The Influence of Taylor Columns on Ocean Dynamics and Sea Ice in the Chukchi Sea

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Introduction

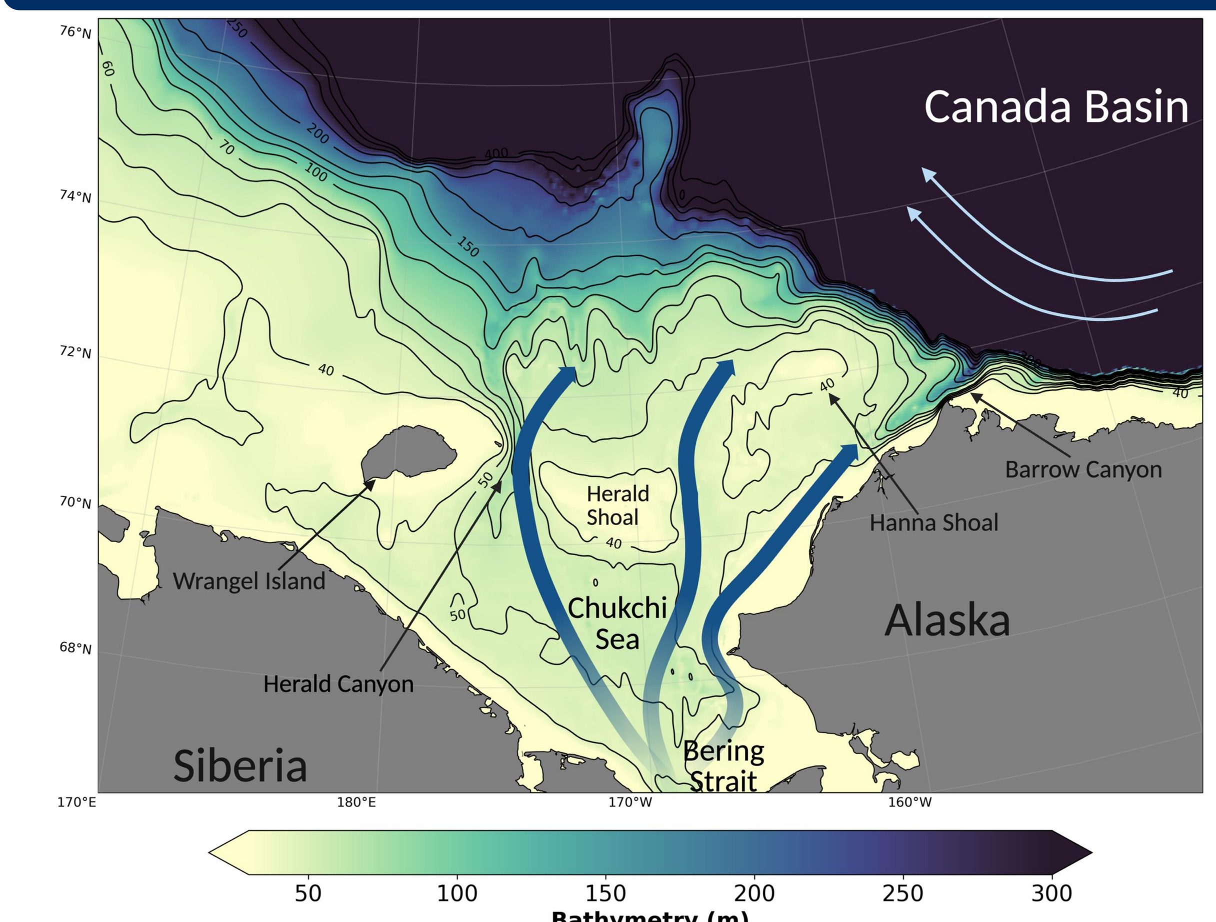

Figure 1. Bathymetry of the Chukchi Sea and surrounding region from the NOAA ETOPO Global Relief Model. The thick blue arrows show the main pathways of Pacific water inflow.

