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Closing the Mass Budget between Bering Strait and the Arctic Basin: The Chukchi Slope Current

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1. Mean Conditions near the Chukchi Shelfbreak

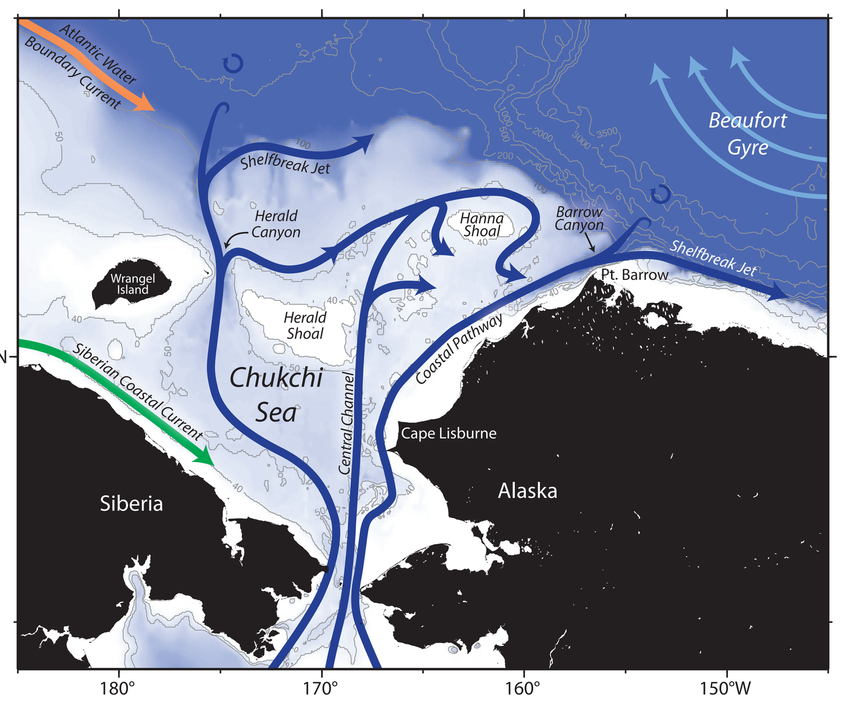

Figure 1: *Presently accepted circulation of the Chukchi Sea, adapted from Brugler et al. (2014).*

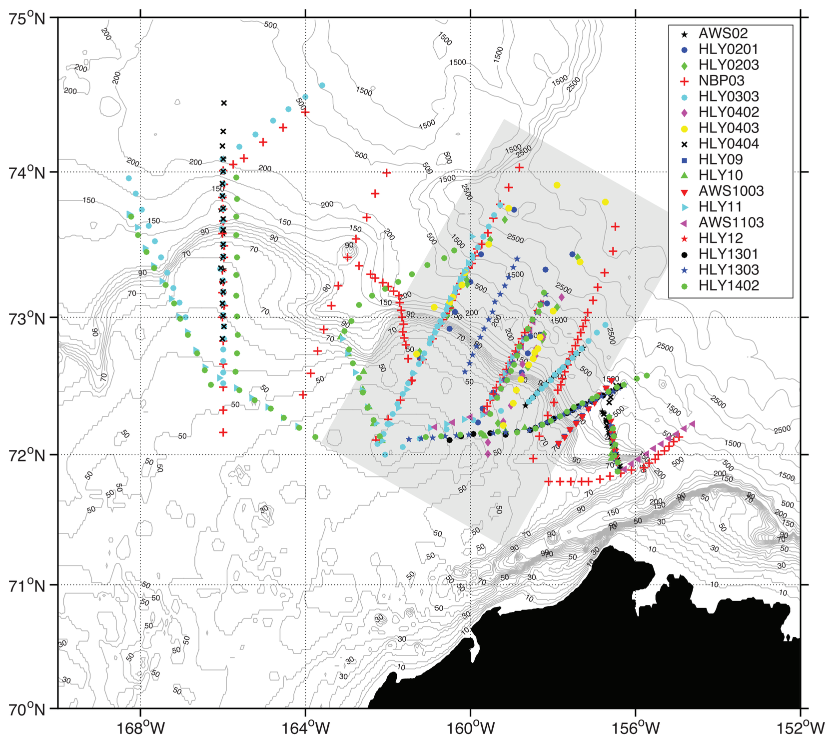

Figure 2: *Compiled hydrographic transects, color-coded by cruise; the shaded region illustrates the region of well-behaved bathymetry used to create the mean across-shelfbreak sections.*

