Circulation and Variability in the Western Arctic Ocean from a High-Resolution Ice-Ocean Model

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Interactions of the Atlantic Water circulation with Pacific Water exported from the Chukchi shelves towards the Chukchi Rise and in the southern Canada Basin are not well understood. Comprehensive modeling provides tools to supplement limited observational data and to improve our knowledge of the circulation in the Western Arctic. The Naval Postgraduate School Pan-Arctic sea ice and ocean model, developed in part for the Shelf-Basin Interactions (SBI) program, provides valuable insights into the circulation of the region. One of the main goals of this effort is to more accurately model the circulation in the main SBI region (i.e. shelves and slopes of the Chukchi and Beaufort seas) as well as the upstream conditions for this region.

To address some of the issues related to the circulation in the Western Arctic, the time-mean and interannually variable velocity fields are analyzed. The bases of this investigation are results from the recently completed 24-year model integration for 1979-2002, forced with realistic daily-averaged atmospheric fields from the European Centre for Medium-Range Weather Forecasts. Velocity output at three separate depth intervals are averaged to present the circulation in the upper ocean, at the halocline depth and in the Atlantic Layer. Decadal variability is analyzed comparing results from the early 1980s, 1990s and 2000s. The Western Arctic Ocean response to the climate regime shifts of the recent decades is estimated by calculating decadal differences of velocity fields at various depths. Property fluxes across the Bering Strait are compared with those downstream across the Chukchi Cap to better understand their variability and to quantify the fate of Pacific Water in the region.

Velocity fields averaged over 1979 through 2001 demonstrate flow through the Bering Strait into the slope region of the Arctic Ocean exhibits greater velocities as compared to circulation in the central portion of the western Canada Basin. Pacific Water flow divides into three main branches as it enters the Chukchi shelf through the Bering Strait and continues to the north. One branch turns westward, adjacent to the Siberian coast, and is subsequently bisected by Wrangel Island with a portion spilling into Herald Canyon and the remainder continuing northwestward into the East Siberian Sea. A second branch flows northward into the Chukchi Sea between Herald and Hanna Shoals and merges with a larger scale eastward boundary flow proceeding towards the Beaufort Sea. The third and smallest branch flows between Hanna Shoal and the Alaskan coast towards Barrow Canyon merging with boundary flow out of the west. The boundary flow continues along the shelf of the Beaufort Sea maintaining a strong signature around the entirety of the western Canada Basin. Comparatively little flow enters the Amundsen Gulf with the majority flowing along Banks Island into McClure Strait and the remainder continuing northeastward along the Canadian Archipelago.

Flow in the deeper regions of the model designated halocline and Atlantic layers indicate a generally cyclonic flow along the slope throughout the Western Arctic. A strong boundary flow signature is sustained in the halocline layer from the Makarov Basin to the Beaufort Sea. Significant flow is observed to pass across the Chukchi Cap via the Northwind Abyssal Plain. Notable northward flow exists along the Northwind Ridge and in the central Canada Basin. Similar to patterns in the upper ocean, the majority of flow bypasses the Amundsen Basin and enters the Canadian Archipelago via the McClure Strait or continues along the slope towards the Alpha Ridge. Atlantic Layer circulation is strong along the slopes from the Makarov Basin to the Chukchi Plateau but diminishes beyond the Northwind Ridge of the Chukchi Cap and displays little organization in the eastern extent of the Canada Basin.

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Figure 2: Salinity cross sections indicating the model defined halocline across cross sections WA01 (2a) and WA02 (2b).
Figure 3: Temperature cross sections indicating the model defined Atlantic Layer across cross sections WA01 (figure 3a) and WA02 (figure 3b).
Figure 4a: 23 Year mean upper ocean circulation (0 - 26 m depth)

Figure 4: Vertically integrated velocities over three layers in the Western Arctic: the upper ocean (4a), halocline (4b) and the Atlantic Layer (4c). Every fourth vector in each direction is shown. Velocity vectors greater than 7 cm/sec in the upper ocean and halocline layer were cut off and the rest are shown using the square root function. Velocity vectors in the Atlantic Layer were not modified.
Figure 4b: 23 Year mean halocline circulation (54 - 149 m)
Figure 4c: 23 Year mean Atlantic Layer circulation (268 - 850 m)

4.00 cm/s
Figure 5: Two-year velocity averages over the time periods 1981-1982 (5a, 5b), 1991-1992 (5c, 5d) and 2000-2001 (5e, 5f) for the upper ocean and halocline layer respectively. Every third vector in each direction is shown. Velocity vectors greater than 7 cm/sec in the upper ocean and halocline layer were cut off and the rest are shown using the square root function.
Figure 5b: 1981-82 halocline circulation (53 - 149 m)

4.00 cm/s
Figure 5c: 1991-92 upper ocean circulation (0 - 26 m)
Figure 5d: 1991-92 halocline circulation (53 - 149 m)

5.00 cm/s
Figure 5e: 2000 - 01 upper ocean circulation (0 - 26 m)

5.00 cm/s
Figure 5f: 2000 - 01 halocline circulation (53 - 149 m)
Figure 6a: 1991-92 and 1981-82 mean velocity difference in the upper ocean (0 - 26 m)

Figure 6: Decadal velocity differences between two year velocity means for the three periods covering the last twenty-three years for the upper ocean and halocline. Every fourth vector is shown.
Figure 6b: 1991 - 92 and 1981 - 82 mean velocity difference in the halocline (53 - 149 m)
Figure 6c: 2000 - 01 and 1991 - 92 mean velocity difference in the upper ocean (0 - 26 m)
Figure 6d: 2000 - 01 and 1991 - 92 mean velocity difference in the halocline (53 - 149 m)
Figure 6e: 2000 - 01 and 1981 - 82 mean velocity difference in the upper ocean (0 - 26 m)
Figure 6f: 2000 - 01 and 1981 - 82 mean velocity difference in the halocline (53 - 149 m)
Figure 7: Twenty-three year averaged velocity in the halocline across the Chukchi Plateau. Four selected cross sections have been selected to quantify volume across the Chukchi Plateau.
Figure 8: Twenty-three year averaged climatological monthly mean across each cross section.
Figure 9: Twenty-three year monthly time series of volume flux across each cross section