River-Shelf-Basin Interactions in the Eastern Beaufort Sea: Initial glider results from the Marine Arctic Ecosystem Study

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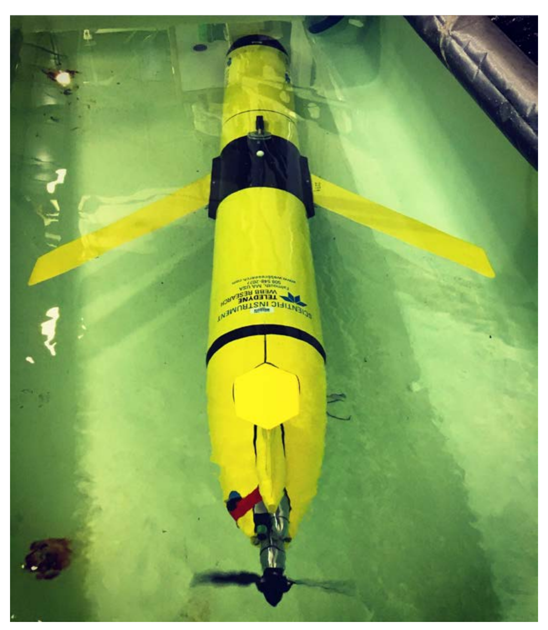
Introduction:

Submarine canyon, valley, and trough regions along continental shelves are regions of active shelf-basin interactions. Traditionally gliders have not been used for studying such regions, especially in the polar oceans due to challenging conditions such as freshwater lenses, strong currents and tides, rapidly changing bathymetries, and potential for sea ice. Employing new glider technologies such as large buoyancy pumps and hybrid thrusters, the Coastal and Polar Physical Oceanography lab (C2PO) explored the Mackenzie Canyon/Trough on the eastern Beaufort Shelf in detail as part of the BOEM-funded Marine Arctic Ecosystem Study (MARES).

MARES is an integrated ecosystem research initiative that aims to better understand the linkages between marine life, human uses, sea ice, atmospheric and oceanic processes and river discharge in the eastern Beaufort Sea. As part of this study, an underwater glider was used to characterize the physical oceanographic environment and the bio-optical properties of the water column over the eastern Beaufort shelf and in the Mackenzie Trough. The glider study was conducted during the summer of 2016 with the assistance of US and Canadian partners. The study aims to significantly advance our understanding of the exchange processes between the Mackenzie River, the shelf, and the Beaufort Sea, and the assess the impacts of the exchange on the ecosystem.

Operations:



The VIMS C2PO lab utilized a hybrid thruster equipped 200 m Slocum glider with an 800 cc extended buoyancy pump. Sensors on the glider included: CTD, Ecopuck (Chl-a, CDOM, Backscatter), DO, PAR, and 120 kHz echosounder. The glider was powered by lithium primary batteries.

The glider was deployed from a coastal vessel at the shelf-break off Kaktovik, AK (R/V Ukpik). The glider traversed into the study region centered on the Mackenzie Trough in Canadian water over a 6-day period. The glider completed 3 full repeat surveys of the Mackenzie Trough with a focus on its western portions over the course of 52 days. The glider was recovered by Canadian partner from the Institute of Ocean Sciences and WHOI scientists during the mooring deployment phase of MARES.

