A Comparative Assessment Between Two Depth-Profiling Systems on Ocean Salinity, Temperature, and Velocity off Hawaiian Coast

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Abstract:

Argo and APL's (Applied Physics Laboratory) EM-APEX (ElectroMagnetic Autonomous Profiling Explorer) floats are deployed to collect vertical measurements of ocean properties to improve general understanding of processes largely related to climate change ramifications, currents, and atmospheric-sea interactions. The global Argo network operates 3000 floats that dive every 10 days, capturing baseline CTD (conductivity, temperature, depth) measurements down to 2000m and velocity estimations based on distance displacement and time between float emergence at the surface. Comparatively, EM-APEX floats specialize in direct measurements of velocity using electrodes and rapid CTD sampling at a shorter 5–7-day interval, providing complementary higher resolution data. Our project assesses means of comparing and integrating trajectory, CTD, and velocity graphs, and to graphically compare low- and high-resolution velocities. We found that standard ocean conditions remain prominent (velocity and temperature decrease with depth, while salinity increases), uncertainties due to inexact float matches arose, and more insight was gained on differences between datasets. The next steps to consider are analyzing other APL floats to provide a more global representation of connection with Argo, and to compare Argo's historical data in similar temporal bounds to better distinguish between natural and resurfacing-time variability from EM-APEX and Argo floats, focusing on a region between Hawaii and California from 2017-2019. We are using the Python programming language to navigate the Argo and APL databases for broadly coincident floats, to distinguish the mixed (upper) layer from the lower layer of the water column via CTD depth-profile.

Background:

Argo is an international collaboration (Fig. 3) that has been deploying autonomous profiling floats throughout the world's oceans since 1999, with the overall objective of improving our quantitative understanding of the ocean interior and air-sea climate variability and interactions. Argo data is free and publicly available.

EM-APEX floats profile autonomously but are more localized and less coordinated with a narrower objective of determining how internal waves transfer heat, energy, nutrients, and chemicals. We focused on one area in 2017 with three deployment regions of EM-APEX floats known as the SMILE experiment.

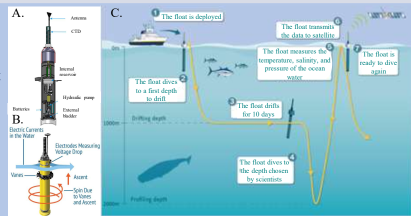
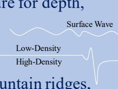


Figure 1: A. An internal diagram of a basic Argo float compared to[1] B. An external diagram of an EM-APEX float and it's velocity measurement system[2] C. How autonomous profiling floats operate[1]

Table 1: Comparing Argo & EM-APEX Pros/Cons

Argo Pros	Argo Cons
• CTD) data spans over two decades providing global historical context • Quality control and visuals for data is well organized and accessible	• 10-day measurement cycle averages out daily or monthly phenomena • ANDRO[3] project coarsely calculated velocity for surface and 1000m vs. direct measurements (Fig. 1)
EM-APEX Pros	**EM-APEX Cons**
• Shorter 5-7-day interval allows detection of short-lived phenomena • Velocity measurements are direct measureme nts, increasing resolution of Argo data	• Not as global or coordinated as Argo • Not as long-lived • This project's focus floats only went 250m deep

What is an autonomous profiling float?
A vehicle that vertically traverses and samples the water column without a ship or human operator. Oil is pumped in and out of external and internal reservoirs to change volume and density to increase or decrease ocean water. They often carry sensors to measure pressure for depth, conductivity for salinity, temperature and more. (Fig. 1)



What are internal waves?
Driven by sea surface wind, sea surface topography (mountain ridges, trenches, etc.), tides from the Moon and Sun, and forces like the Coriolis effect from Earth's rotation, these waves are instances where low-density and high-density water masses rebalance after displacement.

