Closing the mass budget in Barrow Canyon using shipboard and glider data

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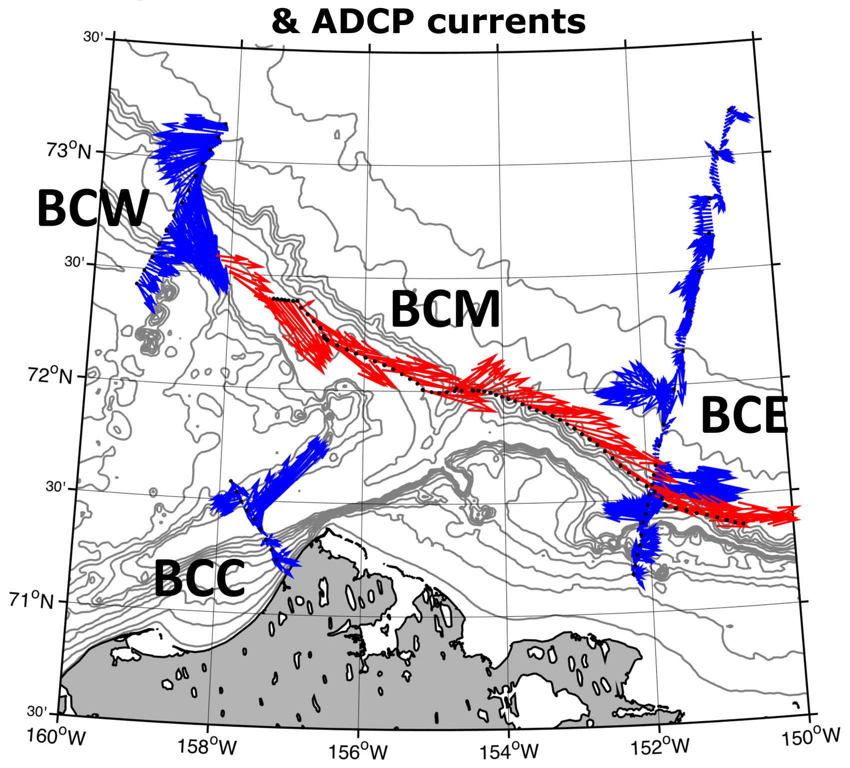
Fig 1: Barrow Canyon CTD Stations & ADCP currents



Abstract

The transport of Pacific water through Barrow Canyon has a significant impact on the heat and freshwater budget of the western Arctic basin. For example, late-fall transport of warm summer Pacific water through the canyon can lead to delayed sea-ice formation. Using a combination of shipboard and glider hydrographic survey data from October 2012, we calculate the volume transports for flows into and out of the mouth of Barrow Canyon. We find that in order to balance the volume transport into the basin at the mouth of the canyon, the eastward flowing shelf-break current to the west of Barrow Canyon must significantly contribute to the along-canyon flow. We also find that the hydrographic structure of the shelf-break front is much more variable to the east of Barrow Canyon than it is to the west. This suggests that there is a strong asymmetry in the stability characteristics of the shelf-break frontal jet on the two sides of Barrow Canyon.

Data & Methods

The data for the study were collected during October 2012 aboard USCG icebreaker *Healy* and from a Slocum glider. The absolute geostrophic velocity are calculated for four sections: Barrow Canyon West (BCW), Barrow Canyon East (BCE), Barrow Canyon Center (BCC), and Barrow Canyon Mouth (BCM) using the shipboard hydrographic and ADCP data (Figure 1, blue sections) as well as glider hydrographic and depth-integrated current data (Figure 1, red section). To obtain the absolute geostrophic velocity, the thermal wind calculated from the potential density sections are referenced to either the shipboard ADCP or the glider depth-integrated velocity data.