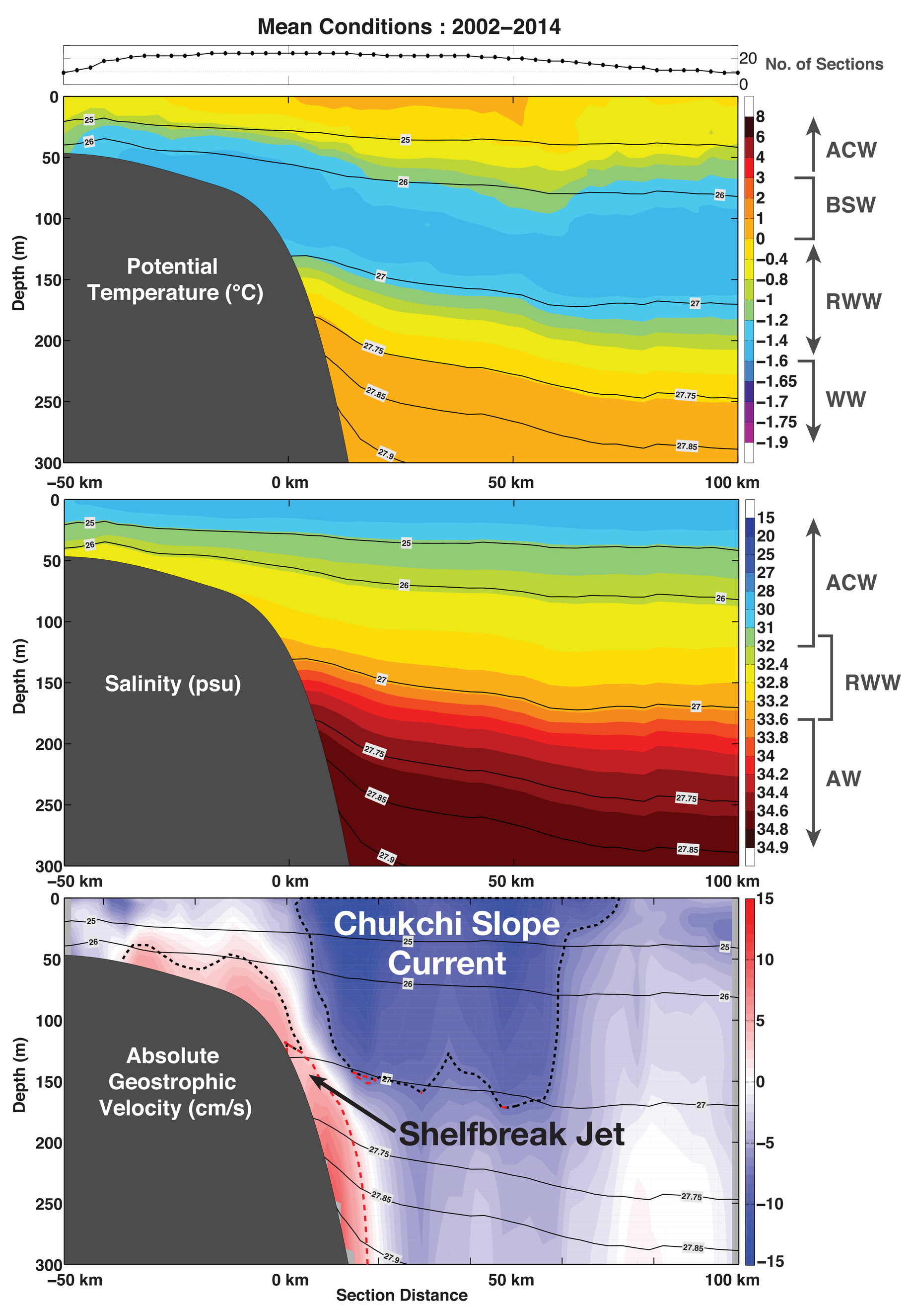

Figure 3: *Mean potential temperature, salinity, and absolute geostrophic velocity sections within the region of well-behaved bathymetry. Black (red) dashes delimit the Pacific (Atlantic) portion of the eastward-flowing, bottom-intensified shelfbreak jet and the westward-flowing, surface-intensified slope current.*

To date, the circulation in the vicinity of the Chukchi shelfbreak has remained unclear, including the flow of the different Pacific-origin water masses as well as the Atlantic water (**Fig 1**). To examine this, we compiled all available hydrographic sections crossing the Chukchi shelfbreak and slope that include direct velocity measurements (shipboard or lowered ADCP). The resulting 46 sections span from 154° to 170° West, representing conditions observed from May through October from 2002 through 2014.