What is an eddy?
An eddy is a slowly evolving circular current that has a lifetime of about a month typically caused by internal waves being canceled out or reaching a state of pressure and density balance (geostrophic balance).

What is the mixed layer?
A dynamic region a couple hundred meters from the surface that has uniform temperature, salinity, and density due to mixing from surface wind and heat transfer processes.[4]

Project Objectives:

To develop insights and strategies for comparing and integrating EM-APEX and Argo data by:

1. Comparing Temperature-Salinity (T/S) and CTD diagrams of Argo floats with the same temporal bounds in 2017 as Region 2 of EM-APEX floats (Fig. 4) and determine what month the mixed layer increases and decreases significantly
2. Examining T/S and CTD diagrams of the same Argo floats (Fig. 4) to see if there are any steep changes in the CTD data that imply warm and salty water is on cold and fresh water ("salt finger" phenomenon).
3. Providing EM-APEX data as a "zoom in" of one month of the Argo data and displaying how that EM-APEX data gives higher resolution of the mixed layer.
4. Showing what an eddy signature looks like in EM-APEX data (specific to CTD and TS cycle) and Argo data.
5. Contrasting the velocity calculation and standard deviation of any Argo float that aligns with the eddy and velocity of EM-APEX data.

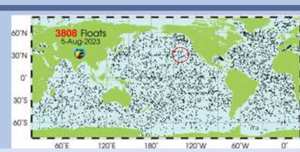


Figure 3: Number of active Argo floats this month, and location of focus on a world map.[1]

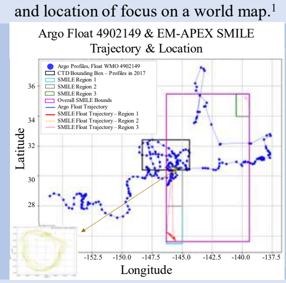


Figure 4: Trajectory of focus Argo float and EM-APEX deployment regions and trajectories; bottom left is a zoom in of the eddy in Region 2.

Highlights

Different ocean float datasets complement each other with CTD and velocity measurements while:

- Telling a story about physical oceanic properties influencing climate change
- Making complex data readable and accessible
- Discovering answers to questions we did not begin with

Methodology:

Conceptual Research to understand data management, ocean/float mechanics, and mission.

Python Research to build skills in using libraries, environments, and git/GitHub

Narrow Question Focus & Approach
Make initial visual comparisons between two Argo floats and Region #1 & 2 of SMILE in 2017 and explore other overlaps when graphing.

Import & Process Argo & ANDRO data from ARGOPY Python package & **reorganize** for easier indexing

Import & Process EM-APEX data, **reorganized** and combined for easier indexing/plotting

Graph, Design, Compare
CTD, T/S, trajectory, and velocity plots using Python in JupyterLab.

Results:

1. Normally, the mixed layer increases in the fall and decreases in the spring. For float 4902149, the transition of shrinking to growing was from May to June (normal)(Fig. 5, 6, & 10)

2. Salt fingers detection is inconclusive from a visual inspection (Fig. 5, 6, & 10)

3-4. EM-APEX provides more data for 0-250 dbar, and that the eddy can be seen in EM-APEX Fig. 7 & 10a, but not in Argo data (Fig. 6a & 10b)due to being filtered out by location/time of data collection (Fig. 7, 8, & 10)

5. There was no floats in ANDRO data intersecting Region 2 (the eddy) of EM-APEX data; velocity data for Region 1 demonstrated the higher resolution data EM-APEX (Fig. 8 & 9)

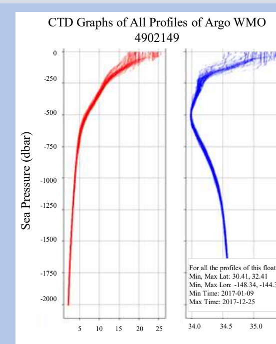


Figure 5: Temperature and Salinity plotted against depth of Argo 4902149 with all profiles in 2017.