- The Chukchi Sea is a shallow, mostly flat basin located between Alaska and Siberia with much of the seafloor at a depth of around 50 m. Two prominent shoals, Herald and Hanna, rise to approximately 40 m. On either side of the Chukchi shelf lie Herald and Barrow canyons, where the seafloor drops sharply by over 100 m.
- Pacific water inflow takes three main pathways from the Bering Strait through the Chukchi Sea. The flow is diverted around the shoals and through the canyons as pictured in Figure 1.
- Due to their geometry and length scale, stagnant columns of water, or Taylor columns, tend to form over the shoals of the Chukchi Sea (Martin and Drucker 1997).
- These Taylor columns trap cold water over the shoals and can cause a delay in ice melt in the early summer. As shown in Figure 2, ice often persists over Herald Shoal while the ice retreats on either side.
- The shoals are important ecological regions as their retention of cold, nutrient-rich water and resilient ice cover provide a significant foraging and haulout area for many Arctic marine animals (Grebmeier et al. 2006, MacCracken 2012, Jay et al. 2012, Clarke et al. 2013).

Methods

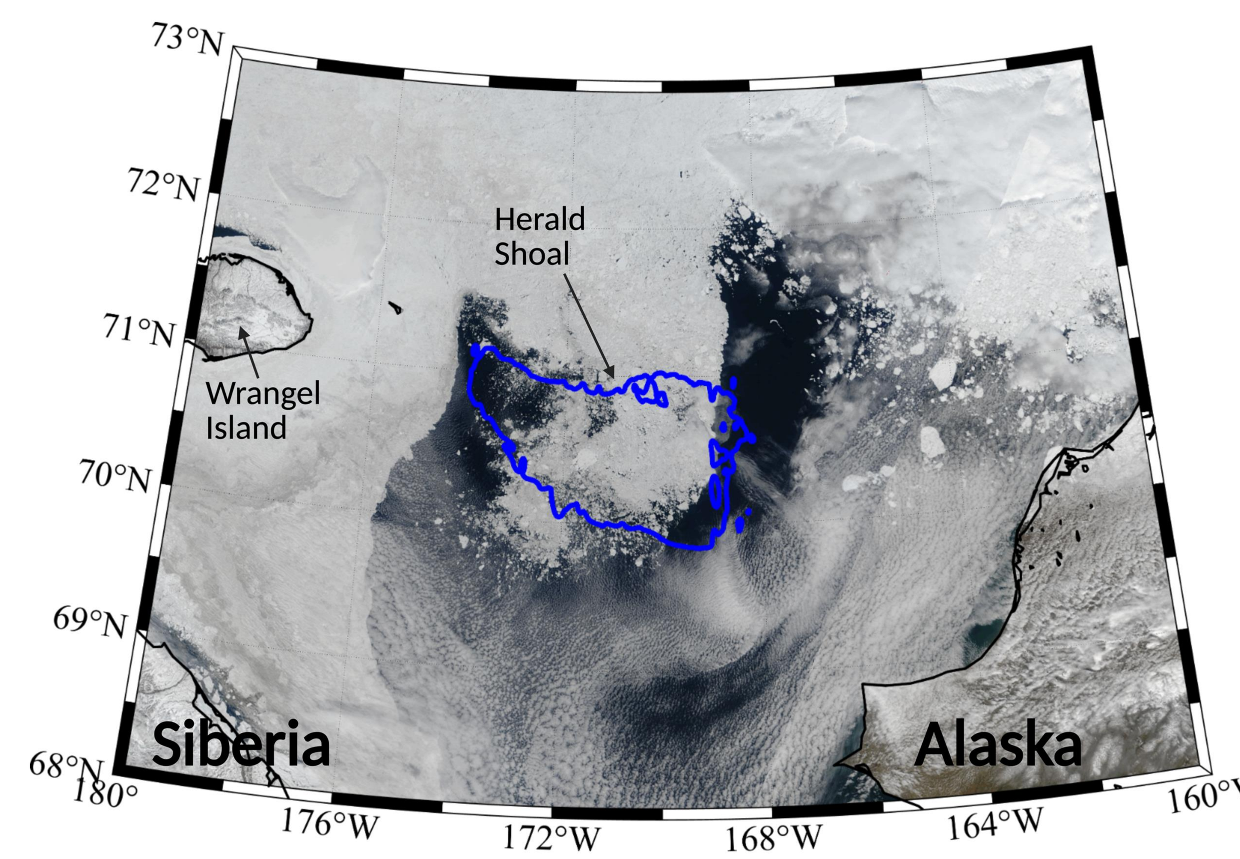

Figure 2. MODIS true colour image showing ice cover in the Chukchi Sea. The image is from June 16, 2018. The 40m isobath is indicated in blue and highlights Herald Shoal.