Using a subset of the transects within a region of well-behaved bathymetry (**Fig 2**) we calculated mean sections of hydrographic properties and absolute geostrophic velocity. This revealed two distinct jets (**Fig 3**): the bottom-intensified eastward current is the Chukchi shelfbreak jet, and the surface-intensified westward current is a previously-undescribed feature that we call the Chukchi slope current.

The mean potential temperature section reveals a layer of Atlantic water from ~150 to 300 m depth, bounded above by a layer of Pacific-origin Remnant Winter Water (RWW) from 50 to 150 m depth. The surface layer consists of a mix of warmer water masses, including Pacific-origin water (Bering Sea Water and Alaskan Coastal Water) and melt water. To compute the transport of the slope current, we consider the individual synoptic sections.

2. The Chukchi Slope Current

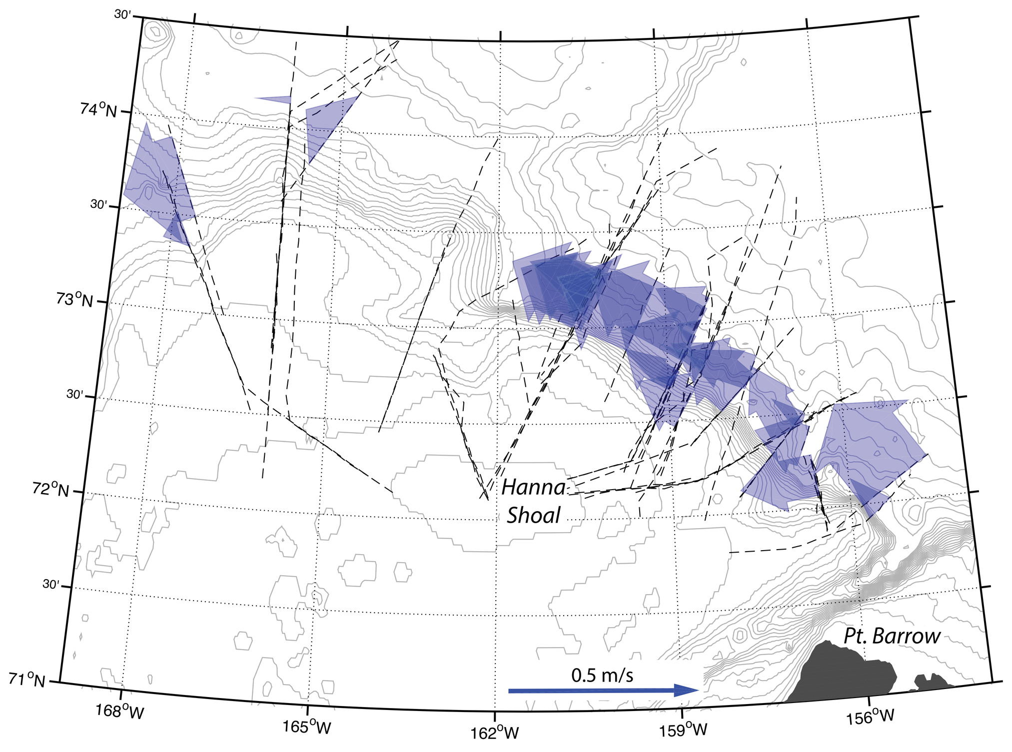

Figure 4: *Realizations of the Chukchi slope current. Each vector represents the mean absolute geostrophic velocity and width of the current within a single section.*

