Dispersal of Dense Waters Formed in Arctic Coastal Polynyas

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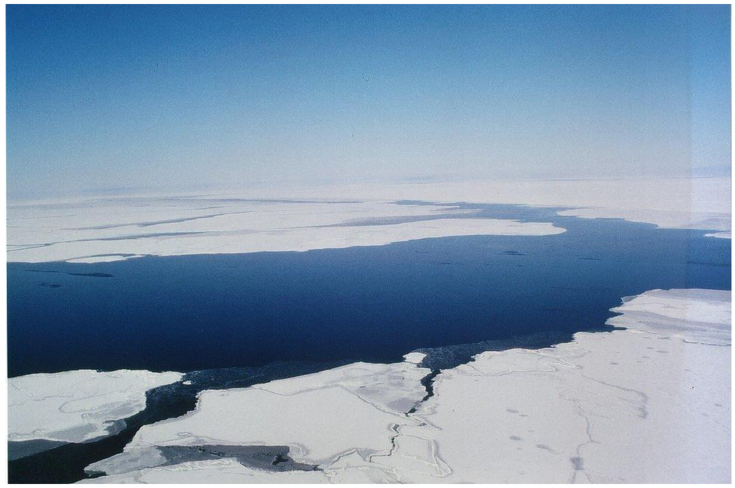

Figure 1: Arctic polynya located in the Laptev Sea, off the northern coast of Siberia.

Polynyas are openings in sea ice near the coastline created by strong offshore-blowing winds (Figure 1). These polynyas are an important component of the Arctic climate system as they enhance the exchanges of heat, moisture and biological and chemical substances between the ocean and atmosphere, and affect local biological communities. Despite their relatively small sizes, coastal polynyas can affect the large-scale Arctic Ocean circulation in the deep basins by supplying dense waters to the Arctic halocline layer, which is located about 50-250 meters below the surface. Because this layer separates the cold, fresh water in the surface mixed layer (about 50 meters thick) from the subsurface relatively warm Atlantic water (250 – about 1,000 meters below the surface), the supply of dense water to the halocline layer helps shield surface-floating sea ice from the vast amount of heat stored at depth.

Due to the constant heat loss to the air, ice is continually generated in coastal polynyas and then pushed away by offshore-blowing winds. During the process of ice formation, salt in the seawater is forced into the water underneath (so-called brine rejection) and forms dense water, which may be a potentially major source of Arctic halocline water. My research, which has been supported by The Clark Arctic Research Initiative, is focused on understanding how these dense waters formed in the coastal polynyas on the northern Alaskan and Siberian coasts travel on the shallow Chukchi Sea continental shelf. This work has resulted in a manuscript that has been accepted for publication in the *Journal of Physical Oceanography*.

In the computer model shown on the next page, a half-ellipse-shaped coastal polynya is located next to a straight coastline in the northern hemisphere, and a uniform downward salt injection is imposed on the sea surface to mimic the brine rejection in real polynyas. The numerical simulations in conjunction with laboratory experiments conducted here at WHOI (and funded by a separate NSF-sponsored project) have revealed two separate bottom transport pathways of the dense water: 1) an offshore bottom dense-water plume moving down the continental slope (downslope) into deeper ambient water and 2) a bottom current flowing along the coast (please see the red patches in Figure 2).