- For this investigation, we use ocean current and temperature data from a global ice-ocean coupled model (NEMO-LIM3) between 1994-1998. We use the eORCA025 configuration with ¼° global horizontal resolution.
- The model is forced by ERA5 atmospheric variables producing outputs at 5-day intervals at a ~15km horizontal resolution in the region.
- Gridded passive microwave ice concentration data at a ~25km horizontal resolution from the NSIDC is also used for this analysis.
- With this data, we examine the timing of sea ice retreat in the Chukchi Sea with particular focus on its two prominent shoals.

Results

- Figure 3 demonstrates the retreat of the ice edge through the Chukchi Sea in July. The ice edge approaches Herald Shoal by July 15th.
- In the last half of the month, the presence of a Taylor column over the shoal is apparent. The retained cold water over the shoal sustains ice cover while melt progresses on either side. The ice retreat over the shoal is delayed by over a week compared to the adjacent areas.
- Figure 4 illustrates the mean July near-surface currents in the Chukchi Sea. The main pathways of Pacific inflow through the shelf are evident as the strongest currents are diverted around the two shoals. Stagnant water is also apparent over most of each shoal, indicating the presence of the Taylor column.
- Figure 5 shows the mean ocean temperature with depth around Herald Shoal in July. In the upper 20m, warmer water is evident on either side of the shoal. As expected, relatively cold water is confined over the shoal. The maximum difference in the mean temperature between the water over the shoal and that on either side reaches nearly 1 °C.