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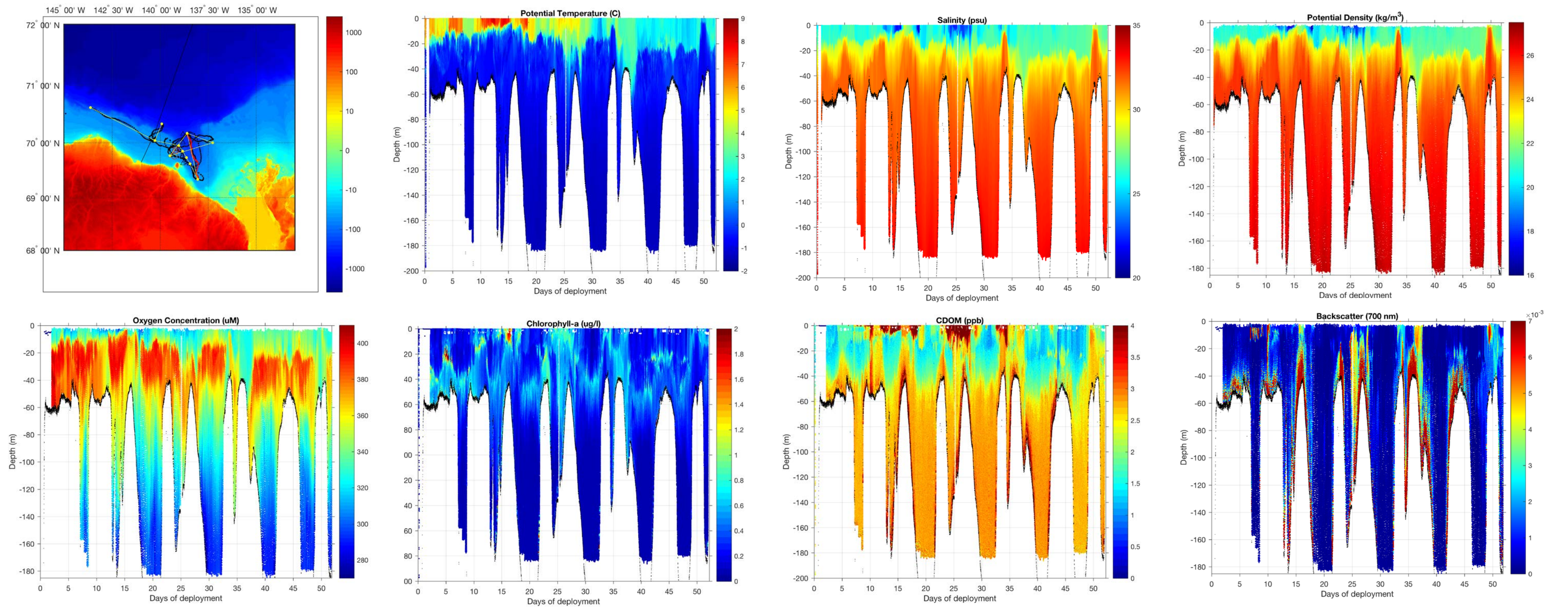
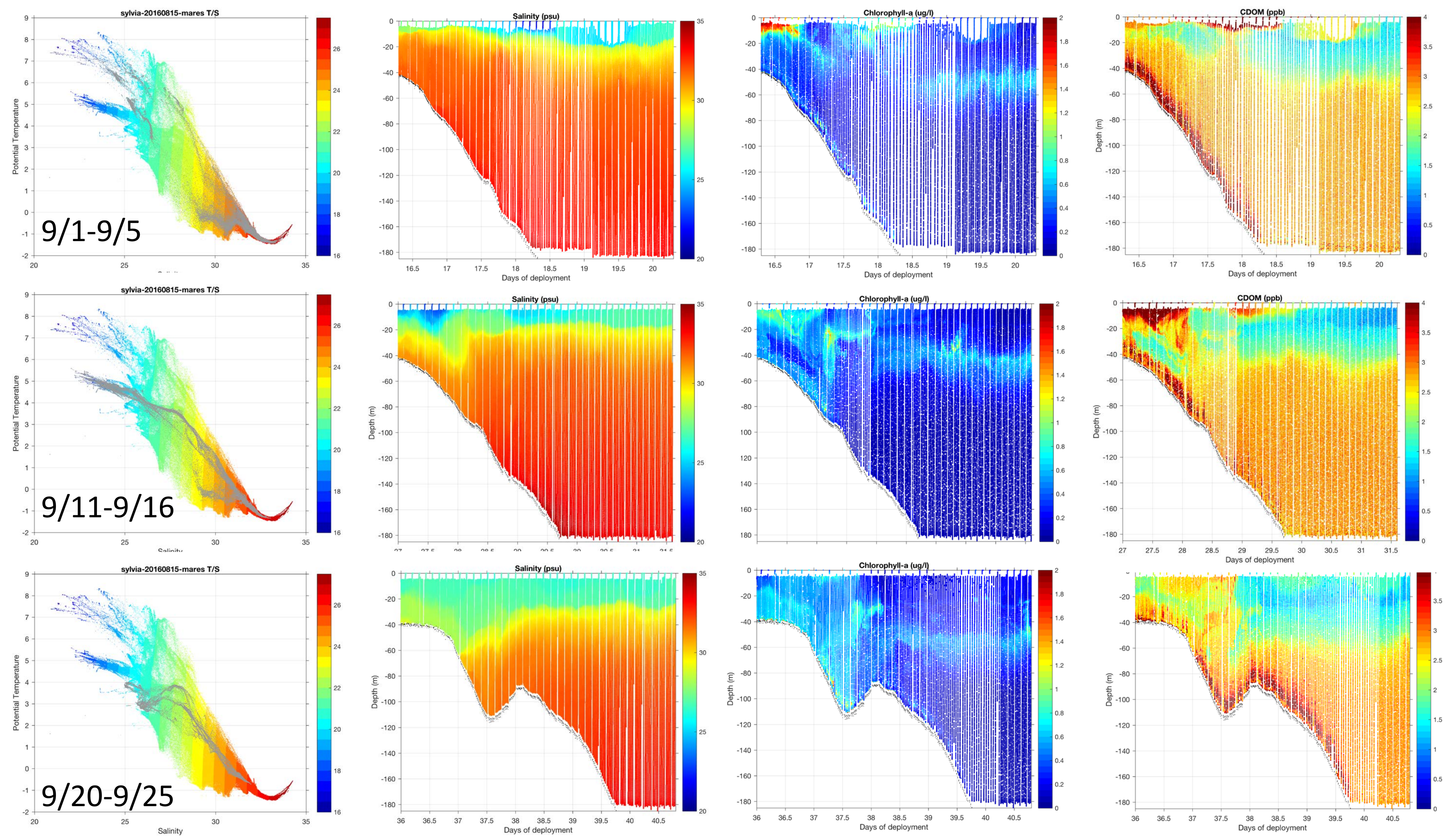
2. *Woods Hole Oceanographic Institution*
3. *Stantec Consulting Services Inc.*