Fig 2: Barrow Canyon T/S

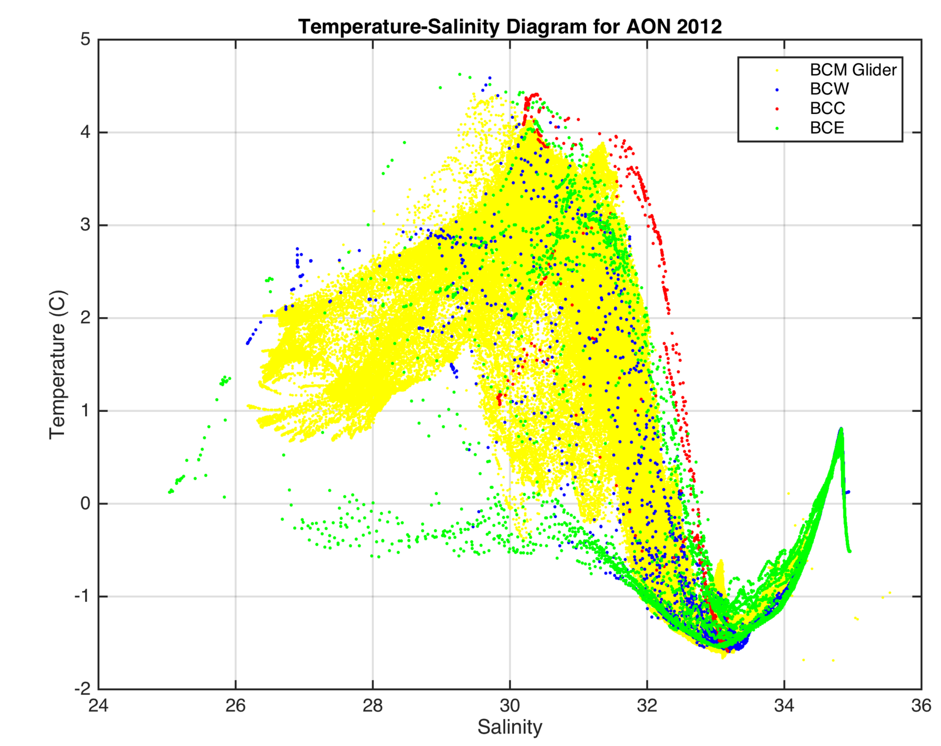


Fig 3: Absolute Geostrophic Velocities

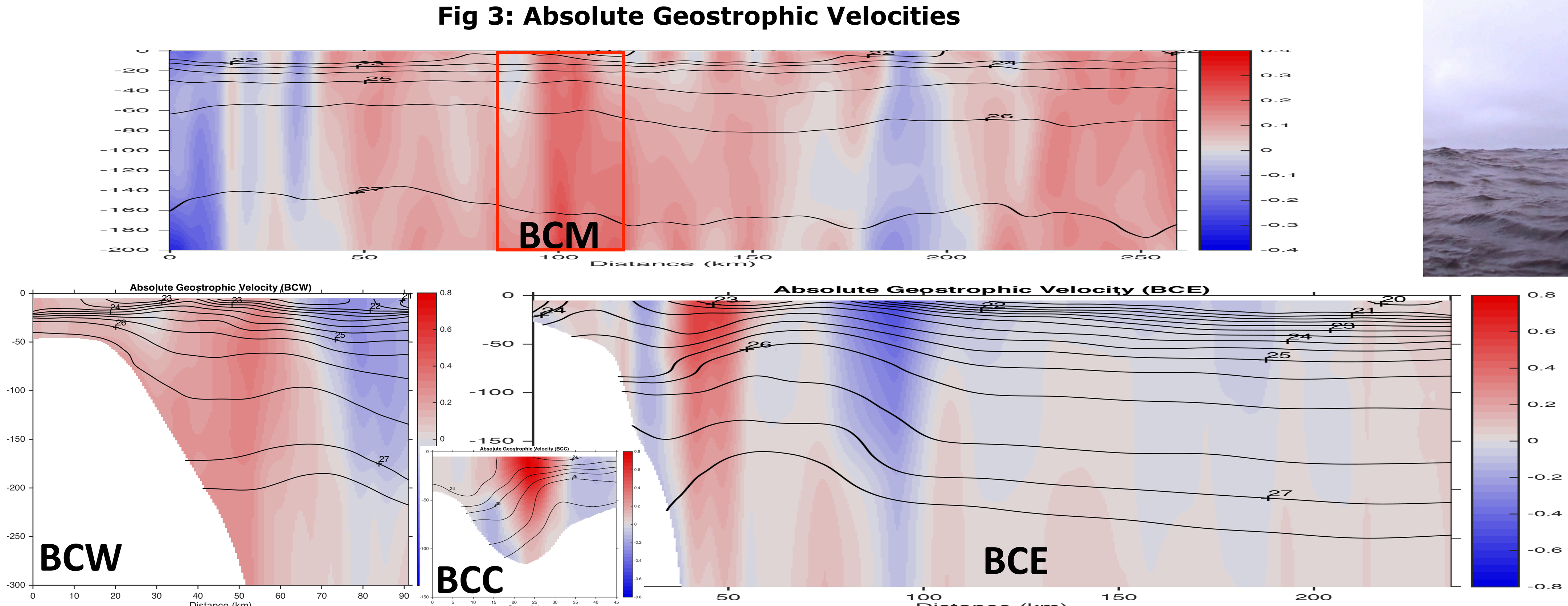
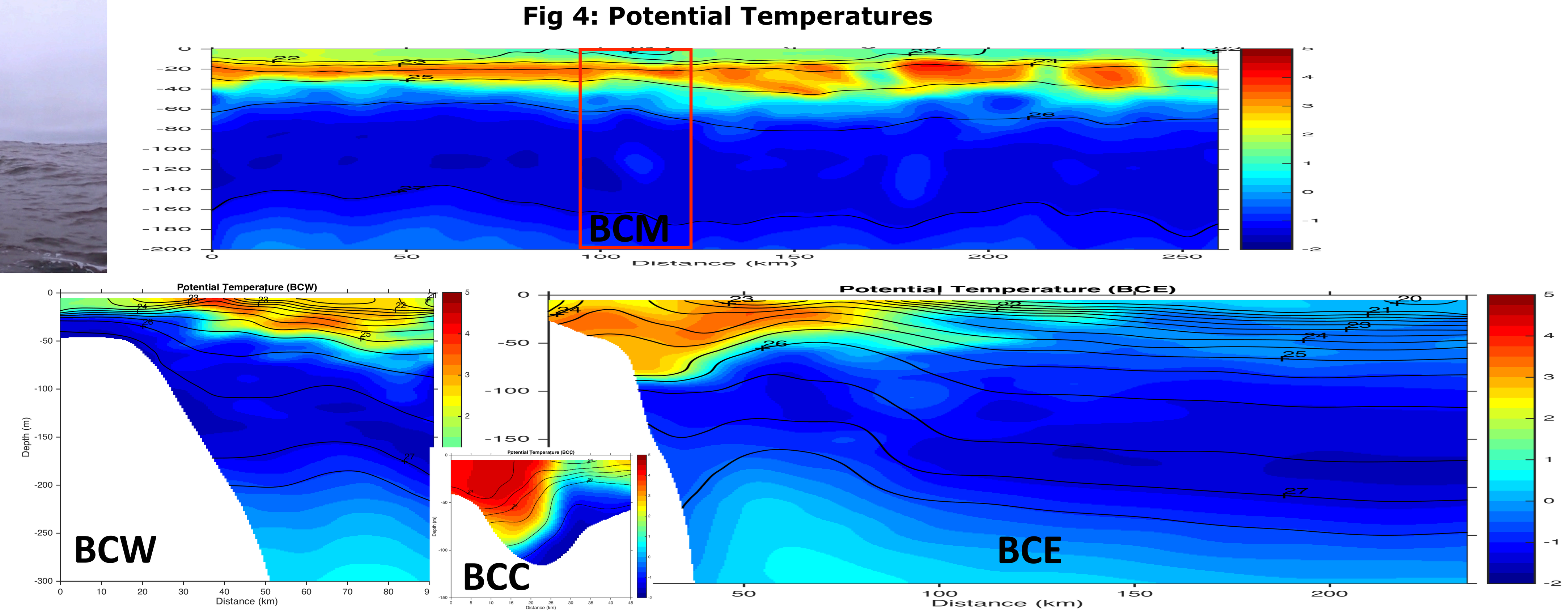