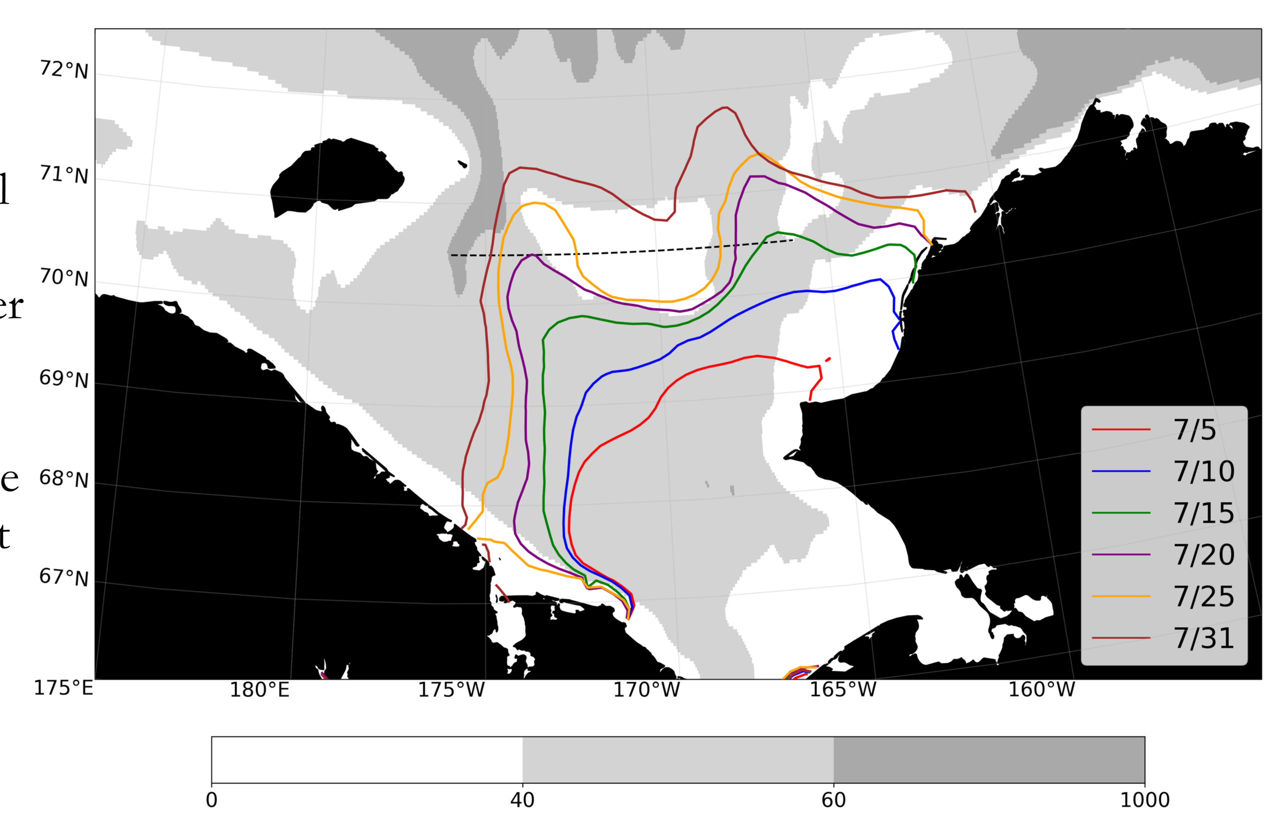

Figure 3. Mean 5-day NISDC ice edge contours for July, averaged between 1994-1998. The ice edge is defined as the 15% ice concentration contour. The bathymetry is shaded with waters shallower than 40m in white. The black dashed line at 70.5°N indicates the location of the cross-section in Figure 5.

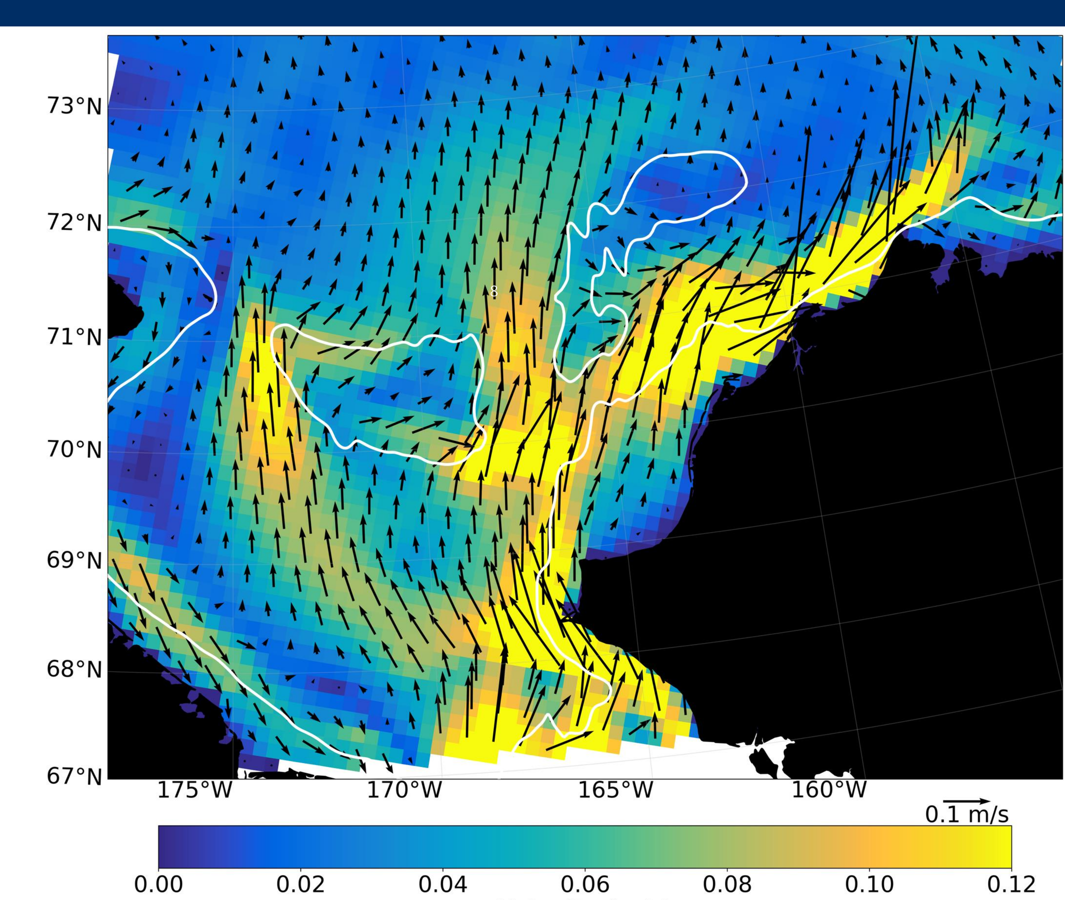

Figure 4. Mean July near-surface (0.49m depth) currents (m/s) from the NEMO-LIM3 simulation. The data is averaged between 1994-1998. The 40m isobath contour is included in white to highlight Herald and Hanna Shoal.