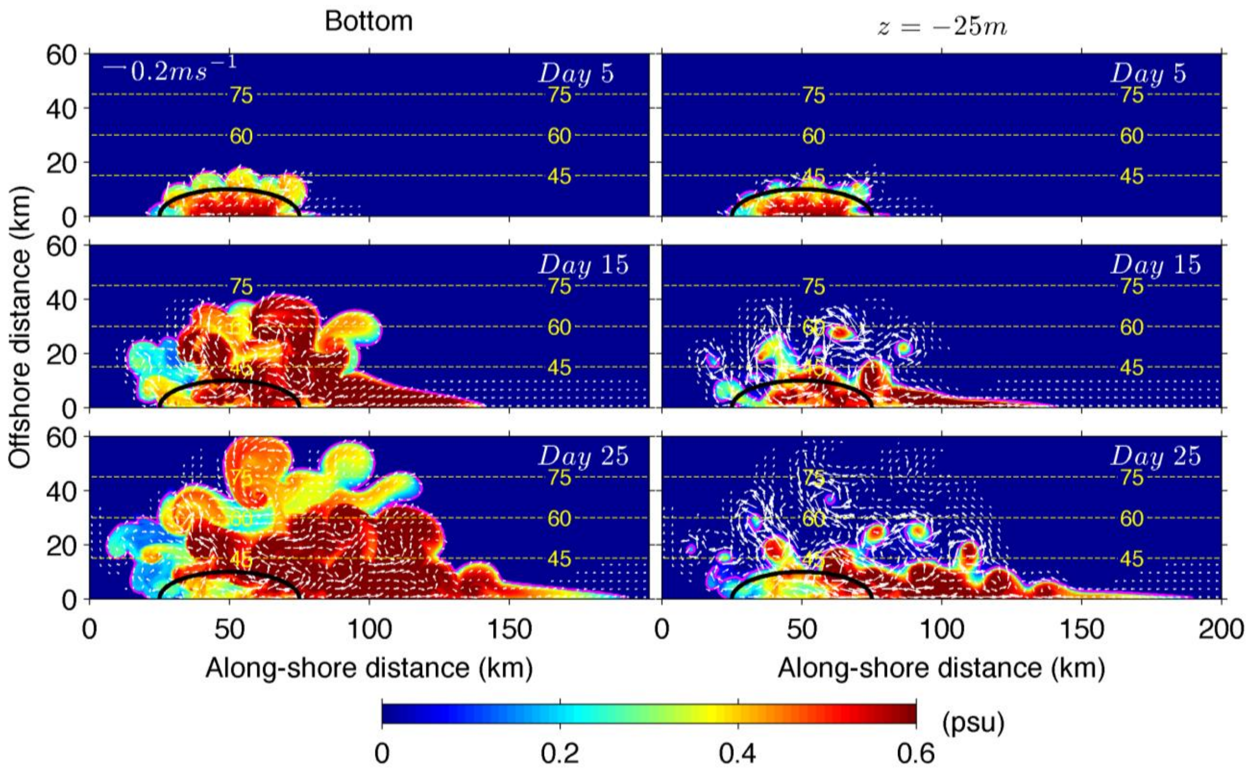

Figure 2: Time series of the dense water (red) and ambient light water (blue) salinity anomaly and velocity vectors (white) near the bottom (left) and at 25 meters below the surface (right). The velocity scale is shown at the upper-left corner of the upper-left panel. Black solid lines outline the polynya-forcing area: dashed yellow lines indicate depth (in meters).

The downslope flowing offshore plume is caused initially by the higher gravitational force exerted on the newly formed dense water; the plume then flows to the right due to the influence of Earth's rotation. Analysis shows that the velocity of the offshore plume is proportional to the ratio of the dense layer thickness and the total water depth. Because of the differences in density of the waters along the shoreline, there is an along-shore pressure force that generates the dense water bottom current flowing along the coastal wall. Computer simulations suggest that only a small portion (3-23%) of the dense water formed in the polynya enters the coastal current, and the percentage depends highly on the ratio of the velocities of the offshore plume and coastal current. This suggests that determining the velocity ratio would be useful for quantifying the amount of dense water formed in real coastal polynyas in the Arctic Ocean.

I also examined whether or not these dense waters formed in idealized polynyas would travel around an island and be stored on a shallow plateau or if the dense waters would drain directly into a neighboring submarine canyon. My motivation for this study was to understand how the dense waters formed in the polynyas next to Wrangle Island in the Chukchi Sea would be affected by the neighboring Herald Canyon. Preliminary simulations suggested that only a small amount of dense water is able to travel around the island. Once the dense water reaches the flank of the canyon, it drains into the canyon due to increased gravitational force along the bottom.

This is a completely new avenue of research for me and I am very grateful for the support from the donors of The Clark Arctic Research Initiative.