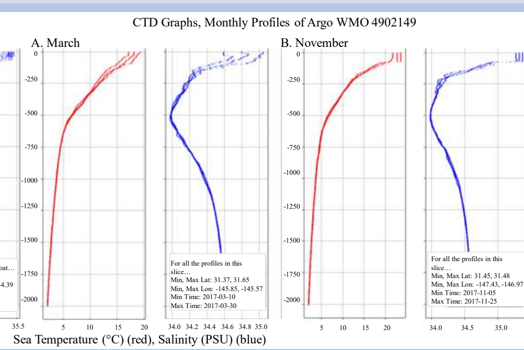


Figure 6: Temperature and Salinity plotted against depth; A. represents all profiles in Argo 4902149 that launched in March 2017, B. represents all profiles in the same float that launched in November 2017.

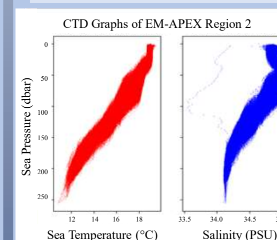


Figure 7: Temperature (red) and Salinity (blue) plotted against depth of Region 2 of EM-APEX floats

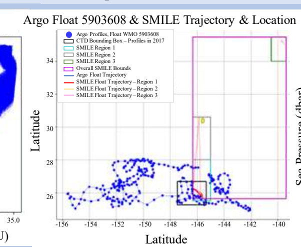


Figure 8: Trajectory of Argo float 5903608 that intersects Region 1 of EM-APEX trajectory (black box is 2017).

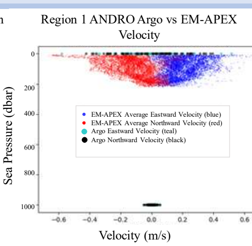


Figure 9: Estimated ANDRO velocities compared with EM-APEX Region 1.

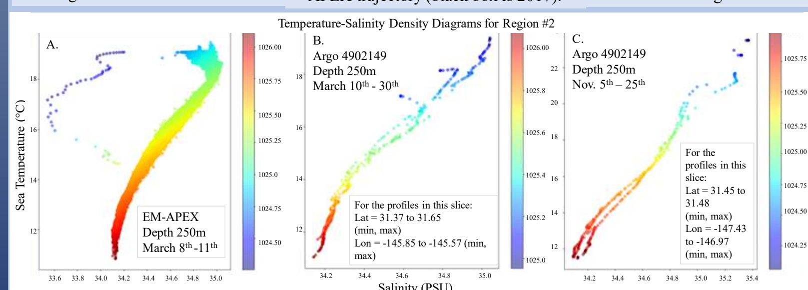


Figure 10: Temperature-Salinity (T/S) diagrams color coded by density calculated in the seawater Python package using T/S; A. represents all profiles in Region 2 of EM-APEX floats, B. represents all profiles of Argo 4902149, March 2017 and intersected EM-APEX Region 2, C. represents all profiles of the same Argo float in November 2017.

Future Work:

- Apply the same CTD, T/S, and velocity comparisons with other Argo and EM-APEX floats from 2017.
- Use Argo data to historically contextualize EM-APEX data, 5, 10, 20 years prior.
- Develop and/or apply an algorithm to better identify salt fingers phenomenon and the mixed layer
- Create a GUI (graphic user interface) that splices together EM-APEX and Argo data
- Apply ANDRO algorithm to float 4902149 and determine whether greater standard deviation implies eddies

Acknowledgements & References

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1. "This data was collected and made freely available by the International Argo Program and the national programs that contribute to it. (https://argo.ucsd.edu, https://www.ocean-ops.org). The Argo Program is part of the Global Ocean Observing System." Argo (2017). Argo float data and metadata from Global Data Assembly Centre (Argo GDAC). SEANOE. https://doi.org/10.17882/42182
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4. Kantha, L, *et al.* 2003. Ocean Mixed Layer. Elsevier Science, 291-298.