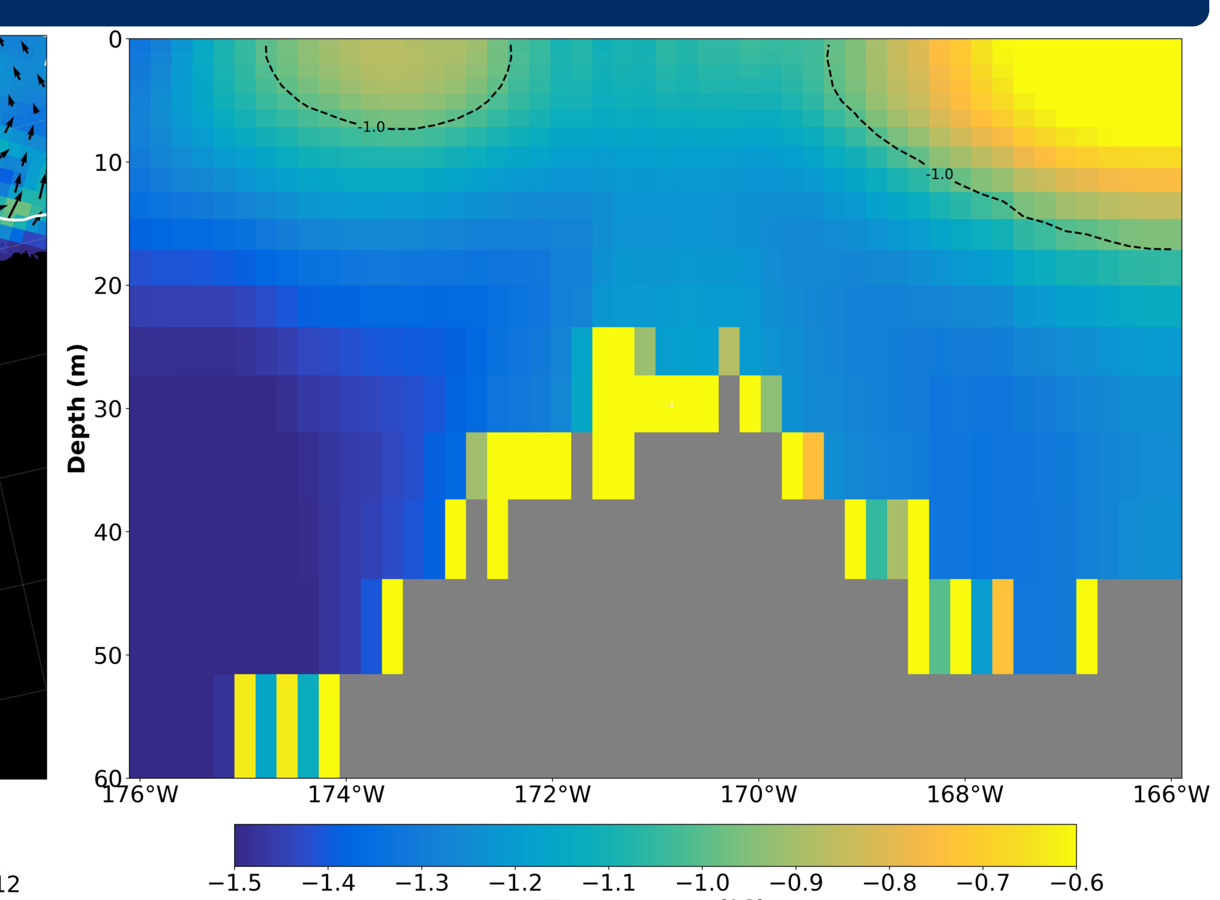

Figure 5. Mean July ocean temperature (°C) with depth over and around Herald Shoal. The data is from the NEMO-LIM3 simulation and averaged between 1994-1998.

Conclusions

- The prominent ocean currents in the Chukchi Sea are diverted around the shoals leaving stagnant water above them.
- This stagnant water is evidence of Taylor columns which form over Herald and Hanna Shoal, trapping cold water and delaying ice melt by over a week in the early summer.
- The delay in ice melt over Hanna Shoal (not pictured) occurs later in the season than Herald Shoal, likely due to its more complex geometry and more northern location.
- The trapped cold water is up to 1 °C colder than the water surrounding Herald Shoal in July.
- Satellite-derived chlorophyll-a data (not shown) indicates elevated primary productivity over Herald Shoal in early summer, likely due to the cold, nutrient-rich water retained above it.
- The next step is to use a higher resolution (<1km) simulation of the NEMO model to further analyze these ocean and sea ice features in the Chukchi Sea.

References and Acknowledgements

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