Mackenzie Trough (MT) Glider Observations:



Temperature data shows seasonal cooling and deepening of the surface mixed layer from mid-August to early October. Fresh (S<25) riverine water from the Mackenzie was found throughout the western flank of the Mackenzie Trough in early September, disappears in the second half of the deployment. Dissolved oxygen data indicate well-oxygenated water in the upper 70 m of the water column with highest values between 10 and 60 m. Chlorophyll-a fluorescence is highest near the surface (upper 20 m) on the shelf, while off the shelf-break mid-water maximum is consistently found between 40 and 60 m. High CDOM fluorescence correspond to either river water or Pacific waters below the seasonal pycnocline. Wind-driven mixing brings Pacific water to the surface and onto the shelves. Backscatter data indicate a persistent sediment layer 10-20 m thick near the bottom.



Three repeat along-canyon axis transects captured the intra-seasonal evolution of freshwater from the Mackenzie River and water column chlorophyll concentrations. Between 150 m and 1000 m isobaths, the surface mixed layer depth was consistently around 20 m. Freshwater from the Mackenzie River was observed to extend up to 80 km from the head of MT, particularly in early September. Shoreward of the 150 m isobath, the pycnocline varied significantly from one section to the next with signs of internal waves with amplitude of 40 m that mixed surface riverine water with Pacific water below the pycnocline. A chlorophyll maximum was found near the surface at the head of MT, while sub-surface chlorophyll maximum between 40 and 60 m was found further offshore. T/S plots from the three periods indicate evolving riverine water end member properties in response to atmospheric cooling, oceanic mixing, and advective forcings.

Working Hypotheses:

- Mackenzie River plume strongly affects the stratification and bio-optical properties of the surface mixed layer.
- Buoyancy driven flow helps with the initial spread of the fresh Mackenzie water at the head of the MT.
- Wind driven mixing and upwelling can bring Pacific water into the mixed layer and on the shelf.
- Steep bottom topography and rapidly varying shelf width along the western portion of MT leads to a sharp frontal boundary and strong currents.
- Energetic events such as storms and internal waves can significantly affect the coupled dynamics in the MT region.

Discussion:

- Mackenzie Trough and the surrounding regions are dynamically complex and strongly influenced by the Mackenzie River plume.
- River-shelf-basin exchange is strongly affected by seasonal heating/cooling, wind driven mixing, and frontal dynamics. However, other processes such as internal waves and lateral advection could also play important roles in the eastern Beaufort Sea.
- There is a sharp difference between water column structure on the shelf versus in the basin, both in terms of the physics as well as the biology. This sets up strong property gradients at the shelf-break front.
- The glider sampling platform with extended buoyancy drive and hybrid thruster has proven to be an effective tool for studying the energetic shelf-break and submarine trough/canyon regions in the Arctic. The extended seasonal deployment effectively captured the changing system dynamics over time.
- A well-instrumented glider enables multi-trophic level investigations through the entire open water season.
- MARES program, focusing on the Mackenzie Trough region, also includes ship-based sampling and moorings in addition to the glider observations. Data collection and analysis are ongoing and synthesis take place after the moorings are recovered in 2018.

Next steps:

- Detailed investigation of the shelf-break frontal kinematics and dynamics at different parts of Mackenzie Trough over the course of the deployment.
- Investigate how external forcing factors such as winds, sea surface height variability, solar insolation, and lateral advection affect the physical and biological variability of the water column.
- Investigating the dynamics of lower trophic levels by combining chlorophyll-a, dissolved oxygen, PAR, and echosounder data.

Acknowledgement:

The authors thank the funding agency BOEM for the support of this important study despite the numerous challenges. The authors would also like to thank the various governmental and corporate partners including the Institute of Ocean Sciences in Canada, U.S. Coast Guard, Canadian Coast Guard, ASL Environmental, Transgroup Logistics, CLS America, Teledyne Webb Research as well as crew of R/V Ukpik and crew of the CCGS Sir Wilfrid Laurier who all have helped to make the field work successful.