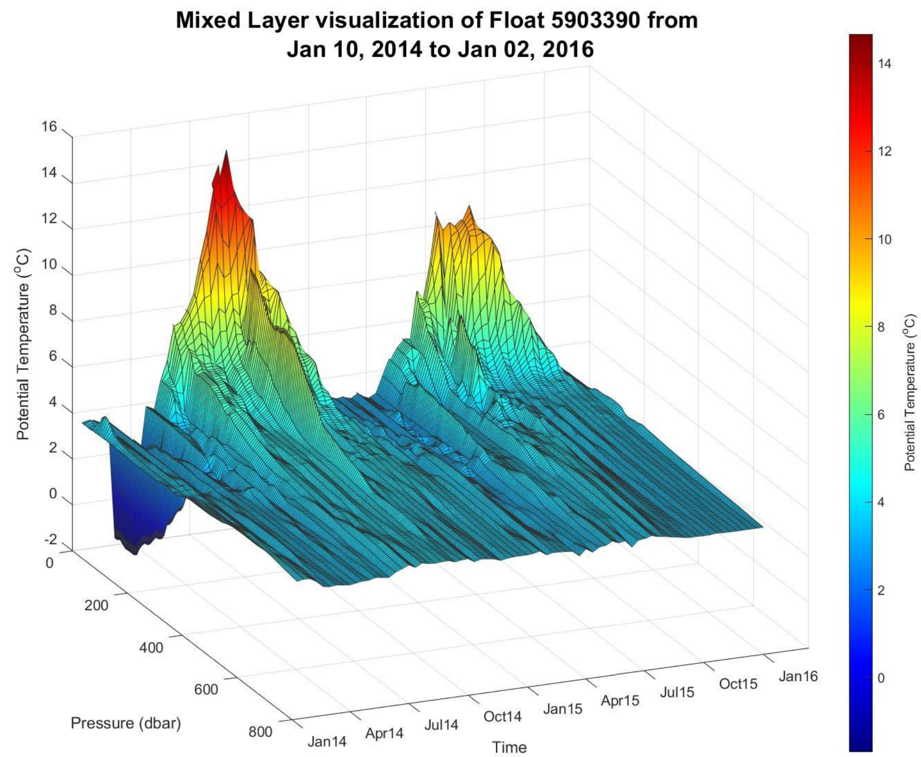


Figure 5: Absolute Salinity vs Conservative Temperature of all data collected from ARGO Float 5903390.

6. Data anomaly

A cold water anomaly was discovered in March 2014. While it is expected to have deep mixed layers in winter, the anomaly of this magnitude has been unparalleled in the 9 years our float has been collecting data. Water down to 200m was below 0°C. Figure 6 is a map to show the region of interest for the following. When first analyzing the data, it is clear that this event was short lived, but incredibly powerful. No other winter cycle had temperatures that got as cold as this anomaly. The following 3d Figure better demonstrates just how uncommon this cold feature is.





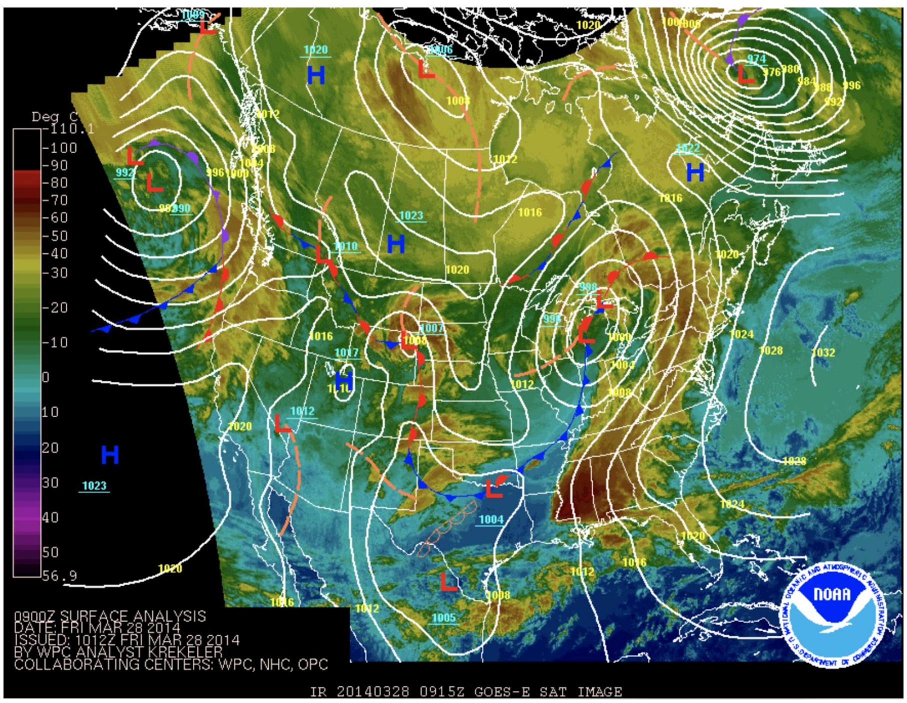
3d visualization of the mixed layer depth, in which the blue outlier is clearly visible.

Figure 7 combines

C. Discussion and Conclusion

As demonstrated by the PT and Salinity graphs in section B, the labrador sea is a clear deep water formation site that is crucial to the NADW and LSW present in the North Atlantic. The extreme atmospheric forces in this region, freezing and wind, suck the heat out of the mixed layer every fall, and act as churners during the winter. There is even possibility of cyclones inputting even more cold water into the sea, as demonstrated by the 2014 anomaly.

After conducting more research to find the source of the anomaly, we found a very powerful midlatitude cyclone that corresponded with the date the argo surfaced. The effects of this storm are felt even 30 days after it occurred, leading us to believe a significant amount of hail or snow was deposited into the sea. This is reinforced by the freshwater input as seen on an earlier salinity graph.



NOAA Radar imagery depicting the "BOMB" low pressure cyclone in the top right.

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Talley L.D., Pickard G.L., Emery W.J., Swift J.H., 2011. Descriptive Physical Oceanography: An Introduction (Sixth Edition), Elsevier, Boston, 560 pp.

https://www.nnvl.noaa.gov/view/#TRUE?timespan=daily&date=2014-03-26&lat=36.915467625897&lon=-63.857203886384&zoom=4 -- NOAA NNVL which archives visible satellite imagery of the March 27-28, 2014 mid-latitude cyclone we believe caused the fresh, cold water anomaly.