Fig 4: Potential Temperatures



Synoptic flow and volume transport

BCC:

- Northward flow down the center of Barrow Canyon with a maximum flow speed of 80 cm/s.
- Up-canyon flow on both the western and eastern flanks of Barrow Canyon with flow speeds in excess of 10 cm/s.
- Notably, the flow out of Barrow Canyon is not attached to either flank of the canyon.
- The net transport associated with the BCC section is 0.34 Sv poleward.

BCW:

- There is a broad band of strong eastward flow over the upper Chukchi Sea slope with a maximum flow speed in excess of 30 cm/s at a depth of 50 m. The eastward flow extends down to depths exceeding 300 m.
- Offshore of the shelf-break and slope, there is a westward surface-intensified flow with a maximum flow speed in excess of 25 cm/s. The transect does not completely capture the band of westward flow.
- Associated with the eastward and westward flows is a doming of the isopycnals suggesting a cyclonic eddy with a radius of 20-30 km. The spatial depth-averaged flow is consistent with the existence of a cyclonic eddy.
- The net transport associated with the BCW section is 1.4 Sv eastward. However, since the section does not fully capture the westward flow of the eddy, we estimate an adjusted net eastward transport of 1.0-1.2 Sv.

BCE:

- There is a complex flow pattern with alternating E-W flow. Over the shelf and shelf-break, the flow is weakly eastward with a maximum flow speed of 4-6 cm/s.
- The flow over the upper slope at the 150 m isobath is a narrow band (~10 km) of westward flow throughout the water column with a flow speed of approximately 10 cm/s.
- The dominant pattern over the mid- to lower-slope is two strong bands of alternating flow: eastward flow inshore, and westward flow offshore. Both bands have comparable speeds of 50 cm/s, although the westward band is wider (25-30 km) versus the eastward flow (15-20 km).
- As was the case at BCW, the eastward and westward alternating flow is associated with a doming of the isopycnals that suggests a cyclonic eddy is also present at this transect with a radius of 30-35 km.
- The net transport associated with the BCE section that includes both sides of the eddy is 0.27 Sv eastward.