Mean Transport

Volume	-0.65 ± 0.11 Sv
Heat	-3.03 ± 0.60 TW
Freshwater	-0.058 ± 0.0085 Sv

Mean Velocity: -14.3 ± 1.26 cm/s

Mean Pacific Water Transport

Volume	-0.50 ± 0.077 Sv
Heat	-2.00 ± 0.45 TW
Freshwater	-0.037 ± 0.0058 Sv

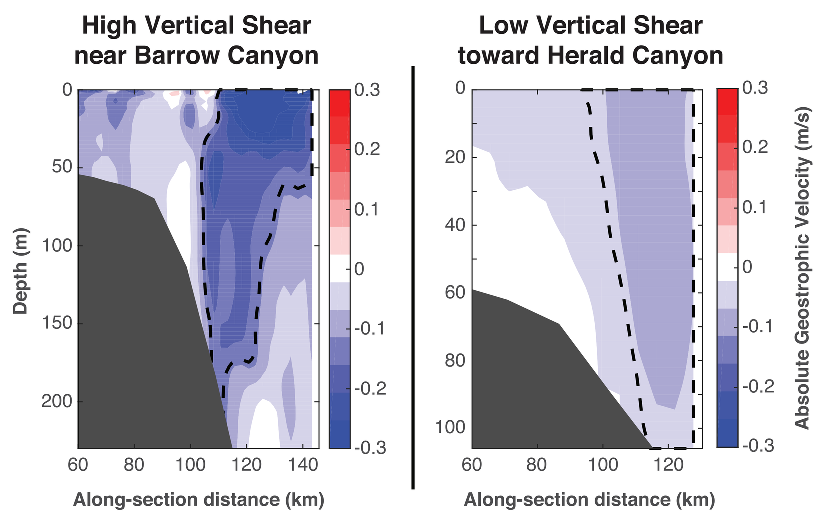

Figure 5: *Representative absolute geostrophic sections of the slope current, demonstrating the decrease in vertical shear of the flow with distance from Barrow Canyon.*

The Chukchi slope current is a persistent feature throughout our domain (**Fig 4**) with no statistically significant change in transport as it flows to the west. It is baroclinically unstable and becomes increasingly barotropic with distance from Barrow Canyon (**Fig 5**). It transports predominantly Remnant Winter Water, although the majority of the current's heat is contained within the two Pacific-origin summer water masses, Bering Sea Water and Alaskan Coastal Water (**Fig 6**).

The transport of the current varies both seasonally and inter-annually (**Fig 7**). The increase in transport in October is likely due to the enhanced easterly winds in autumn (*Schulze and Pickart*, 2012). Similarly, the easterly winds at Point Barrow have become stronger from 2002 to 2014, implying that variations in transport (and heat flux) are largely wind-driven. This is quantified in **Fig 8** which also indicates that, in the absence of wind, the volume transport of Pacific water in the Chukchi slope current is 0.48 ± 0.39 Sv (error is one standard deviation).

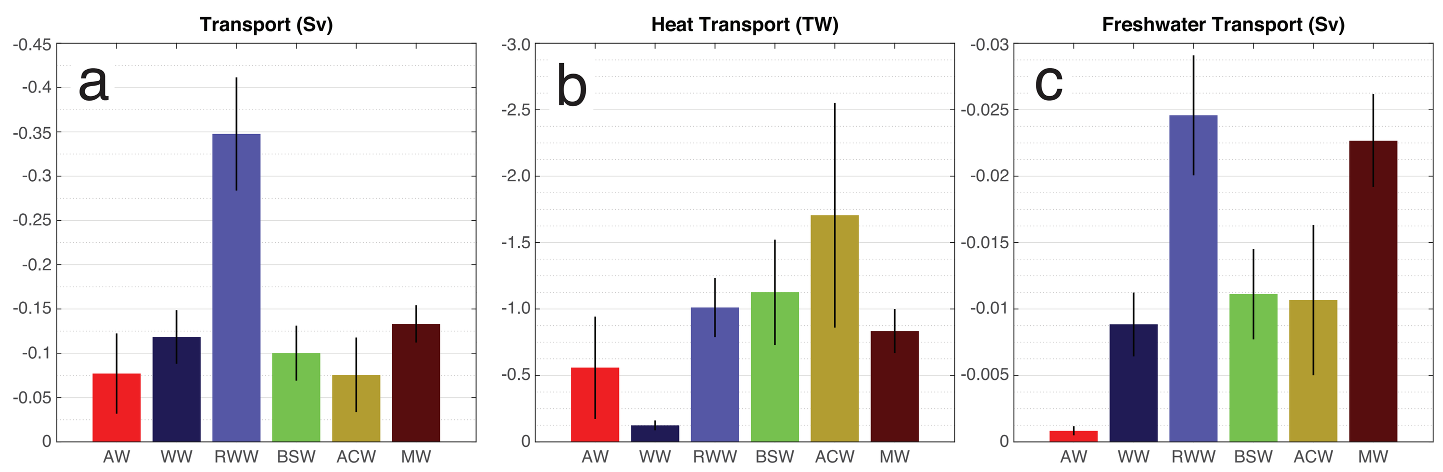

Figure 6: *Mean (a) volume transport (b) heat transport and (c) freshwater transport of the slope current by water mass: Atlantic Water (AW), Winter Water (WW), Remnant Winter Water (RWW), Bering Sea Water (BSW), Alaskan Coastal Water (ACW), and Melt water (MW). Error bars are standard errors.*

