Mean Flow Structure & Transport of the Alaska Coastal Current

Background: Pacific water entering the Arctic Ocean through Bering Strait is transported across the shallow and expansive Chukchi Sea through one of three major transport pathways. Two of the pathways are in the Eastern Chukchi Sea: one is steered by the Central Channel through Herald Shoal and Hanna Shoal, and the other is the Alaska Coastal Current (ACC) which flows into Barrow Canyon (Coachman 1975, Weingartner et al. 2005). Despite previous observational efforts, the mean summer-time hydrographic and current structure of the ACC in the eastern Chukchi Sea has not been fully characterized. Observations from shipboard CTD and ADCP survey data collected over the past decade quantify the mean state of the ACC by focusing on five key sections: Bering Strait, Central Shelf, Barrow Canyon Head, Barrow Canyon Center (also known as the IBO site), and Barrow Canyon Mouth. The left side of the plot characterizes the mean conditions in the mid- to late-summer period. The right side of the plot presents a comparison between an early-summer survey conducted during the ICESCAPE program and data from the mid- to late-summer period.

Chukchi Sea: Circulation pattern:

- The Chukchi Sea has a mean depth of 50 m and an along flow distance scale of 1000 km. Two major canyons cut into the shelf: Herald Canyon to the west and Barrow Canyon to the east. They are separated by Herald and Hanna Shoals in the middle. In between the two shoals is a topographic depression called Central Channel.
- The northeast flow from Bering Strait separates at Point Hays into the Central Channel branch and the ACC. Flow from the Central Channel progresses around both sides of Hanna Shoal into the head of Barrow Canyon.
- The outflow from Barrow Canyon forms part of the Beaufort shelfbreak jet at BCC.

Distribution of light summer water masses:

- Cold and saltier water results at depth in the northern Chukchi Sea in mid-summer. The coldest of which (T = -1 C) is the newly ventilated Pacific winter water (NVWW). As the summer progresses, the dense water advects northward and is replaced by the warm Pacific water flowing through Bering Strait. The last vestiges of winter water flows along the slow Central Channel branch out of Hanna Shoal. This water flows through Barrow Canyon and is dense enough to ventilate the upper halocline of the western Arctic basin.

Composite section near the ACC:

- The ACC extends to the bottom and is weakly bimodal. Green lines delineate the region of southeastern flow of 5°C or higher. The velocity and hydrographic sections indicate that the ACC simultaneously transports both warm and fresh summer ACW and cold and saline NVWW. As the summer progresses, the dense water advects northward and is replaced by the warm Pacific water flowing through Bering Strait. The last vestiges of winter water flows along the slow Central Channel branch out of Hanna Shoal. This water flows through Barrow Canyon and is dense enough to ventilate the upper halocline of the western Arctic basin.
- The poleward transport along each composite section from Bering Strait to the mouth of Barrow Canyon is calculated from the advected geostrophic sections referenced using shipboard ADCP and SeaWiFS data. The summertime Bering Strait transport is estimated from published figures by Wodacek et al. (2006). The mean along canyon wind speed is calculated for BCC and BCM and the transport values are then de-coupled using the linear relationship on the left. Remarkably, the average poleward transport across each sections north of Barrow Canyon are the same within ±10%. This implies that most of the transport flowing through the eastern side of Bering Strait eventually ends up at Barrow Canyon.

Effect of winds on Barrow Canyon transport:

- Transport in Barrow Canyon is significantly correlated with the wind (r = 0.85, p < 0.01), suggesting that wind-driven forcing plays a significant role in determining the transport measurements for individual sections on BCC and BCM.

References:

Coachman L., S. Aagaard, and T. Ingbretsen. 1975

Coachman L., S. Aagaard, and T. Ingbretsen. 1998

Coachman L., S. Aagaard, and T. Ingbretsen. 2010

Formation of the Chukchi Summer Water (CSW)

- We compare hydrographic observations in the eastern Chukchi Sea between the typical mid- to late-summer state (characterized on the left side of the plot) with the early-summer ICESCAPE survey conducted in June-July 2010. Despite previous observational efforts, the mean summer-time hydrographic and current structure of the ACC in the eastern Chukchi Sea has not been fully characterized. Observations from shipboard CTD and ADCP survey data collected over the past two decades quantify the mean state of the ACC by focusing on five key sections: Bering Strait, Central Shelf, Barrow Canyon Head, Barrow Canyon Center (also known as the IBO site), and Barrow Canyon Mouth. The left side of the plot characterizes the mean conditions in the mid- to late-summer period. The right side of the plot presents a comparison between an early-summer survey conducted during the ICESCAPE program and data from the mid- to late-summer period.

Location & Origin of the Chukchi Summer Water:

The CSW was only observed in the region between Icy Cape and Barrow Canyon Head (right panel above). It is surrounded by cold winter water on all sides. The water immediately above it is also warmer than the surrounding surface water (left panel above).

T-S at Bering Strait (2009-2010):

- T-S measurements at the Bering Strait (Burnet et al. 2006) indicate that no water with properties similar to CSW was observed as the water flowed through Bering Strait in 2010 (left panel). However, downstream measurement at the AON mooring located on the Beaufort shelfbreak showed evidence of CSW. All of this suggests that the CSW formed locally in the eastern Chukchi Sea.

Local formation of Chukchi Summer Water:

In early-summer, water column is stratified with cold and salty water on the bottom, and warmer and fresher summer type water on top. Normally, the salinity of the surface water, which is composed of mostly ACW, close to the coast and BFW (farther offshore), is less than 32.6 PSU. However for early-summer, saliter with salinity of 32.6 PSU and density of 0.2 kg/m^3 was observed in the surface layer. This salty and dense water is typical of winter water, not summer water. We hypothesize that the late ice melt back in 2010, combined with strong solar isolation in late June, resulted in rapid warming of the water column filled with salty winter water led to the formation of the warm and salty CSW.

Formation Mechanism and fate of Chukchi Summer Water:

- CSW observations (left panel) of the Chukchi Sea in June 2010 and T-S observation at the AON mooring (right panel, color coded by month) shows. The SST and ice coverage map (not shown) clearly indicates the development of a late season polynya off the coast of Icy Cape. Note that while SST indicate that the polynya has warmed to temperature above 2°C, it is surrounded by cold water and the warm water off Icy Cape is not connected to the warmer water to the south. Concurrent meteorological observations downstream show CSW like water flowing through a month later in July, right panel.)