BCM (glider):

- Along the Chukchi and Beaufort shelfbreaks, the flow is mainly eastward.
- Relative to the mean angle of shelf-break isobaths along the glider section, the cross-isobath flow is directed mostly offshore except at the western-most part of the section over the Chukchi shelfbreak.
- As the glider crossed Barrow Canyon it experienced strong down-canyon flow extending over the full sampling depth of the glider (200 m) with a maximum flow speed in excess of 30 cm/s. Interestingly, the flow has both surface and 'bottom' intensification.
- The net transport associated with a 50 km along-shelfbreak segment centered on Barrow Canyon Mouth is 1.2 Sv.

Synoptic Transport Budget: The total inflow into Barrow Canyon (BCW + BCC) is 1.5 Sv +/- 0.2 Sv, and the outflow from Barrow Canyon (BCE + BCM) is also 1.5 Sv +/- 0.2 Sv.

Water masses and large cyclonic eddies

Water masses:

- Even in mid-October, Alaskan Coastal Water (ACW) (T > 3 C) is present at all the transects (Figure 2). This suggests that ACW is being advected to the regions due west of Barrow Canyon and due east of Barrow Canyon.
- Summer water dominates the shelf and shelf-break on the eastern side of Barrow Canyon (Figure 4). The summer water appears to be transported by the coastal boundary current along the Beaufort shelf/shelf-break. There also appears to be an offshore flux of warm summer water from the boundary current consistent with von-Appen and Pickart (2012).
- Summer water is only found offshore of the shelfbreak on the western side of Barrow Canyon. It appears to be associated with the cyclonic eddy over the slope.
- Cold Pacific Winter Water (PWW) (T < -1 C) is also present in all four transects (Figure 2, 4). This suggests that the surface intensified current in Barrow Canyon is transporting both warm ACW and PWW from early summer to early fall, consistent with the summer time climatology Barrow Canyon transport (Gong and Pickart, in press.).

Large cyclonic eddies:

- We sampled two large cyclones near the shelf-break on the transects due west and east of Barrow Canyon (Figure 3).
- The two cyclonic eddies on both sides of Barrow Canyon are nearly twice as large (50-70 km in diameter) as the typical eddies found in the Beaufort Sea (~30 km) (Pickart et al., 2005).
- Unlike the anti-cyclonic eddies found by Pickart et al. (2005) downstream of Barrow Canyon, these two eddies are cyclonic and have a deep doming isopycnal signature that extends to depths beyond 300 m.
- The transport associated with the cyclone circulation is 1.4 to 2 Sv in the upper 300 m of the water column.
- Warmer Atlantic Water is elevated by nearly 100 m at the core of the cyclonic eddies to depths shallower than 200 m.
- The observation of large cyclonic eddies in this region is quite rare, and the formation mechanism is currently unknown. We hypothesize that they spin up by stretching of the water column as the flow exits the central portion of Barrow Canyon (Figure 4, BCC section).
- Notably, easterly wind is likely required to cause the outflow from Barrow Canyon to head directly offshore (versus turning eastward along the Beaufort shelfbreak). Easterly winds were observed for extended periods of time during the October 2012 cruise.

Boundary Current Variability:

- The along-shelfbreak glider sections show more hydrographic variability in the upper 200 m of the water column east of Barrow Canyon than west of Barrow Canyon (Figure 4, BCM section).
- There are a number of eddy-like features with an along-shelf length scale of 15-25 km (Figure 4, BCM section). These are consistent with eddy formation associated with instability of the boundary current (Spall et al., 2008).
- The lack of significant variability along the shelf-break west of Barrow Canyon (Figure 4, BCM section) suggests that eddy formation from the boundary current is not as active in this region.

References:

Gong, D., & Pickart, R. S. (in press). Summertime Circulation in the Eastern Chukchi Sea. *Deep Sea Research Part II: Topical Studies in Oceanography.*

Pickart, R. S., Weingartner, T. J., Pratt, L. J., Zimmermann, S., & Torres, D. J. (2005). Flow of winter-transformed Pacific water into the Western Arctic. *Deep Sea Research Part II: Topical Studies in Oceanography*, *52*(24), 3175-3198.

Spall, M. A., Pickart, R. S., Fratantoni, P. S., & Plueddemann, A. J. (2008). Western Arctic shelfbreak eddies: Formation and transport. *Journal of Physical Oceanography*, *38*(8), 1644-1668.

von Appen, W. J., & Pickart, R. S. (2012). Two configurations of the western Arctic shelfbreak current in summer. *Journal of Physical Oceanography*, *42*(3), 329-351.