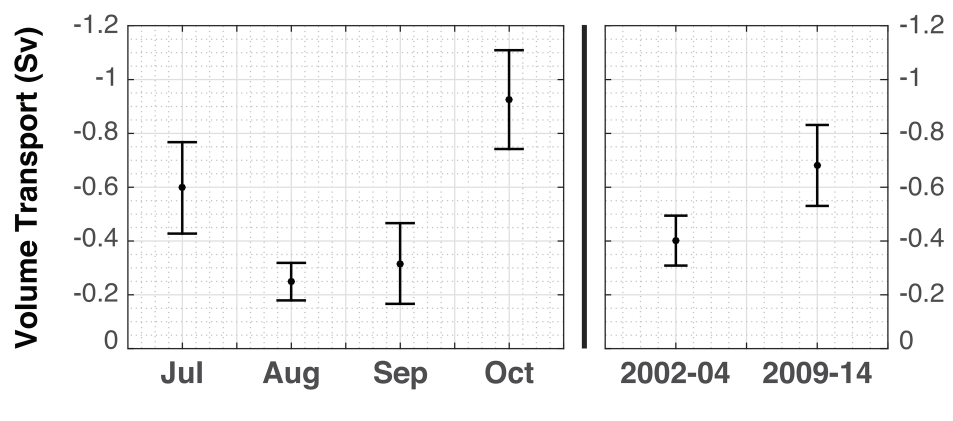

Figure 7: *Slope Current Pacific-origin volume transport on seasonal and interannual timescales.*

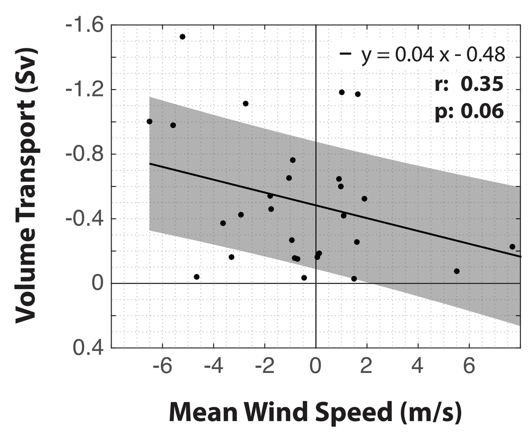

Figure 8: *Pacific water transport vs local along-shelfbreak wind speed (3-day average prior to each section's midpoint), including the linear regression.*

3. Pacific Water Mass Budget of the Chukchi Sea

The mean mass budget for the Chukchi Sea is presented in **Fig 9** (black numbers), where the transport of the Beaufort shelfbreak jet (plus errors) was calculated by *Nikolopoulos et al.* (2009), the transport through the Bering Strait was estimated by *Roach et al.* (1995), and the Bering strait transport errors were estimated by *Woodgate et al.* (2012). The mass budget balances within the error bars, although there is likely some net outflow – on the order of 0.2 Sv – from the shelf via Long Strait into the East Siberian Sea, and through Herald Canyon into the Canada Basin. The no-wind transport values are shown in red.

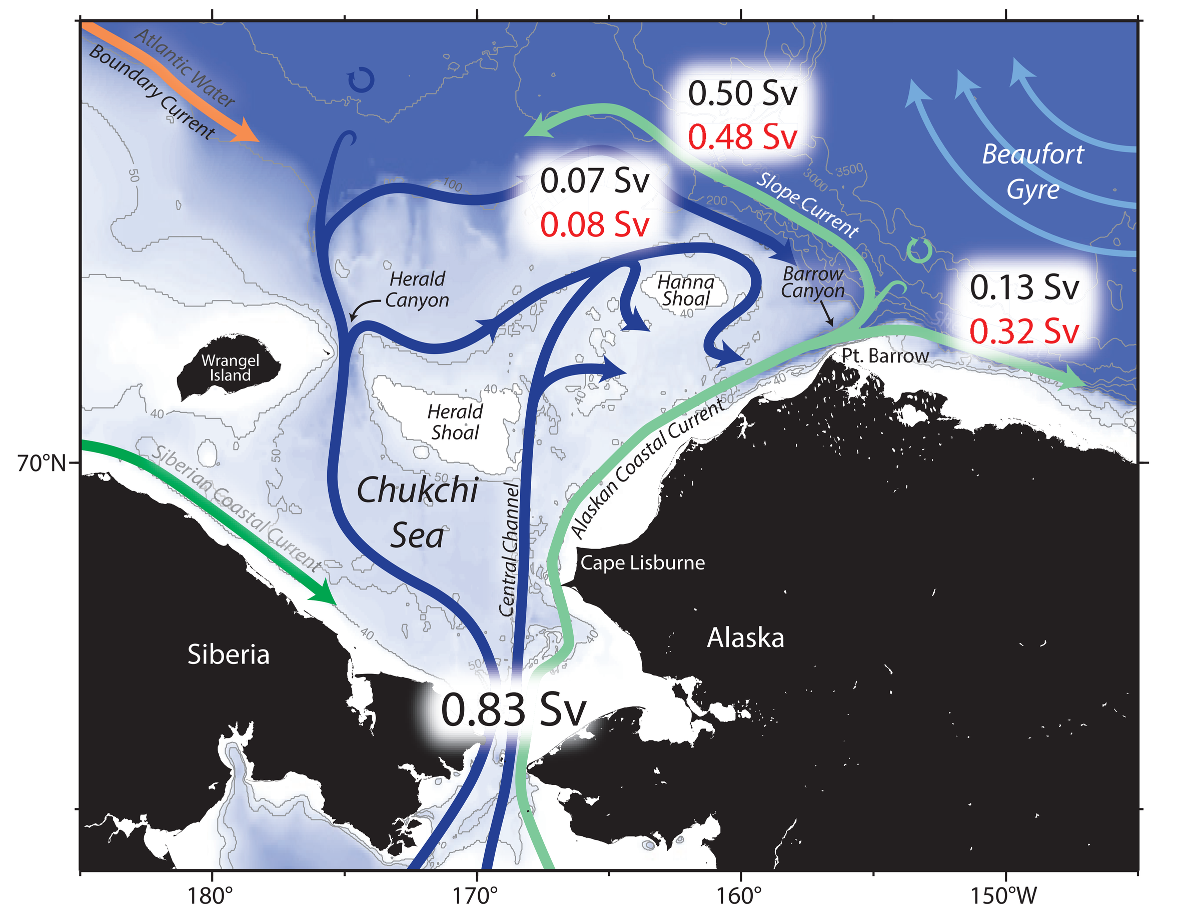

Figure 9: *Mean (in black) and no-wind (in red) transports within the Beaufort Shelfbreak Jet, Chukchi Slope Current, and Chukchi Shelfbreak Jet. The schematic now includes the Chukchi Slope Current and eastward extension of the Chukchi Shelfbreak Jet.*

Mean Mass Budget

$$
\begin{aligned}
0 &= [\text{Bering Strait Inflow}] - [\text{Barrow Canyon Outflow}] \\
&\quad - [\text{Herald Canyon Outflow}] \\
\text{Barrow Canyon Outflow} &= [\text{Beaufort Shelfbreak Jet}] + [\text{Chukchi Slope Current}] \\
&\quad + [\text{Loss to Arctic}] - [\text{Chukchi Shelfbreak Jet}] \\
\text{Herald Canyon Outflow} &= [\text{Chukchi Shelfbreak Jet}] + [\text{Loss to Arctic}]
\end{aligned}
$$

$$
\begin{aligned}
0 &= [0.83 \pm 0.1] - [(0.13 \pm 0.08) + (0.50 \pm 0.08) - (0.07 \pm 0.03)] \\
&\quad - [(0.07 \pm 0.03) + (\text{Loss to Arctic})] \\
\text{where } (\text{Loss to Arctic}) &= \mathbf{0.20 \pm 0.26\ Sv}
\end{aligned}
$$

4. Conclusions

- **Data from a collection of shipboard transects have revealed the presence of a heretofore unknown westward flowing current along the Chukchi Sea continental slope, which we call the Chukchi Slope Current. It transports 0.50±0.08 Sv of Pacific-origin water westward from Barrow Canyon.**
- **The Slope Current exhibits significant seasonal (+0.5 Sv) and interannual (+0.3 Sv) variability, which is likely wind-driven.**
- **The discovery of the Chukchi Slope Current brings us closer to closing the Pacific water mass budget of the Chukchi Sea.**

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Works Cited:

Brugler, E. T., R. S. Pickart, G. Moore, S. Roberts, T. J. Weingartner, and H. Statscewich (2014), Seasonal to interannual variability of the pacific water boundary current in the beaufort sea, Progress in Oceanography, 127, 1–20.

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